[redacted]

19 March 2018

Ref: BPT/115/18

Dr Tom Hatton

Independent Scientific Panel Inquiry
Locked Bag 33
Cloisters Square, Perth WA 6850
Phone: 08 6145 0999
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Dear Dr Hatton

Re: Independent Scientific Panel Inquiry into Hydraulic Fracture Stimulation in Western Australia

Beach Energy Ltd welcomes the opportunity to provide comment into the Scientific Inquiry into Hydraulic Fracture Stimulation in Western Australia

The impacts and risks associated with the processes of Hydraulic Fracture Stimulation (HFS) are well understood and well documented. With appropriate application of scientific and engineering methods HFS can be executed safely and ongoing risks can be reduced to an acceptable level for the community and the companies involved in developing hydrocarbon resources.

While Beach Energy Ltd (Beach) is a new operator in the Perth Basin, having acquired Lattice Energy Limited's assets from Origin Energy Limited on 31 January 2018, Beach has significant operational experience in safely and responsibly fracture stimulating tight gas reservoirs in the Cooper Basin in South Australia. Further Beach is a joint venture participant in Santos' Cooper Basin operations where many hundreds of fracture stimulation treatments have been safely conducted to maintain gas production crucial in the east coast gas market.

In April 2012 RPS Aquaterra Pty Ltd and Beach authored the Environmental Impact Report for fracture stimulation of Deep Shale Gas and Tight Gas Targets in the Cooper Basin, South Australia (EIR) and the corresponding Statement of Environmental Objectives (SEO). Within these two documents is a thorough risk assessment and the management strategies respectively to undertake fracture stimulation safely and with respect for the environment and community in which we operate.

We include the EIR and SEO which reflect the level of assessment, monitoring, stakeholder engagement and regulatory compliance undertaken in hydrocarbon exploration, appraisal and development.

As identified by the Government of Western Australia[1] there is an estimated 220 Tcf of shale gas and 12 Tcf of tight gas resources in the Perth Basin. Beach is a participant in the Corybas and Senecio fields that are identified as two of the tight gas reservoirs. AWE announced 2C contingent resources to the ASX of 0.4 Tcf associated with tight gas reservoirs in Senecio, Waitsia, Synaphea, Irwin, Dongara, Elegans/Corybas late in

[1] https://frackinginquiry.wa.gov.au/background-papers article Resource Description and Hydrogeology

2017[2]. With a moratorium in place, a valuable resource for the State of WA will remain untested and undeveloped, forgoing royalty revenue, job opportunities and longer term security of gas supply. Fortunately for the AWE and Beach joint venture the recently discovered Waitsia field contains conventional reserves over 820 PJ that do not require fracture stimulation and will be developed and recovered prior to addressing the tight gas potential in and around these fields. For other licence holders in the Perth Basin their resource opportunity is associated with the tight gas potential in their permits.

We thank the Government of Western Australia Independent Scientific Panel for providing the opportunity to provide submissions to the inquiry.

If you require additional information please do not hesitate to contact our office.

Yours sincerely,

pp

Geoff Barker
Group Executive, Development

Other References:

U.S. EPA (US Environmental Protection Agency). 2016. Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States. Office of Research and Development. Washington DC EPA/600/R-16/236Fa

King G.E. and King D.E. 2012 Environmental risk arising from Well-construction Failure: Difference Between Barrier and Well Failure, and Estimates of failure frequency Across Common Well Types, Locations and Well Age: Society of Petroleum Engineers (SPE) 166142, November 2012 SPE Production and Operations. pp 323-344

Environmental Impact Report, Fracture Stimulation of Deep Shale Gas and Tight Gas Targets in the Nappamerri Trough (Cooper Basin), South Australia (Beach Energy 2012, available on Beach's website and http://www.petroleum.statedevelopment.sa.gov.au/legislation_and_compliance/environmental_register#SEO)

Canadian Association of Petroleum Producers (CAPP) – Shale Gas and in particular their guiding principles and operating practices for hydraulic stimulation http://www.capp.ca/canadaIndustry/naturalGas/ShaleGas/Pages/default.aspx

www.fracfocus.org a website in the United States where companies can report fracture stimulation treatments for public and regulatory disclosure. A total of approximately 180,000 wells are registered. The site provides information regarding hydraulic fracturing, well design, US state regulations and chemical usage. Much of this information is contained within the background papers provided as part of the WA inquiry.

[2] *AWE upgrades Waitsia reserves and resources, 19 December 2017, ASX announcement, volumes in release are AWE share and are predominantly in the Beach and AWE JV area (50% AWE, 50% Beach)*

ENVIRONMENTAL IMPACT REPORT

Fracture Stimulation of Deep Shale Gas and Tight Gas Targets in the Nappamerri Trough (Cooper Basin), South Australia

Prepared by:

RPS

[redacted]

and:

Beach Energy

[redacted]

A273B-Cooper Basin Fracture Stimulation EIR; Rev 1 / July 2012

Document Status

Version	*Purpose of Document*	*Orig*	*Review*	*Review Date*	*QA Review*	*Release Approval*	*Issue Date*
Rev A	*Preliminary draft for discussion*	*RPS/Beach*					*10 Feb 2012*
RevB	*Updated preliminary draft for discussion*	*RPS/Beach*					*27 Feb 2012*
RevC	*Revised draft for discussion*	*RPS/Beach*					*29 Feb 2012*
Rev D	*Revised draft*	*RPS/Beach*					*9 March 2012*
RevE	*Revised draft*	*RPS/Beach*					*16 March 2012*
RevF	*Revised draft*	*RPS/Beach*					*22 March 2012*
RevG	*Draft for issue to DMITRE*	*RPS/Beach*	*SM*	*23 March 2012*	*SM*	*MP*	*23 March 2012*
RevH	*Additional Beach edits to draft. Issued to DMITRE for information.*	*Beach*	*SM*	*4 April 2012*	*SM*	*MP*	*4 April 2012*
Rev0	*Formal issue to DMITRE.*	*Beach/RPS*	*SM/MP*	*5 April 2012*	*SM/BW*	*MP*	*5 April 2012*
Rev1	*Comments incorporated from public consultation period and document finalised.*	*Beach*	*MP*	*5 July 2012*	*BW/SM*	*MP*	*5 July 2012*

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Summary

Together with the overlying Eromanga Basin, the Cooper Basin forms Australia's largest onshore oil and gas development and has been a major supplier of gas and a significant supplier of oil and LPG to south-eastern Australia for over forty years.

This Environmental Impact Report (EIR) addresses the application of fracture stimulation to the exploration and appraisal of shale and tight gas in the Nappamerri Trough in the South Australian Cooper Basin. Fracture stimulation is the injection of fluid, largely water, into a petroleum well, to create small cracks or fractures in the formations near the well and allow gas to flow to the well more easily. Fracture stimulation of conventional oil and gas reservoirs has been successfully undertaken in several hundred wells in the Cooper Basin since 1968, to improve the commerciality of lower permeability zones in the same formations that Beach Energy is exploring for shale and tight gas.

This EIR recognises the larger volumes of fluid involved in fracturing these targets compared to conventional gas reservoirs and also reflects the increased level of public interest in fracture stimulation in other Australian States and overseas.

Environment

The Nappamerri Trough area is characterised by three land systems – the floodplains, channels and dunes of the Cooper land system, the gibber slopes of the Merninie land system and the dunefields of the Tingana land system. Within the area, the Cooper Creek is the main drainage feature. It flows in almost every year and, in large floods, inundates vast areas of floodplain. Vegetation ranges from open woodland along the Cooper Creek and the more frequently inundated areas to open shrublands and grasslands dominated by ephemeral and short lived perennial species. A number of State-listed rare or threatened plants and a relatively small number of fauna species listed under State and Commonwealth legislation occur in the region. Site-specific scouting and assessment is carried out prior to clearing well leases that are used for drilling and fracture stimulation to ensure there are no significant impacts on flora and fauna.

Stakeholders

The Cooper Creek region is culturally significant to the Yandruwandha-Yawarrawarrka people. Work Area Clearances are carried out with the Yandruwandha-Yawarrawarrka native title claimant group in advance of all activities to ensure that cultural heritage values and significant places are not impacted. Non-indigenous heritage sites include sites associated with the failed Burke and Wills expedition and the subsequent settlement of inland South Australia and Queensland.

The region is very sparsely populated and the principal land uses include pastoralism, oil and gas production and processing, conservation and tourism. Much of the Nappamerri Trough region lies within the boundary of the multi-use Innamincka Regional Reserve. Innamincka is the only township in the region and the Moomba, Ballera and smaller satellite production facilities house the petroleum industry workforce. The Nappamerri Trough region also overlaps the south-eastern boundary of the large triangular area defined as the Coongie Lakes Wetland of International Significance which is listed under the Ramsar Convention.

Beach Energy is committed to maintaining effective communication and good relations with all stakeholders. Beach has been undertaking a program of consultation with directly affected parties and other stakeholders. Issues raised to date have been integrated into this report where relevant.

Aquifers

The Great Artesian Basin (GAB) is the dominant hydrogeological feature in the region. In the Nappamerri Trough, the principal GAB aquifers are generally too deep for widespread pastoral use and the use of artesian water is generally limited to converted petroleum wells. Shallower aquifers in Tertiary and Quaternary sediments are accessed for pastoral use via scattered wells, with water quality ranging from fresh to saline. There is a small number of water wells in the region of the Central Nappamerri Trough (approximately 20 wells over an area of approximately 1,600 km^2) most of which access shallow groundwater.

Environmental Impact Assessment

Aspects of the environment addressed in this document that are potentially (or commonly perceived to be) impacted by fracture stimulation activities include:

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

The assessment of potential impacts to deeper aquifers indicates that:

- Leakage to aquifers due to loss of well integrity is not likely to occur and the risk is managed by well design and construction, pressure testing and cement bond logging, monitoring of injection pressures, safety trip out systems on pumping units, and installation of a tubing string after stimulation.
- Fracture propagation into overlying Great Artesian Basin (GAB) aquifers and potential contamination of these aquifers is not likely to occur due to the significant physical separation between the targets and the GAB aquifers and the geomechanical properties of the strata.
- Leakage to GAB aquifers through geologic media is not likely to occur, as the Permian target intervals are separated from the GAB by approximately 400 m of limited permeability Nappamerri Group siltstone. Furthermore, seismic information indicates there are no large scale faults that connect the Permian to the GAB.

With respect to impacts to soil, shallow groundwater and surface water, the assessment indicates that:

- Spills or leaks of fuels and stimulation additives are mitigated by storing and handling of materials with appropriate secondary containment and immediate clean up and remediation of any spills.
- Pond design, construction, location and operational controls mitigate risks to the integrity of the pond liner and wall that may result in spills or leaks of pre-stimulation water or flow-back fluids that are contained within the ponds. Spill response procedures result in immediate assessment, fencing, clean up and remediation measures in the event of a leak or spill.
- Wells will not be situated in areas that are subject to regular flooding to avoid inundation from flood events.
- The exploration and appraisal activities are generally spread out in nature with only a small number of existing water wells in the vicinity. The hydrological impact of sourcing water from shallow groundwater is expected to be relatively short-lived and limited in extent. Water supply wells and existing stakeholder bores will be monitored for potential impacts.

The body of this EIR reviews the potential of the activities to impact on public safety, cultural heritage, stock, native fauna and flora or result in significant noise and air emissions, radioactivity and seismic events. Each of these has been assessed to be a low risk. With the fracture stimulation activities, increased traffic has the potential to result in road safety incidents. This risk will be reduced by installing signage, communicating activity plans with stakeholders to increase awareness of activity, posting speed restrictions as required, conducting on-going driver training and dust mitigation measures where appropriate to improve visibility.

Beach is confident that with the implementation of the management measures outlined in the EIR, the proposed activities do not present a significant level of environmental risk.

1 Introduction

1.1 Background

The Cooper Basin, and the overlying Eromanga Basin, are located in north-east South Australia and south-west Queensland. The region forms Australia's largest onshore oil and gas development and has been a major supplier of gas and a significant supplier of oil and LPG to south-eastern Australia for over forty years. Production from conventional gas reservoirs in the region has been in decline, and the development of additional gas resources is required to extend the supply of natural gas from the region over the longer term.

Beach Energy is undertaking exploration to evaluate the deep shale gas and basin-centred gas potential of the Nappamerri Trough in the Cooper Basin. The focus of this exploration is evaluating the size and commerciality of the gas resources in low permeability[1] sandstones and shales.

These exploration targets fall within the category of 'tight' gas or 'unconventional' gas as they have lower permeability than conventional oil and gas reservoirs. They are located at depths of approximately 2,600 to 3,600 m in the Permian sediments of the Cooper Basin.

In order to maximise recovery of gas and potentially allow commercial production, wells drilled in low permeability sandstone and shales are treated by a process known as fracture stimulation or hydraulic fracturing. The fracture stimulation process involves the injection of fluid, largely water, to create small cracks or fractures in the formations near the well, which allow gas to flow to the well more easily.

Fracture stimulation of conventional oil and gas reservoirs has been carried out in several hundred wells in the Cooper Basin since 1968, to improve the commerciality of lower permeability zones in the same formations that Beach is exploring for basin-centred gas. It is considered to be a relatively routine and low risk component of oil and gas drilling and well operations in this basin.

Fracture stimulation operations are currently carried out under the Environmental Impact Report and the Statement of Environmental Objectives for Drilling and Well Operations in the Cooper Basin (Santos 2003 and Santos 2009).

This Environmental Impact Report has been developed to address the fracture stimulation of deep shale gas and other deep tight gas reservoirs in detail. The requirement for this document has principally been driven by the larger volumes of fluid involved in fracturing these targets compared to conventional gas reservoirs, as well as the increased level of public interest in fracture stimulation in other Australian states and overseas.

This document focuses on the fracture stimulation process carried out after the well has been drilled. It does not re-visit other aspects of drilling and well operations (such as preparation of the well lease and access, drilling, casing and cementing of the well, camps, well operation and monitoring, well abandonment and well lease restoration) which are covered by the Environmental Impact Report and the Statement of Environmental Objectives for Drilling and Well Operations in the Cooper Basin (Santos 2003 and Santos 2009).

1.2 Beach Energy Company Profile

Beach Energy is an Adelaide-based oil and gas exploration and production company which has interests in more than 300 petroleum tenements located in Australia, USA, Egypt, Tanzania, New Zealand and Papua New Guinea. During the financial year 1 July 2011 to 30 June 2012 Beach will have participated in drilling more than 100 wells of which more than 30 will have been managed by Beach.

Within the Cooper Basin, Beach is involved with licences that cover over 50,000 square kilometres.

[1] Permeability is a measure of the ease of flow of fluids through the rock

In the South Australian section of the basin, Beach operates exploration activities in several Petroleum Exploration Licences (PEL) including PEL91, PEL92, PEL94, PEL95, PEL106 (Brownlow), PEL107 and PEL218 and is a joint venture participant in several additional licences. Beach also operates oil and gas development and production in Petroleum Production Licences (PPL) including PPL204, PPL205, PPL210, PPL212, PPL220, PPL224 and PPL239.

In the year ending 30 June 2011 Beach produced 6.6 million barrels of oil equivalent and expects to produce 7.5 million barrels in the financial year to 30 June 2012.

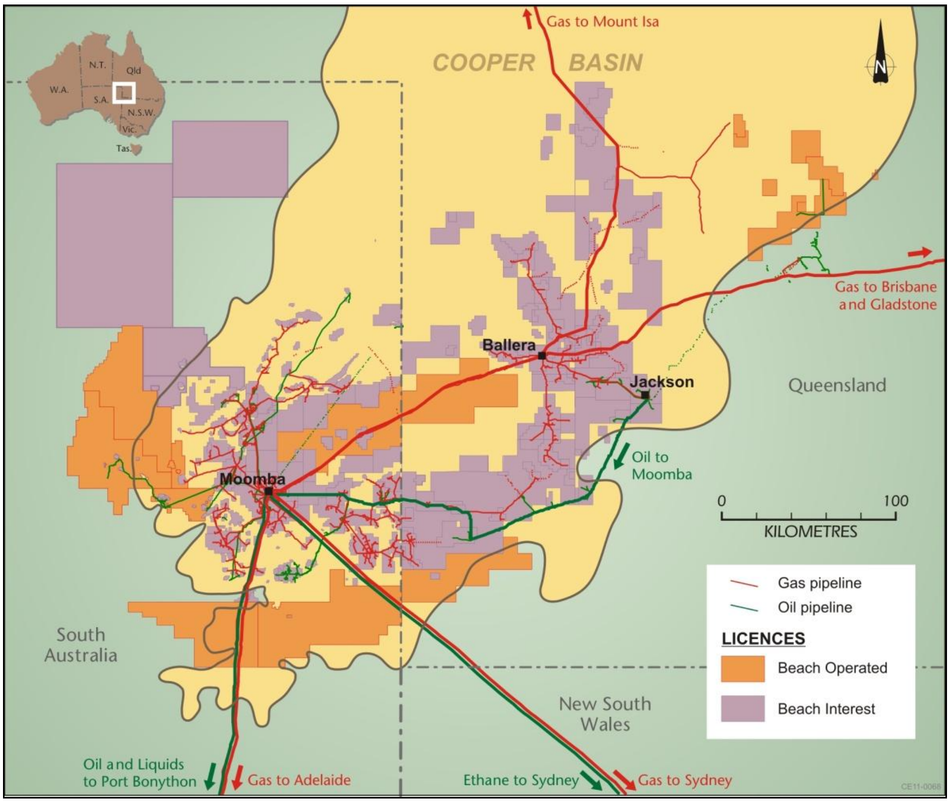


Figure 1: Beach Energy licence areas (operated / interest) in the Cooper Basin

1.2.1 Beach Energy's Unconventional Gas Exploration in the Nappamerri Trough

The Nappamerri Trough, which extends in a north-easterly direction from south of Moomba in South Australia to north of Ballera in Queensland, is the principal focus for Beach's exploration and appraisal of unconventional gas resources. Beach currently holds PEL218 which covers a significant proportion of the central Nappamerri Trough.

The Nappamerri Trough region is shown in Figure 2.

During the exploration and appraisal phase, it is anticipated that a number of wells will be drilled and fracture stimulated to evaluate the resource and the feasibility of production. The number and location of these wells will depend on the results of on-going drilling and testing.

If the exploration results are positive, Beach would expect to move towards development and production of these gas resources in the region. The scale of development activity would be dependent on exploration results, but it is expected that it may be similar in scale to the conventional gas fields that exist in the Cooper Basin. If a significant level of activity is proposed, Beach expects that it may need to develop a further Environmental Impact Report and Statement of Environmental Objectives addressing additional aspects of development of these resources not contemplated by the activities discussed in this document.

1.3 About this document

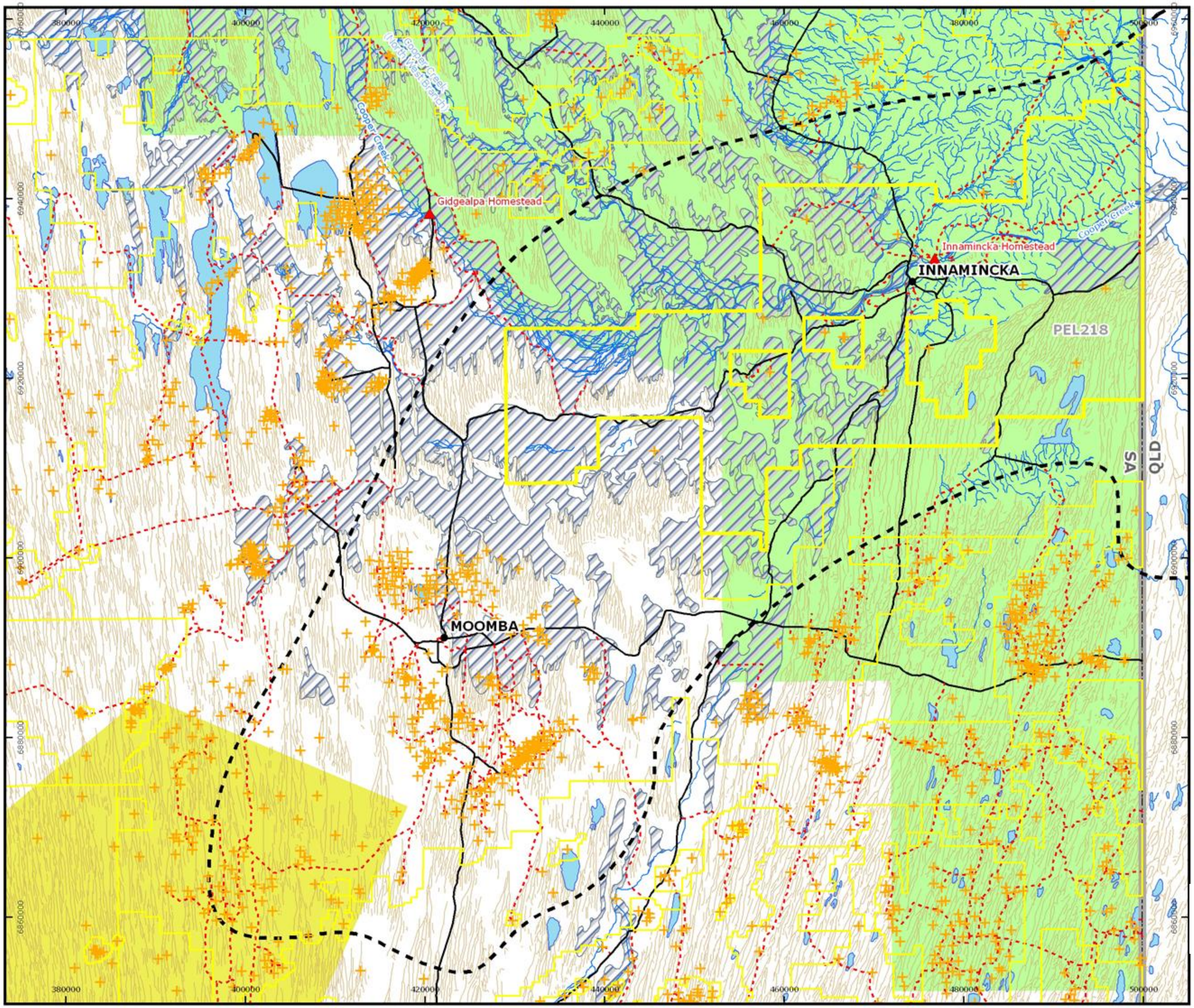
This document has been prepared to satisfy the requirements of an Environmental Impact Report (EIR) under the *Petroleum and Geothermal Energy Act 2000*. It has been prepared in accordance with current legislative requirements, in particular Section 97 of the Act and Regulation 10 of the *Petroleum and Geothermal Energy Regulations 2000*.

The regulator, Department for Manufacturing, Innovation, Trade, Resources and Energy (DMITRE), is to undertake an Environmental Significance Assessment of this document to classify the activities which are the subject of this EIR as ‘low’, ’medium’ or ‘high’ impact (refer Section 2.1.3). Following this classification, a Statement of Environmental Objectives (SEO) will be developed reflecting the activities and impacts detailed in this document or other assessments that may be required depending on the classification. The SEO will outline the environmental objectives that must be achieved and the criteria on which achievement of the objectives is to be assessed.

This document relates to fracture stimulation activities using high volumes of water in deep shale gas and tight gas targets in the Cooper Basin, South Australia. It focuses on Permian age targets in the Nappamerri Trough which occur at depths of approximately 2,600 m to 3,600 m (see Figure 2 and Section 4.2.4 for discussion). The principal targets are the Roseneath and Murteree Shales and the Epsilon, Patchawarra, Daralingie and Toolachee Formations.

As indicated in Section 1.1, this document focuses on the fracture stimulation process carried out after the well has been drilled. Other aspects of drilling and well operations such as preparation of the well lease and access, drilling, casing and cementing of the well, camps, well operation and monitoring, well abandonment and well lease restoration are covered by the Cooper Basin Drilling and Well Operations Environmental Impact Report (Santos 2003), the Cooper Basin Drilling and Well Operations Statement of Environmental Objectives (Santos 2009) and are not re-visited in this document. Existing SEOs are also in place for other Cooper Basin operations that are not covered in this document, including the Geophysical Operations Statement of Environmental Objectives (Santos 2006) and the Beach Production Statement of Environmental Objectives (Beach 2009).

This document (and the resultant SEO) covers a relatively broad geographical area, rather than relating to a specific site or sites. This approach has been applied in many other EIRs and SEOs that have been developed under the Petroleum and Geothermal Energy Act for the Cooper Basin and other regions of the State. As discussed in Section 2.1.4, additional site-specific and technical detail for operations at individual well sites must be provided under the activity notification / approval requirements of the Act, including a demonstration that the activities are covered by (and are compliant with) an applicable SEO.



LEGEND

- Localities
- Homestead
- Petroleum Well
- Roads
- Tracks
- Drainage
- Sand Ridges
- State Boundaries
- Land Subject To Inundation
- Intermittent Lakes
- Strzelecki Regional Reserve
- Innamincka Regional Reserve
- Nappamerri Trough
- Petroleum Exploration Licence PEL218
- Petroleum Exploration Licences

N

0 10 20

Kilometres

SCALE 1:600,000 @ A4

GDA 1994 MGA Zone 54

DATA SOURCES
DWLBC
Geoscience Australia
DENR
RPSAQT

RPS Aquaterra

FIGURE 2:
Cooper Basin Showing Nappamerri Trough

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2 Legislative Framework

This chapter briefly describes the legislative framework that currently applies to petroleum activities in South Australia.

2.1 Petroleum and Geothermal Energy Act

The legislation governing onshore petroleum exploration and production in South Australia is the *Petroleum and Geothermal Energy Act 2000* and *Petroleum and Geothermal Energy Regulations 2000*. This legislation is administered by DMITRE. Key objectives of the legislation include:

- to create an effective, efficient and flexible regulatory system for exploration and recovery or commercial utilisation of petroleum and other regulated resources
- to minimise environmental damage from the activities involved in exploration and recovery or commercial utilisation of petroleum and other regulated resources
- to establish appropriate consultative processes involving people directly affected by regulated activities and the public generally
- to protect the public from risks inherent in regulated activities.

The Act and Regulations are objective-based rather than prescriptive. An objective-based regulatory approach principally seeks to ensure that industry effectively manages its activities by complying with performance standards that are cooperatively developed by the licensee, the regulatory authority and the community. This contrasts with prescriptive regulation where detailed management strategies for particular risks are stipulated in legislation.

Regulated resources, as defined in Part 1 of the Act, are:

- a naturally occurring underground accumulation of a regulated substance
- a source of geothermal energy, or
- a natural reservoir.

A reference in the Act to petroleum or another regulated substance extends to a mixture of substances of which petroleum or other relevant substance is a constituent part. Regulated substances as defined in Part 1 of the Act are:

- petroleum
- hydrogen sulphide
- nitrogen
- helium
- carbon dioxide
- any other substance that naturally occurs in association with petroleum; or
- any substance declared by regulation to be a substance to which the Act applies.

Regulated activities, as defined in Section 10 of the Act, are:

- exploration for petroleum or another regulated resource
- operations to establish the nature and extent of a discovery of petroleum or another regulated resource, and to establish the commercial feasibility of production and the appropriate production techniques
- production of petroleum or another regulated substance
- utilisation of a natural reservoir to store petroleum or another regulated substance
- production of geothermal energy
- construction of a transmission pipeline for carrying petroleum or another regulated substance
- operation of a transmission pipeline for carrying petroleum or another regulated substance.

2.1.1 Statement of Environmental Objectives

As a requirement of Part 12 of the Act, a regulated activity can only be conducted if an approved Statement of Environmental Objectives (SEO) has been developed. The SEO outlines the environmental objectives that the regulated activity is required to achieve and the criteria upon which the objectives are to be assessed.

As detailed earlier, subsequent to classification by the regulator of the activities covered by this EIR, a corresponding SEO for fracture stimulation of deep shale gas and tight gas activities will be developed for consultation and approval (Section 2.1.3).

2.1.2 Environmental Impact Report

In accordance with Section 97 of the *Petroleum and Geothermal Energy Act 2000*, an Environmental Impact Report (EIR) must:

- take into account cultural, amenity and other values of Aboriginal and other Australians insofar as those values are relevant to the assessment
- take into account risks to the health and safety of the public inherent in the regulated activities
- contain sufficient information to make possible an informed assessment of the likely impact of the activities on the environment.

As per Regulation 10 of the *Petroleum and Geothermal Energy Regulations 2000*, the EIR must include:

- a description of the regulated activities to be carried out under the licence (including their location)
- a description of the specific features of the environment that can reasonably be expected to be affected by the activities, with particular reference to the physical and biological aspects of the environment and existing land uses
- an assessment of the cultural values of Aboriginal and other Australians which could reasonably be foreseen to be affected by the activities in the area of the licence, and the public health and safety risks inherent in those activities (insofar as these matters are relevant in the particular circumstances)
- if required by the Minister – a prudential assessment of the security of natural gas supply
- a description of the reasonably foreseeable events associated with the activity that could pose a threat to the relevant environment, including information on:
  - events during the construction stage (if any), the operational stage and the abandonment stage
  - events due to atypical circumstances (including human error, equipment failure or emissions, or discharges above normal operating levels)
  - information on the estimated frequency of these events
  - an explanation of the basis on which these events and frequencies have been predicted
- an assessment of the potential consequences of these events on the environment, including;
  - information on
    - the extent to which these consequences can be managed or addressed
    - the action proposed to be taken to manage or address these consequences
    - the anticipated duration of these consequences
    - the size and scope of these consequences and
    - the cumulative effects (if any) of these consequences when considered in conjunction with the consequences of other events that may occur on the relevant land (insofar as this is reasonably practicable); and
  - an explanation of the basis on which these consequences have been predicted
- a list of all owners of the relevant land
- information on any consultation that has occurred with the owner of the relevant land, any Aboriginal groups or representatives, any agency or instrumentality of the Crown, or any other interested person or parties, including specific details about relevant issues that have been raised and any response to those issues, but not including confidential information.

2.1.3 Environmental Significance Assessment and SEO Consultation Requirements

The EIR is submitted to DMITRE and an Environmental Significance Assessment is undertaken to determine whether the activities described in the EIR are to be classified as 'low', 'medium' or 'high' impact. A corresponding SEO is prepared, reflecting the impacts and measures identified in the EIR or other assessments that may be required as determined by the classification.

The classification also determines the level of consultation DMITRE will be required to undertake prior to final approval of the SEO as follows:

- Low impact activities do not require public consultation and are subjected to a process of internal government consultation and comment on the EIR and SEO prior to approval.
- Medium impact activities require a public consultation process for the EIR and proposed SEO, with comment sought for a period of at least 30 business days.
- High impact activities are required to undergo an environmental impact assessment under the provisions of the *Development Act 1993*.

The level of impact of a particular activity is assessed on the basis of the predictability and manageability of the impacts on the environment. Where the environmental impacts are predictable and readily managed, the impact of the activity is considered low. Where the environmental impacts are less predictable and are difficult to manage, the impact of the activity is potentially high.

Once the approval process is complete, all documentation, including this EIR and its associated SEO, must be entered on an environmental register. This public Environmental Register is accessible to the community from the DMITRE website.

2.1.4 Activity Notification / Approval Process

Prior to commencing a regulated activity, Section 74(3) of the Petroleum and Geothermal Energy Act requires that:

- The Minister's prior written approval is required for activities requiring high level supervision (as per Regulation 19), and
- Notice of activities requiring low level supervision is to be given at least 21 days in advance (as per Regulation 18).

In order to obtain written approval for activities requiring high level supervision, an application and notification of activities (in accordance with Regulation 20) must be submitted to the Minister at least 35 days prior to the commencement of activities.

The notification of activities must provide specific technical and environmental information on the proposed activity and include an assessment to demonstrate that it is covered by an existing SEO.

Consequently, the activity notification process provides an additional opportunity for DMITRE to ensure that the proposed activities and their impacts can be effectively managed and are consistent with the approvals obtained in the EIR and SEO approval process. This is particularly relevant for activities that are conducted under an SEO that applies to a broad geographical area, as it provides site-specific detail that is not usually contained in the generic documents.

The site-specific detail provided would include an assessment of the environment of the proposed location, investigation of specific issues (such as the likelihood of occurrence of threatened species or areas of sensitive landscape) and proposed measures to minimise impacts to key issues (e.g. low impact techniques for sensitive areas, sensitive locations to avoid). Fracture stimulation notifications would typically include details of fracturing fluid additives and proposed handling and disposal methods of flowback fluids.

2.2 Other Legislation

A variety of legislation applies to petroleum activities. Legislation that is particularly relevant to petroleum exploration and fracture stimulation is listed below (note that this is not a comprehensive list of all applicable legislation).

Commonwealth
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)
Native Title Act 1993
Aboriginal and Torrens Strait Islander Heritage Protection Act 1984

South Australia
Aboriginal Heritage Act 1988
Crown Lands Act 1929
Environment Protection Act 1993
Fire and Emergency Services Act 2005
Heritage Places Act 1993
National Parks & Wildlife Act 1972
Native Title (South Australia) Act 1994
Native Vegetation Act 1991
Natural Resources Management Act 2004
National Trust of SA Act 1955
Occupational Health, Safety and Welfare Act 1986
Public and Environmental Health Act 1987.

Commonwealth Environment Protection and Biodiversity Conservation Act

Approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is required for activities that impact matters of national environmental significance including World Heritage properties, National Heritage places, Ramsar wetlands of international importance, listed threatened species and ecological communities and migratory species.

In regard to petroleum activities in the Cooper Basin, issues that potentially require approval under the EPBC Act are relatively limited and can generally be avoided by site selection and implementation of field procedures (e.g. avoiding impacts to surface drainage and significant wetland areas or flagging and avoiding significant sites). Based on current knowledge, Beach believes that a requirement for approval under the Act is not likely to be triggered.

Native Vegetation Act

Exploration activities that are approved under the Petroleum and Geothermal Energy Act do not require approval under the *Native Vegetation Act 1991* for clearance of native vegetation, provided that the activities are in accordance with accepted industry environmental management practices for facilitating the regrowth of native vegetation and there is no practicable alternative involving the clearance of less vegetation or of vegetation that is either less significant or more degraded (see regulation 5(1)(zc) of the *Native Vegetation Regulations 2003*).

Environment Protection Act

The Environment Protection Act imposes a general duty of care not to undertake an activity that pollutes, or might pollute the environment unless all reasonable and practicable measures have been taken to prevent or minimise any resulting environmental harm. Environmental authorisations are required to undertake activities prescribed under the Act. The Environment Protection Act does not apply to petroleum exploration activity undertaken under the Petroleum and Geothermal Energy Act or to wastes produced in the course of an activity (not being a prescribed activity of environmental significance) authorised by a lease or licence under the Petroleum and Geothermal Energy Act when produced and disposed of to land and contained within the area of the lease or licence.

Natural Resources Management Act

Drilling of new water sourcing bores or conversion of petroleum wells to water supply wells requires a permit under this Act. Extraction of groundwater within the Far North Prescribed Wells Area generally requires a licence / allocation under this Act, however there is an authorisation in place to take groundwater for drilling, construction and testing of hydrocarbon wells. This Act and the SA Arid Lands Regional Natural Resources Management Plan (SAAL NRM Board 2010) also set out a number of water affecting activities that must not be undertaken without a permit. These are usually avoidable by careful planning and siting of infrastructure to maintain water flows.

National Parks and Wildlife Act

This Act provides for the establishment and management of reserves and the conservation of wildlife in a natural environment. Innamincka Regional Reserve is established under this Act, which provides the Department of Environment and Natural Resources rights as landowner and direct involvement in the approval of Petroleum and Geothermal Energy Act licences and Statements of Environmental Objectives that cover the regional reserve (which must be approved by the Minister for Environment and Conservation).

3 Background to Unconventional Gas Exploration in the Cooper Basin

This section provides background on unconventional gas exploration in the Cooper Basin, to assist in understanding the discussion of fracture stimulation in the following sections.

3.1 Conventional and Unconventional Targets

3.1.1 Conventional hydrocarbon generation and accumulation

Sedimentary rocks, such as those prevalent in the Cooper Basin, are formed when sand grains and clay particles are deposited, accumulate and become buried over many millions of years. When quartz sand grains compact and cement together to form rocks, these are known as sandstones. When fine grained quartz and clay particles compact these become siltstones, shales and mudstones. When the sediments are deposited, the small pore spaces between the grains in these rocks are water filled as the sediment is carried by a river to a lake or to the sea. This pore space potentially becomes a storage place for oil and gas, collectively known as hydrocarbons, if gas and oil can eventually find its way into the rock.

The source of the hydrocarbon that migrates into the pores is organic matter that is buried with sediments. Rocks which have organic matter that generates, or has generated gas or oil are known as source rocks.

The simplest source rock model to understand is the conversion of a peat swamp into coal. As the organic matter becomes buried deeper, the pressure and heat in the sediment increases and the material transforms into coal. During this process, hydrocarbons are generated which escape from the structure of the coal and migrate into layers of sediment that have been deposited above the coal.

Another common source rock is shale. Shale is a fine-grained sedimentary rock made up predominantly of quartz and clay particles together with organic matter. While coal has very high organic content, typically more than 85%, shale has lower organic content typically less than 10%.

As oil is lighter than water, and gas lighter still, it migrates through the pore spaces of the overlying layers of rock. The ease with which it moves depends on the permeability of the rocks. Permeability is a measure of the ability of a rock to conduct fluid and is related to how connected the pore spaces are in the rock. The gas released from a source rock will migrate through permeable rocks upwards until it reaches a barrier. The barrier is usually caused by a layer of rock that has very little to no permeability, such as shale, and is commonly referred to as a seal or cap. The hydrocarbon will continue to migrate upward along the barrier until it either reaches a place where it will pool or it will escape to the surface at a natural seep.

Hydrocarbons accumulate in structures or traps which have been created by folding of the rocks due to tectonic movements. Other common traps are related to the presence of faults caused by tectonic movement, or the absence of permeable rock due to the geological setting in which the permeable sandstone has accumulated. These pools of gas and oil (shown in red and green in Figure 3), where the hydrocarbon is contained within permeable sandstones and trapped by a sealing layer and a structure, are conventional oil and gas targets.

The most common type of trap in the Cooper Basin is an anticline. Anticlines are dome shaped structures in the rock caused by the folding and bending of strata from movement of the earth’s surface. The volume of oil or gas stored in a conventional hydrocarbon accumulation, typically called an oil or gas field, is governed by the pore space in the rock and the volume of rock within the anticline or dome that is confined by the seal.

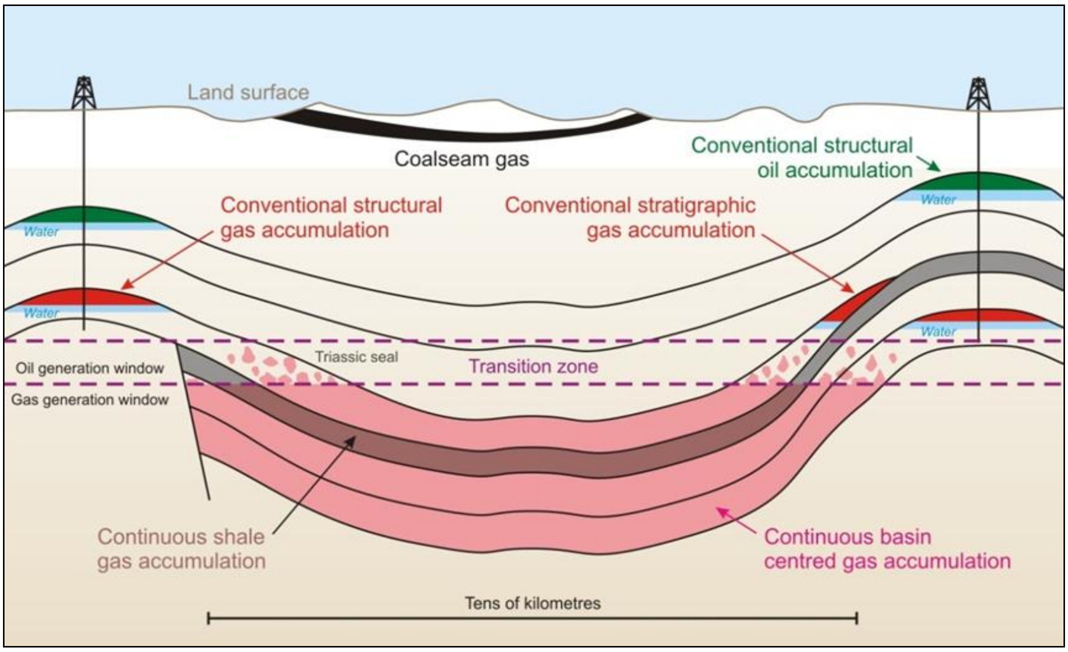


Figure 3: Illustration of the differences between conventional hydrocarbon traps in anticlines and a basin-centred gas play (modified from Schenk and Pollastro 2002).

3.1.2 Basin-centred gas and shale gas targets

Shale gas, tight gas and basin-centred gas are generally termed as unconventional gas however the term 'unconventional ' does not refer to either the gas itself or the methods used to extract it. There is no difference between gas produced from conventional reservoirs and that produced from basin-centred or shale gas. The gas is still sourced from organic matter and is natural gas that can be processed and distributed. The method of extraction has also been used for conventional oil and gas for decades, including in the Cooper Basin.

The difference between conventional and unconventional gas refers to where the gas is found and produced from underground. Exploration focuses on shale and tight oil and gas systems where hydrocarbons have been generated but have not been able to migrate, rather than on underground structures such as anticlines and highly permeable sandstones.

Due to very low permeability of the source rock, or surrounding strata adjacent to the source, the gas becomes regionally trapped by an inability to migrate further, rather than a structure (Figure 3 above depicts the presence of shale gas and basin-centred gas in a deep trough not confined by a structure). As the gas is not pooled in discrete traps, these hydrocarbon accumulations are also known as continuous plays. The shales and tight gas intervals tend to extend over vast distances - several thousands of square kilometres in the case of the Nappamerri Trough shown in Figure 4.

Another characteristic of both basin-centred gas and shale gas plays is the presence of over-pressure. If the gas generated from organic matter cannot migrate out, the reservoir pressure will increase. Additionally, conventional hydrocarbon accumulations have water sitting immediately beneath the column of oil and/or gas, whereas water is generally not found within a basin-centred gas system.

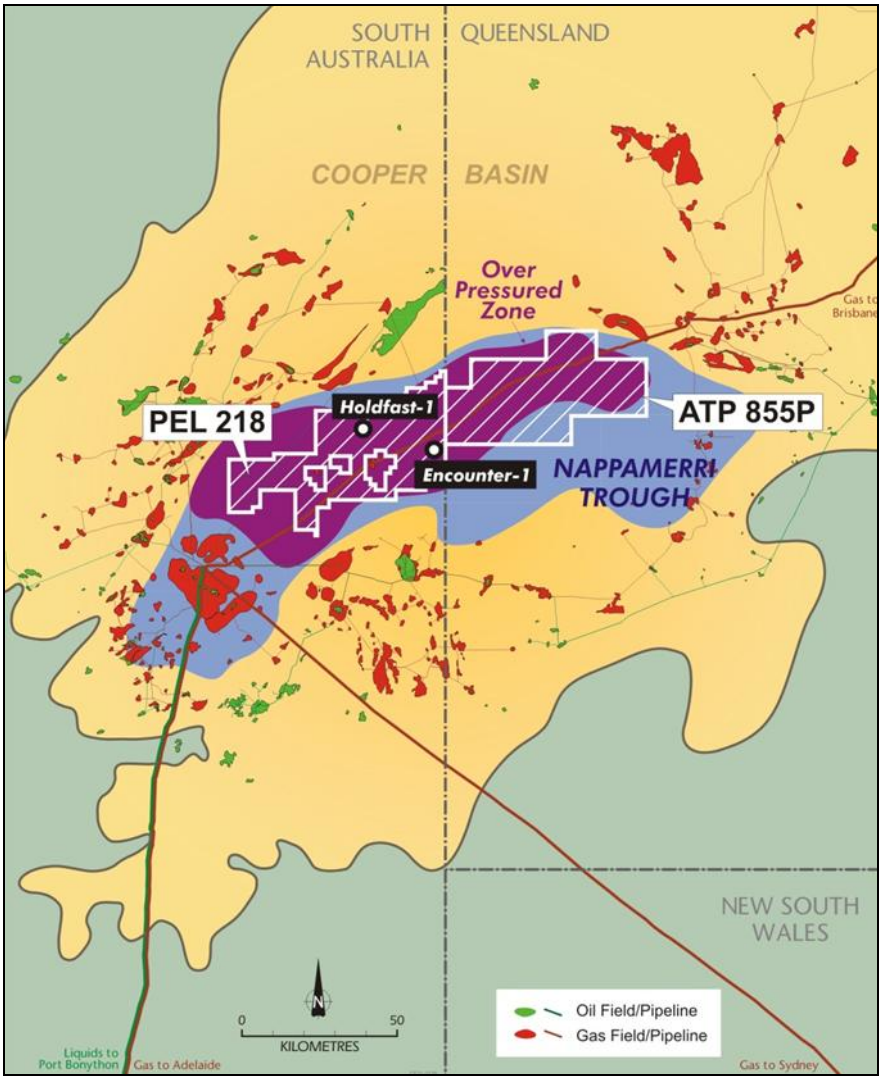


Figure 4: Location of the Nappamerri Trough over pressured zone (also referred to as the Central Nappamerri Trough)

3.2 Shale Gas and Basin-centred Gas Exploration

The Cooper Basin is a mature hydrocarbon production province. Exploration commenced in 1959 with the drilling of Innamincka-1, but it was not until 1963 and the drilling of the ninth exploration well (Gidgealpa-2), that gas was discovered. By 1969 gas was being supplied from Moomba to Adelaide with Sydney being connected in 1976. By the late-nineties, a gas processing plant was constructed at Ballera and gas from the Queensland section of the basin was being supplied to Brisbane and Mt Isa through newly constructed pipelines. To date approximately 6 Tcf of gas has been produced from the Cooper Basin.

Oil production has also been a target for drilling in the area but is generally found in the shallower Eromanga Basin, held in the porosity of the sandstone aquifers of the Great Artesian Basin and trapped in localised structures.

Historically it was thought that the source rocks for gas in the Cooper Basin were coals in the Toolachee and Patchawarra formations. The Roseneath and Murteree shales, which are thick and continuous throughout the area, were thought to be poor quality source rocks. However studies conducted by Beach Energy in 2007 and 2008 suggested that these shale intervals were source rocks for gas.

Beach undertook a two well exploration program in summer 2010 / 2011 where a thorough assessment of shale gas potential was made from information collected during the extensive coring and well evaluation program. Additionally, the wells were drilled to penetrate the top 50 m of the Patchawarra formation on structural low points in the trough to test the basin-centred gas model. The evaluation indicated potential for significant volumes of gas, both in the shales and in the tight sand intervals of the Cooper Basin in the Nappamerri Trough. Considerable tight gas potential deeper in the Patchawarra remains untested.

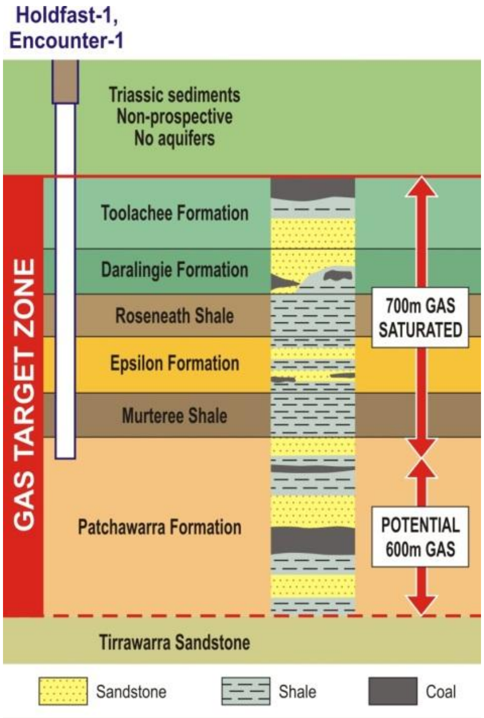


Figure 5: Schematic of exploration targets in the Holdfast-1 and Encounter-1 wells

Beach also conducted fracture stimulation (under the Drilling and Well Operations SEO (Santos 2009)) to evaluate key uncertainties including the direction of fracture propagation (horizontal or vertical). Horizontal fracture propagation would require a different longer term well design to the typical horizontal well used in shale gas development elsewhere in the world.

Holdfast-1 was successfully stimulated in June 2011 and tiltmeter monitoring indicated the generation of vertical fractures. The well was flow tested and production logging was undertaken to understand contribution of the intervals. Gas production from the Patchawarra interval confirmed the presence of the basin-centred gas play in the trough and flows from the shale intervals encouraged Beach to progress to the next stage of evaluation.

For the shale zones, horizontal wells with multi-stage stimulation are required to understand the deliverability potential of these intervals and determine the steps to converting this significant resource into reserves. For the basin-centred gas play, where gas is trapped in tight sands, additional vertical wells are required to assess the full extent of the Patchawarra interval, deliverability potential, variability in reservoir quality with depth and areal limits of the basin-centred model.

Due to the low permeability nature of these reservoirs, fracture stimulation, traditionally a method employed in enhancing production from conventional reservoirs in the development phase of activities, will be required in the exploration and appraisal stage. Without stimulation these zones will not produce and an assessment of their potential cannot be made.

4 Description of the Environment

4.1 Climate

The region has an arid climate, with low average rainfall and high evaporation. Seasons are generally characterised by hot dry summers and mild dry winters. Rainfall in the area is highly erratic, with the annual average being about 100 to 200 mm. There is no distinct seasonal rainfall pattern and rainfall is often associated with thunderstorm activity and as a consequence can be localised and intense. Annual rainfall can be recorded in one event (Arid Areas Catchment Water Management Board 2006).

Temperatures vary from cool in winter to hot in summer, with diurnal variations also being high. In summer, the average maximum and minimum temperatures are approximately 37°C and 23°C respectively, and in winter 20°C and 7°C. The maximum recorded temperature at Moomba Airport is 47.3°C and the minimum -0.5°C (BoM 2012). A summary of climate records for Moomba Airport (Station 017123; BOM 2012) is provided in Table 1.

Table 1: Temperature and rainfall records for Moomba

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Mean Daily Max (°C)	38.5	36.6	33.8	29.1	23.6	19.9	19.5	22.6	27.4	30.2	33.7	36.2	29.3
Mean Daily Min (°C)	24.6	23.7	20.4	15.6	10.7	7.3	6.5	8.3	12.4	15.7	19.5	22.0	15.6
Mean Rainfall (mm)	15.2	37.5	16.3	7.7	10.2	10.1	18.6	5.6	15.1	11.5	24.3	15.2	186.9
Median Rainfall (mm)	3.9	13.6	2.2	1.4	1.0	3.6	5.2	1.0	2.2	5.2	8.8	6.2	157.9

Bushfires are relatively rare in the region, as the vegetation is generally sparse and fuel loads are low. However, grass fires initiated by lightning strikes can occur in years such as when favourable seasonal conditions have resulted in heavy growth of forbs and grasses.

4.2 Biophysical Environment

4.2.1 Land systems

The area is characterised by three land systems – the floodplains, channels and dunes of the Cooper land system, the gibber slopes of the Merninie land system and the dunefields of the Tingana land system (Marree SCB 2004). These land systems are described in Table 2 and shown in Figure 6 and Plate 1 to Plate 5.

The majority of the area overlying the Nappamerri Trough falls within the Cooper land system. In this region this land system consists predominantly of broad areas of floodplain, the defined drainage lines of the Cooper Creek, Ooranie Creek and Strzelecki Creek, and scattered patches of sand dunes.

Plate 1: Merninie land system

Table 2: Land systems in the area

Land System	Description	Land Unit	Soils
Cooper	Waterholes, braided channels, floodplains, ephemeral lakes of the Cooper and Strzelecki Creeks. Periodically flooded parallel sandridges and interdune areas	Waterholes and channels	Pale grey sandy to silty clays. Similar soils present in braided channels and temporary waterholes on Cooper and Strzelecki Creeks.
		Floodplain	Extended flats behind braided channels – pale sandy clays with veneer of pale grey sands. Sandy clay layer is hard setting at about 25 cm and forms a hardpan, preventing deeper water penetration. Also areas of grey self-mulching cracking clay soils with “crabholes” and deeper water penetration. Gilgai flats – pale grey self-mulching cracking clays, with gilgai formation. Large clay interdune areas are similar.
		Sandplains	Slightly above the level of the extended flats. Sandy loams, with a hard setting layer at about 20cm.
		Dunes	Vary from older red siliceous sands (which are older and may have a clayey core) to whitish siliceous sands.
		Coongie Lakes	Grey clays, with sediment deposited on lake floors.
Merninie	Long, gradual and gentle silcrete gibber slopes with occasional mesas, alluvial plains and drainage lines with small clayey floodouts	Gibber	Duplex – shallow fine sandy loam over a light clay, with a dense gibber surface. Gibber coverage is variable ranging from 20 -100%.
		Alluvial Plains	Red self-mulching uniform soils (sandy clays) and gradational red calcareous earths (sandy clay loam at the surface grading into sandy clay or medium clay at depth.)
		Drainage Lines	Sandy or gravelly, with small clay floodout areas.
Tingana (formerly listed as Della or Strzelecki)	Long parallel sandridges of red, yellow or white aeolian sands, with semi-mobile crests, sandy and clayey interdunes and numerous claypans and internal soakages.	Dunes	Relatively stable slopes and semi- mobile crests with deep, red siliceous sands. Lower slopes are clayey sands to red sandy clay loams.
		Interdunes and claypans	Narrow interdunes –massive (non-cracking) red sandy clay loam usually with shallow loamy sand veneer. Wider interdune areas (up to 1km) – red self-mulching cracking clay soils with frequent areas of claypan and non-cracking massive red earths. Low limestone or kopi rises – present in some interdunes as minor component. Surface soils are sandy loams, becoming calcareous at depth. Claypan swamps – massive red earths at margins with brown or grey cracking self-mulching clays in lower parts.

Source: (Marree SCB 2004)

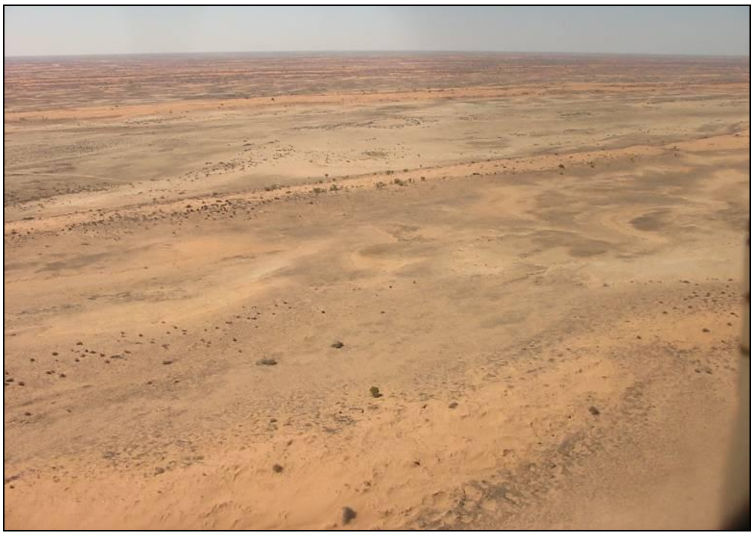
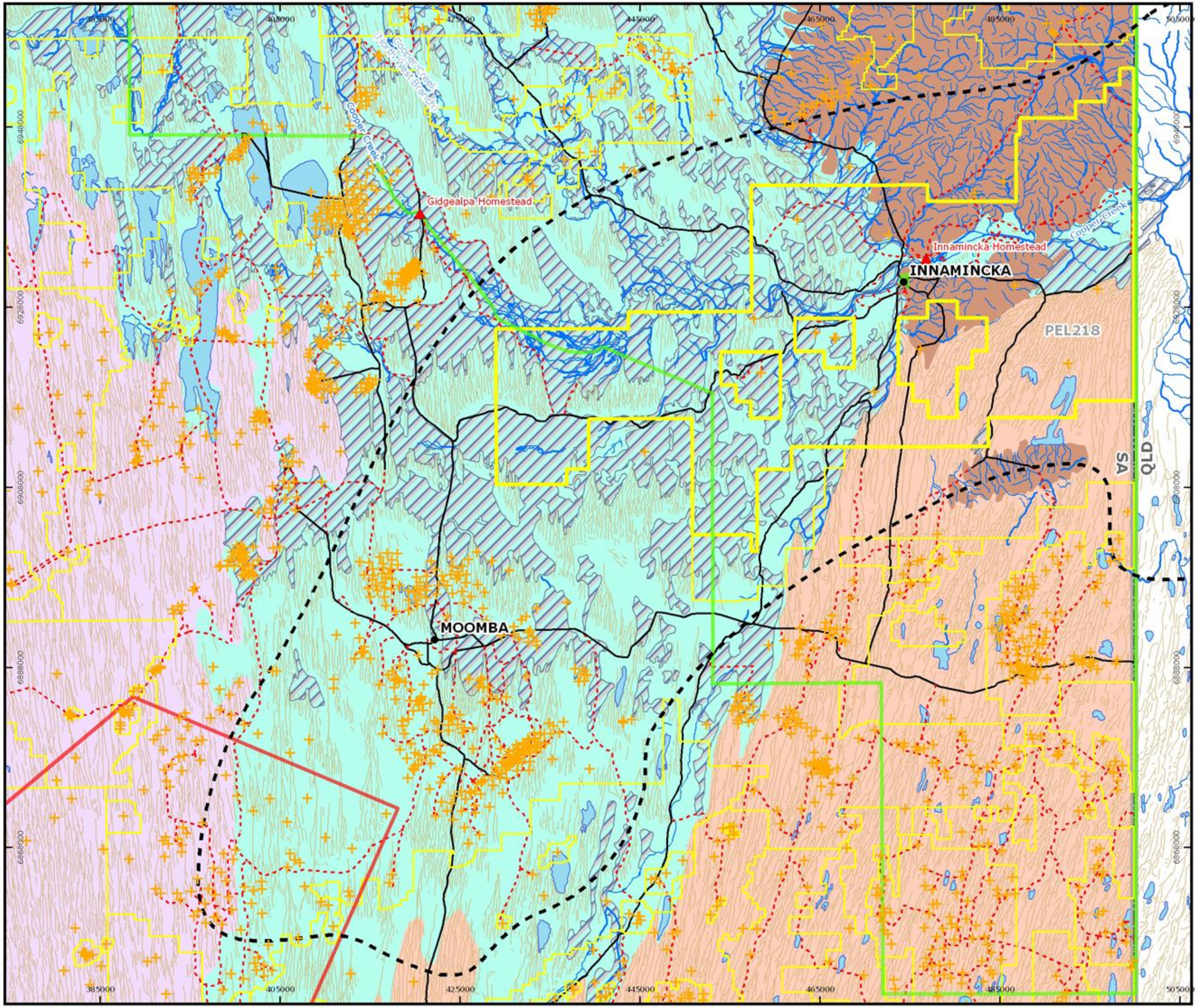


Plate 2: Tingana land system dunefields

Plate 3: Cooper land system (sandy rise overlooking floodplain in 2011)

Plate 4: Cooper land system (floodplain south of Cooper Creek in 2009)

Plate 5: Cooper land system (Cooper Creek near Innamincka)



DATA SOURCES
DWLBC
Geoscience Australia
DENR
RPSAQT

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no guarantee is given that the information portrayed is free from error or omission. Please verify the accuracy of all information prior to use.

RPS Aquaterra

FIGURE 6:
Land systems in the area

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4.2.2 Flora and Fauna

4.2.2.1 Vegetation

Typical vegetation of the Cooper, Merninie, and Tingana land systems is described in Table 3.

Table 3: Vegetation of land systems in the area

Land System	Land Unit	Vegetation
Cooper	Waterholes and channels	Tall woodland is supported; river red gum and coolibah, with eurah, bean tree, Broughton willow wattle whitewood and native orange. Usually an understorey of lignum, with groundcover of short-lived perennials or annuals; cannonball, tangled poverty bush, ruby saltbush and annual saltbushes. Overstorey is primarily coolibah with occasional river red gum and cooba. Lignum stands are dense.
	Floodplain	Flats behind braided channels – Coolibah, with whitewood and spotted emubush on sandier patches, forms a woodland to open woodland. Shrub layer of old man saltbush, Queensland bluebush and lignum. Subshrubs include red and other copperburrs and poverty bushes. Annuals include buckbush and onionweed. Gilgai flats – Chenopod shrubland of Queensland bluebush dominates, but variations depend on frequency of flooding. Swamp canegrass or lignum may appear as single species stands or, mixed with each other and the Queensland bluebush.
	Large clay interdune corridors	The same species as above, with additional copperburrs in the groundcover. Responses to rain particularly in clay swales, may be prolific, with buttongrass, New Zealand spinach, buckbush and pigweed common
	Sand plains	Low open woodland including whitewood, prickly wattle, sandhill wattle, some coolibah, needlewood and beefwood over a mixed grass and subshrub groundcover: mulga grass, oatgrass, katoora, mulka with buckbush, goathead burr, tangled lechenaultia and copperburrs.
	Dunes	Low woodland or tall shrubland of whitewood, narrow-leaf hopbush, needlewood and sandhill wattle over kerosene and mulga grasses, buckbush and grey copperburr. The majority of red dunes on Innamincka are semi-mobile, with crests and upper slopes carrying sandhill canegrass and ephemeral species. Lobed spinifex may be present. Pale dunes are recent deposition from the floodplains, and are more mobile. Perennial cover may be sandhill wattle, eurah and occasionally coolibah, with a hummock grassland cover of lobed spinifex, and ephemeral species.
	Coongie Lakes	River red gum, which halts at Coongie Lake on the northwest branch but extends further on the main channel. Lakes to the north have coolibah as the dominant tree. Surrounds are effectively equivalent to the various floodplain units (above). Lake floors when drying out may contain spiny sedge, but other vegetation is ephemeral although when present may be in large quantities. Species include nardoo, New Zealand spinach, Bogan flea and Cooper clover. Water bodies when present contain mats of duckweed and water primrose.
Merninie	Gibber	Vegetation is open perennial grassland of Mitchell grass with neverfail, ephemeral or short-lived perennials; mulga grass, woolly copperburr, pearl copperburr, grey copperburr, buckbush and goathead burr. In drought, Mitchell grass grazed to ground level and dead copperburrs, leads to an unvegetated appearance.
	Alluvial Plains	Mitchell grass perennial grassland, but with few other grasses. Most common secondary species is short-winged copperburr.
	Drainage Lines, Creeks & Channels	Lined with gidgea and red mulga, with whitewood, sandalwood, colane and sennas, red gum on the occasional deeper channels.
Tingana (formerly Della or Strzelecki)	Dune upper and midslopes	Low woodland or tall shrubland of whitewood, narrow-leaf hopbush, needlewood and sandhill wattle in the north, with whitewood becoming infrequent in the south. Midstorey of lobed spinifex and thorny saltbush, or sandhill canegrass where crests are semi-mobile, and a groundcover of ephemerals and short-lived perennials particularly kerosene and mulga grasses, buckbush and grey copperburr.
	Interdunes	Treeless apart from occasional groves of very low senna or needlewood. Cover is perennial grass and short-lived perennial copperburrs and similar; curly Mitchell grass, neverfail, mulka, copperburrs and poverty bushes. Low limestone or kopi rises are present in some interdunes – main cover is low shrubland of low bluebush or cottonbush, with grey copperburr, buckbush, pale poverty bush, goathead burr, neverfail and annual grasses. Bladder saltbush appears to the south.
	Claypan swamps	Shrubland of lignum, Queensland bluebush and swamp canegrass, either mixed or in single species stands, with perennial grasses neverfail and mulka. Following water run-on, ephemeral growth includes tall copperburr, common joyweed, Bogan flea and pop saltbush. Claypan swamps diminish in size and importance to the south with Queensland bluebush component of swamp vegetation disappears, with swamp canegrass becoming more important.

Source: (Marree SCB 2004)

<u>Threatened Ecological Communities</u>

No nationally significant threatened ecological communities have been identified in the Nappamerri Trough region through EPBC Act protected matters database searches or previous field inspections.

Three vegetation communities that potentially occur within the area are listed as 'of concern' in the listing of threatened ecosystems of the Non-Agricultural Region in South Australia (Neagle 2003; DEH Provisional list 2005). They are generally at threat from introduced herbivore grazing which removes vegetation and changes plant species composition. These communities are:

- *Eucalyptus coolabah* ssp. a*rida* (Coolibah) Woodland on levees and channel banks of regularly inundated floodplains
- *Atriplex nummularia* (Old-man Saltbush) Open Shrubland with occasional emergent *Eucalyptus camaldulensis* (River Red Gum) or *E. coolabah* ssp*. Arida* (Coolibah) on low sandy rise of floodplains
- *Chenopodium auricomum* (Golden Goosefoot) Shrubland on cracking clay depressions subject to periodic waterlogging.

<u>Threatened Plant Species</u>

Database searches (DENR 2011, DSEWPC 2012) indicate that there are a number of State-listed flora species that have previously been recorded in the region (see Table 4). No flora species of national conservation significance were highlighted in database searches and none have been detected within the area during previous field inspections.

The potential presence of State-listed rare or threatened species at specific well sites is addressed in initial scouting and site assessment conducted under the Drilling and Well Operations SEO (Santos 2009).

Table 4: Listed plant species recorded in the area

Species	Common Name	AUS	SA
Acacia tenuissima	Slender Wattle	-	R
Bergia occultipetala		-	V
Callitriche sonderi	Matted Water Starwort	-	R
Eremophila polyclada	Twiggy Emubush	-	R
Eryngium vesiculosum	Prostrate Blue Devil	-	R
Frankenia cupularis		-	R
Gilesia biniflora	Western Tar-vine	-	R
Mimulus prostratus	Small Monkey-flower	-	R
Osteocarpum acropterum var. deminutum	Wingless Bonefruit	-	R
Osteocarpum pentapterum	Five-wing Bonefruit	-	E
Phlegmatospermum eremaeum	Spreading Cress	-	R
Pimelea penicillaris	Sandhill Riceflower	-	R
Swainsona oligophylla		-	R
Zygophyllum humillimum	Small-fruit Twinleaf	-	R

Regions: AUS: *Environment Protection and Biodiversity Conservation Act 1999*; SA: *National Parks and Wildlife Act 1972*
Status Key: V: Vulnerable; R: Rare; E: Endangered

4.2.2.2 Fauna

Terrestrial and avian fauna species present in the area include:

- **Mammals**: Small mammals such as Fat-tailed and Stripe-faced Dunnarts, Giles Planigale, Sandy Inland Mouse and House Mouse are common. Other mammals present include Little

Broad-nosed Bat, and Short-beaked Echidna. Larger mammal species include the Red Kangaroo, Dingo, and non-native species Cattle, Cat, European Rabbit and Fox.

- **Reptiles:** Common reptiles include Fat-tailed Gecko, Eastern Brown Snake, Sand Goanna, Gidgee Skink, Painted Dragon, Mulga Snake, Curl Snake and Inland Taipan.
- **Amphibians**: Ten frog species have been recorded in the Cooper Creek system including several species of burrowing frog (e.g. Trilling Frog, Water-holding Frog) which may be relatively widespread and others (Desert Froglet, Green Tree Frog, Broad-palmed Frog) that would be restricted to areas near water (i.e. the Cooper Creek) except during flooding.
- **Birds**: Bird species present include Australian Magpie, Galah, Brown Falcon, Budgerigar, Black-faced Woodswallow and Little Corella.

The Cooper Creek system supports a diverse array of aquatic fauna including waterbirds, fish, frogs and aquatic invertebrates. The wetlands associated with the north-west branch of the Cooper Creek, including Coongie Lakes, are recognised as a region of exceptional ecological value. The aquatic invertebrate fauna is abundant and diverse and includes an array of insects, crustaceans and gastropods (Reid and Puckridge 1990). Aquatic vertebrates include Desert Rainbow Fish, Water Rat, Macquarie Tortoise and a diverse frog population. The fish community of the north-west Cooper Creek system is one of the most significant in South Australia as it is close to its original composition, with only two exotic species present (Reid and Puckridge 1990). Two species of fish, the Lake Eyre Callop and Cooper Creek Tandan, are endemic to the Cooper Creek catchment.

The Coongie Lakes system supports enormous numbers and diversity of water birds. These wetlands have been recognised as internationally significant under the Ramsar Convention, providing a feeding, resting and breeding site for large numbers of migratory and nomadic birds. The most abundant species during flooding include Grey Teal, Pink-eared Duck, Wood Duck, Australian Pelican, Great Cormorant, Black Swan, Eurasian Coot, Black-tailed Native-hen, and Red-necked Avocet. The Cooper Creek system (particularly areas such as Coongie Lakes) also supports rare or threatened waterbird species such as Freckled Duck, Musk Duck, Little Egret and Intermediate Egret (DEHAA 1998).

In dry periods, aquatic fauna are concentrated in refuges such as Coongie Lakes and the permanent waterholes on the upstream reaches of the Cooper in South Australia. During flooding, these fauna increase rapidly in abundance and occur across the vast area of channels, waterholes, swamps and floodplains in the Cooper Creek system.

Threatened and significant fauna species

Table 5 lists the significant fauna species that have been recorded or are potentially present within the area, as identified through database searches (DENR 2011, DSEWPC 2012).

The potential presence of rare or threatened species for specific well sites is addressed in initial scouting and site assessment conducted under the Drilling and Well Operations SEO (Santos 2009).

Table 5: Threatened fauna species recorded or potentially occurring in the area

Family	Species name	Common name	AUS	SA
Birds	*Actitis hypoleucos*	Common Sandpiper		R
	Amytornis barbatus	Grey Grasswren		R
	*Amytornis barbatus barbatus**	Grey Grasswren (Bulloo)	VU	R
	Anas rhynchotis	Australasian Shoveler		R
	Anhinga novaehollandiae	Australasian Darter		R
	Aprosmictus erythropterus	Red-winged Parrot		R
	Apus pacificus	Fork-tailed Swift	Mm, Lis	
	Ardea alba	Great Egret,	Mi, Mm, Lis	
	Ardea ibis	Cattle Egret	Mi, Mm, Lis	
	Ardea intermedia	Intermediate Egret		R

Family	Species name	Common name	AUS	SA
	Ardeotis australis	Australian Bustard		V
	Biziura lobata	Musk Duck		R
	*Botaurus poiciloptilus**	Australasian Bittern	E	V
	Cacatua leadbeateri	Major Mitchell's Cockatoo		R
	Cladorhynchus leucocephalus	Banded Stilt		V
	Egretta garzetta	Little Egret		R
	Elanus scriptus	Letter-winged Kite		R
	Falco hypoleucos	Grey Falcon		R
	Falco peregrinus	Peregrine Falcon		R
	Grantiella picta	Painted Honeyeater		R
	Grus rubicunda	Brolga		V
	Hamirostra melanosternon	Black-breasted Buzzard		R
	Lophoictinia isura	Square-tailed Kite		E
	Merops ornatus	Rainbow Bee-eater	Mi, Lis	
	Myiagra inquieta	Restless Flycatcher		R
	Ninox connivens	Barking Owl		R
	Oxyura australis	Blue-billed Duck		R
	Phaps histrionica	Flock Bronzewing		R
	Plegadis falcinellus	Glossy Ibis		R
	Podiceps cristatus	Great Crested Grebe		R
	Stictonetta naevosa	Freckled Duck		V
	*Rostratula australis**	Australian Painted Snipe	VU	V
Mammals	*Notomys fuscus*	Dusky Hopping-mouse	VU	V
	Pseudomys australis	Plains Mouse (Plains Rat)	VU	V
	Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat		R
Reptiles	*Aspidites ramsayi*	Woma		R
	Emydura macquarii	Macquarie Tortoise		V
	Proablepharus kinghornii	Blacksoil Skink		R

Regions: AUS: *Environment Protection and Biodiversity Conservation Act 1999*; SA: *National Parks and Wildlife Act 1972*

Conservation Codes: En or E: Endangered, Vu or V: Vulnerable R: Rare; Mm: Migratory Marine species; Mi: Migratory wetland species; Lis: Listed overfly marine area

* Predicted by the EPBC Act database; no DENR biological database records in the area

4.2.3 Surface Water

Cooper Land System

The Cooper Creek system is the dominant surface water feature in the area. The Cooper Creek originates in catchments in south-west Queensland. During periods of low flow, most water flows through the North-West Branch of the Cooper Creek into the Ramsar-listed Coongie Lakes and Lake Goyder. If flows are large enough to fill these lakes, additional water flows down the main branch of the Cooper towards Lake Hope and eventually discharges into Lake Eyre.

The main channel of the Cooper Creek is generally well defined and connects a series of ephemeral swamps and permanent and semi-permanent waterholes. During floods, the main channels overflow and floodwaters spill into the vast floodplain via numerous distributory channels.

Significant local rainfall events can also result in shallow inundation of floodplains, inter-dune claypans and other areas of poorly drained impermeable soil, which can persist for days to weeks or longer. Local rainfall and run-off also results in flow in ephemeral watercourses, most of which drain into either the Cooper or Strzelecki Creeks.

Cooper Creek flows are unregulated and extremely variable. Flow occurs in one or more discrete pulses each year and several months may pass without flow (Puckridge *et al.* 1999). Flow in the Cooper Creek occurs in almost every year, and in most years it reaches the Coongie Lakes (DEH 2008).

The mean annual flow in the Cooper Creek is in the order of 1.4 million megalitres, with a median annual flow (at Cullyamurra Waterhole, near Innamincka) of 399,100 ML (NRW 2007, DWLBC 2007). The highest annual flow was over 14 million megalitres in 1974. Flow can occur in any month, and zero flows have also been recorded in all months of the year. It has been estimated that there is a 98% chance that flow rates will exceed 1m^3/s at Innamincka each year (Kotwicki 1986).

During periods of high flow, floodwaters overtop the banks of the Cooper and flow southwards down the Strzelecki and Ooranie Creeks. Cooper Creek floods that are large enough to flow into Strzelecki Creek and its floodplain are relatively rare events. Previous investigations have estimated that floods of this size have an average frequency of approximately one in ten years (Puckridge *et al.* 1999). Flows into Ooranie Creek are more frequent, with an average frequency in the order of 1 in 5 years (SEA 1992, Puckridge *et al.* 1999). Table 6 outlines the frequency and extent of flow classes in the Cooper Creek that have been derived from the gauging station at Cullyamurra Waterhole, upstream of Innamincka.

Strzelecki Creek is predominantly dry. It can receive some localised inflow from heavy rainfall events but generally only flows during very large Cooper Creek floods, when water flows southwards from Innamincka towards Lake Blanche (a distance of approximately 200 km).

Table 6: Cooper Creek flow classes, frequency and extent

Flow Class	Daily Flow Volume (ML/day)	Total Volume (ML)	Frequency	Comment
1	600 – 1,200	14,000 – 40,000	Annual	Since 1973 there have been Class 1 floods, or larger, every year. All water flows into the North-West Branch of Cooper Creek.
2	1,200 – 2,500	40,000 – 130,000	1-2 years	Most water flows into the North-West Branch, but a proportion flows into the main branch of Cooper Creek.
3	2,500 – 5,400	130,000 – 220,000	1-2 years	Significant part of flows into the main branch as far as Embarka Swamp.
4	5,400 – 18,000	220,000 – 400,000	2 years	Significant flow enters the main branch, to the lower main branch and the lower Cooper Creek.
5	18,000 – 40, 000	400, 000 – 1,400,000	2-5 years	Significant flow occurs out of Coongie Lakes into the lower Cooper Creek as far as Lake Hope.
6	40,000 – 100,000	1,400,000 – 2,400,000	5 years	Results in flows into Wilpinnie Creek. Flow into this area can disrupt gasfield installations.
7	100,000 – 180,000	2,400,000 – 4,500,000	10 years	Results in flows into Strzelecki Creek but not as far as Lake Blanche. Flows occur along the lower Cooper Creek.
8	180,000 – 450,000	4,500,000 – 10,750,000	20 years	Flow into Lake Eyre North and fill Lake Blanche. Class 8 flood was the largest flow pulse in 1990.
9	> 450,000	> 10,750,000	100 years	A Class 9 flood occurred in 1974, but no satellite images are available to determine flood extent.

Source: Puckridge *et al.* (1999), Santos (2003)

During very large floods, much of the floodplain area within the Cooper land system becomes inundated. However, within this land system, there are areas of dunefield, isolated sand dunes and patches of higher ground that are not subject to flooding, as evident in Figure 6 above.

<u>Tingana and Merninie Land Systems</u>

Significant drainage lines are generally absent in the Tingana land system. Surface water catchments are typically restricted to individual interdune corridors. Surface water ponds in interdune corridors, often collecting in claypans and occasionally salt lakes within the interdune. Infiltration rates are generally low, and surface water may remain in the swales and claypans for a few days to a few weeks or more, depending on the rainfall event and rates of evaporation.

The Merninie land system is characterised by a network of small, defined drainage lines, which carry runoff from larger rainfall events. These drainage lines typically flow for only a short time (e.g. six to twelve hours) after rainfall has ceased. Many of these drainage lines terminate in clayey floodouts or larger channels, which within the Nappamerri Trough region generally drain to the Cooper Creek.

Flood events in the Cooper Creek do not result in inundation in the Tingana and Merninie land systems.

4.2.4 Geology

This section provides a broad regional geological context (based on the information contained in Santos 2003) and then provides more detail on the geology of the Nappamerri Trough.

The Eromanga and Cooper Basins are located in central and eastern Australia. The Cooper Basin is a north-east, south-west trending basin that extends over an area of about 153,000 km^2 in north-east South Australia and south-west Queensland (Stanmore 1989). It is unconformably overlain by the Eromanga Basin. The saucer-shaped Eromanga Basin extends over a much larger area of around one million square kilometres in Queensland, New South Wales, South Australia, and the south-east of the Northern Territory (Figure 7). The Eromanga Basin is overlain by the Lake Eyre Basin.

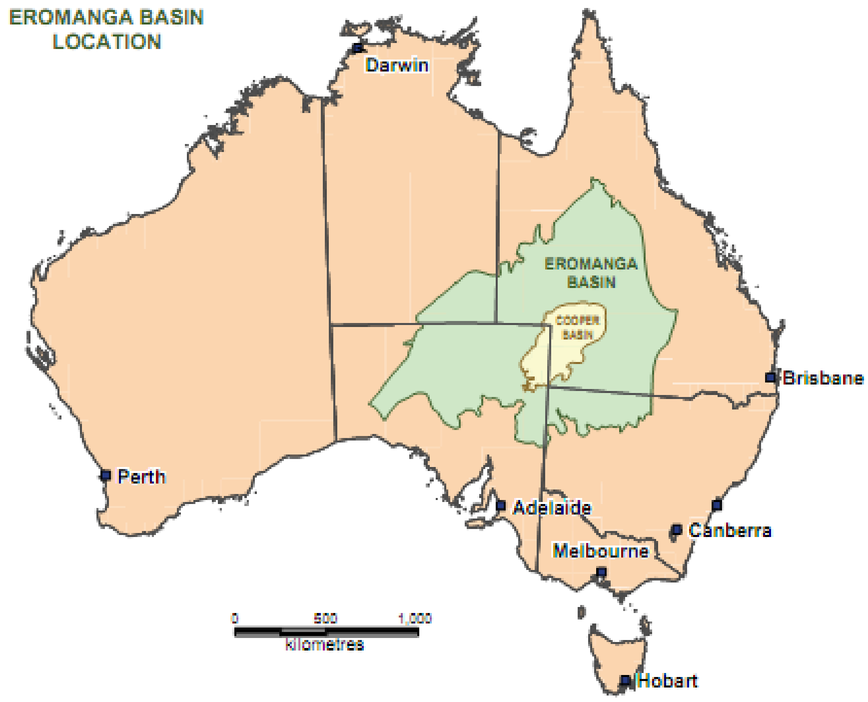


Figure 7: Cooper and Eromanga Basin location map

In the north-east of South Australia, the Lake Eyre Basin consists of the surface sediments described in Section 4.2.1, on floodplains, wetlands, tablelands, gibbers, salt pans. At depth, units include the Yandruwantha Sand (medium to coarse grained sand), the Namba Formation (deltaic and lacustrine clay, silt and sand), and the Eyre Formation (sandstone and shale). The thickness of Lake Eyre Basin sediments in the Moomba area is generally in the range 200 – 300 m (Drexel and Preiss 1995).

Below the Lake Eyre Basin section lie the Eromanga Basin sediments which are between 1200 m and 2,700 m thick (Gallagher and Lambeck 1989). These sediments were deposited under fluvial (river), lacustrine (lake) and later shallow-marine conditions, and are broadly continuous across the basin (Vine 1976). These sediments are gently folded in some areas and contain a succession of geographically extensive sandstone formations that serve as oil reservoirs and regional aquifers known as the Great Artesian Basin.

Located underneath the Eromanga Basin section, the total Cooper Basin sediment accumulations exceed 1,500 m in some places and are characterized by fluvial, deltaic, and swamp deposits that include some coal measures (Thornton 1979). These sediments contain petroleum reservoirs (mainly gas) and aquifers.

The stratigraphy of the Cooper and Eromanga Basins is shown in Figure 8.

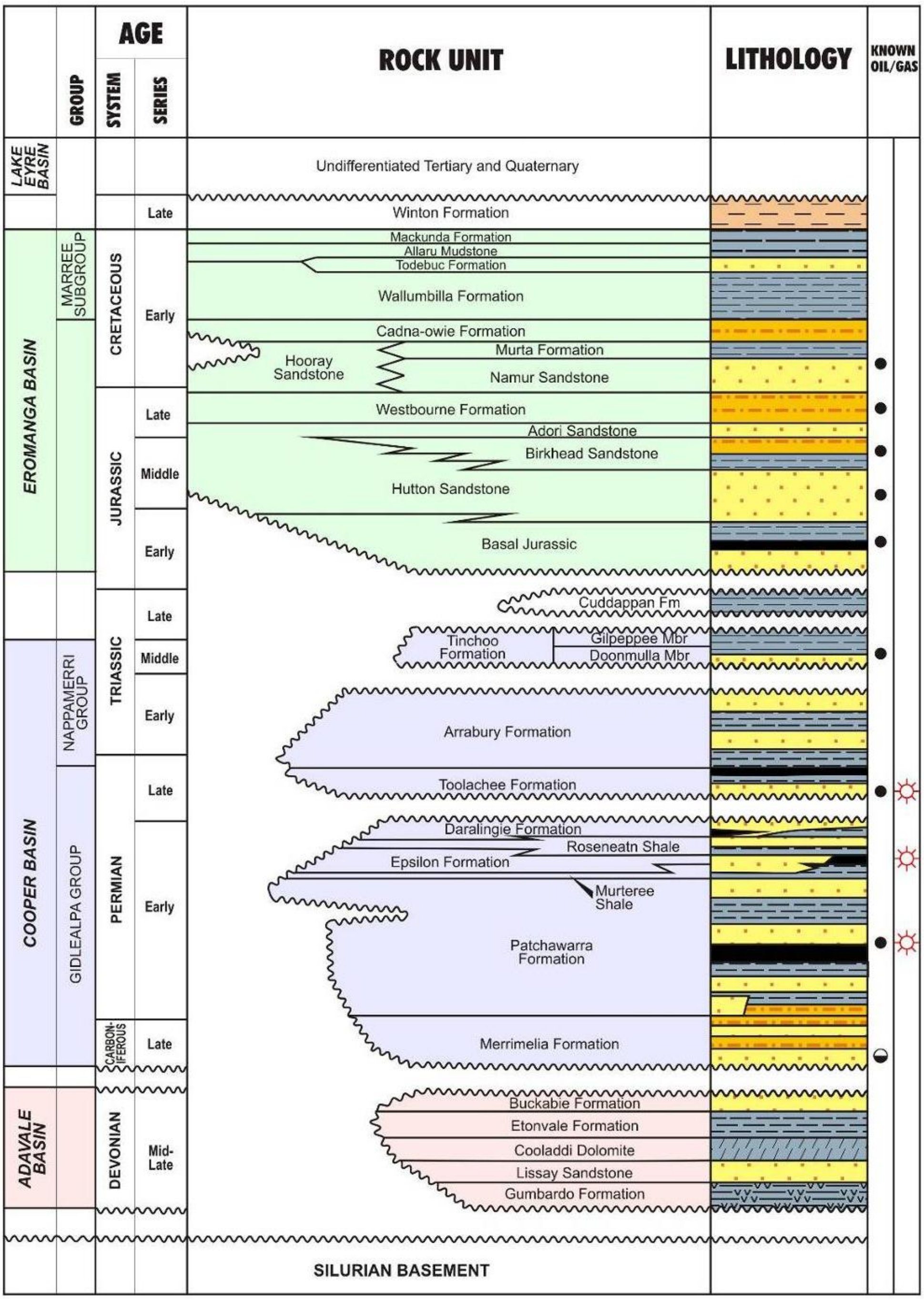


Figure 8: Cooper and Eromanga Basin stratigraphic chart

The tectonic history of the Cooper and Eromanga Basins is complex and has been characterised by several periods of rift-related subsidence and compressional uplift and erosion. This history has resulted in the Cooper Basin being subdivided into a number of large scale sub-troughs separated by fault bounded ridges. The historical evolution of the Cooper and Eromanga Basins is discussed by Kuang (1985), Finlayson et al. (1988), Gallagher (1988), Hunt et al. (1989) and Stanmore (1989). The Cooper and Eromanga Basins are currently subject to a regionally compressive stress regime. Motion along fault bounded basement blocks results in strong local stress variations. Evidence from well bore geomechanics shows that conditions for movement on faults are present and that the structural evolution of the area is ongoing.

4.2.4.1 Central Nappamerri Trough

The Nappamerri Trough is the deepest and largest of three north-east to south-west trending depocentres (sites where sediment has deposited and accumulated) within the Cooper Basin. The Nappamerri Trough is separated from the Patchawarra and Tenappera Troughs by the Gidgealpa-Merrimelia-Innamincka Ridge to the north and the Murteree-Nappacoongee Ridge to the south (Figure 9).

The area referred to in this section as the Central Nappamerri Trough encompasses the area to the far east of the trough within South Australia and in particular is covered by PEL218, a large and contiguous block covering approximately 1,600 km^2.

Figure 9: Structural elements of the Cooper-Eromanga Basin (showing the Nappamerri Trough)

The Nappamerri Trough formed as a result of multiple phases of structural deformation. Mid Carboniferous deformation created an underlying structural grain in Basement rocks. Three main post Carboniferous structural events affected the formation of the trough. Early Permian east-west oriented compression at the Daralingie Unconformity caused reverse and thrust faults. This event separated the originally continuous basin into several troughs. Late Triassic compression rejuvenated the earlier features and the later middle Cretaceous north-west directed shortening reactivated major pre-existing structures (Flottman et al, 2004). The reactivation of pre-existing structures along the ridges resulted in

a relatively complex fault and stress model along the ridges, but left the Central Nappamerri Trough structurally simple.

Although 2D seismic coverage of the Central Nappamerri Trough is currently sparse compared to other areas of the basin, very few large faults have been interpreted on the existing seismic indicating the majority of the stress caused by the compressional events was taken up by the faulting and fractures along the ridges. As a result of the lack of major faulting in the Central Nappamerri Trough there are currently no known instances of communication between deeper reservoir and shallower aquifer systems within the central trough area. Elsewhere in the basin, due to thinning of the geological sequences, the Cooper Basin formations and the Eromanga Basin formations become juxtaposed.

Prior to the drilling of the Encounter-1 and Holdfast-1 wells in 2010 and 2011 respectively, seven petroleum exploration wells were drilled through to the Patchawarra Formation within the Nappamerri Trough from 1971 to 1997 (Burley-1, Burley-2, Burley-3, Kirby-1, Kirby-2, Bulyeroo-1 and McLeod-1). These wells have provided valuable information regarding the stratigraphy, lithology and stress regimes of the Nappamerri Tough.

Stratigraphy

The Central Nappamerri Trough contains a full representation of the Cooper and Eromanga Basin sediments. Basement rock in the Central Nappamerri Trough is represented by radioactive granites which provide the high heat flow seen in the trough. A summary of the stratigraphy intersected in the Central Nappamerri Trough is shown in Table 7 and cross sections of the Jurassic and Permian formations are shown in Figure 10 and Figure 11.

Table 7: Summary of the stratigraphy in Central Nappamerri Trough

Formation	Classification	Lithologies	Average Central Nappamerri Trough thickness (m)
Winton Formation	Aquifer	siltstone, sandstone, minor claystone, coal	865
Mackunda Formation	Aquifer	siltstone, sandstone	90
Allaru Mudstone	Aquitard	siltstone	225
Toolebuc Formation	Aquitard	siltstone, minor limestone	55
Wallumbilla Formation	Aquitard	siltstone, minor sandstone	425
Cadna-owie Formation	Aquitard	siltstone, fine grained sandstone	86
Murta Formation	Aquitard	siltstone, sandstone	65
Namur Sandstone	Aquifer	sandstone, siltstone	74
Westbourne Formation	Possible aquifer	sandstone, siltstone	130
Adori Sandstone	Aquifer	sandstone	30
Birkhead Formation	Aquitard	siltstone, sandstone, mudstone	75
Hutton Sandstone	Aquifer	sandstone, siltstone	135
Poolowanna Formation	Aquifer	sandstone	57
Nappamerri Group	Aquitard	siltstone, sandstone	412
Toolachee Formation	Reservoir	sandstone, siltstone, mudstone, coal	140
Daralingie Formation	Potential reservoir, predominantly aquitard	siltstone, sandstone	60
Roseneath Shale	Unconventional reservoir, aquitard	mudstone, siltstone	100
Epsilon Formation (multiple sands)	Reservoir	sandstone, siltstone, mudstone, coal	132
Murteree Shale	Unconventional reservoir, aquitard	mudstone, siltstone	73
Patchawarra Formation	Reservoir	sandstone, siltstone, mudstone, coal	351
Tirrawarra/Merrimelia Formation	Potential reservoir	sandstone, siltstone, mudstone	200

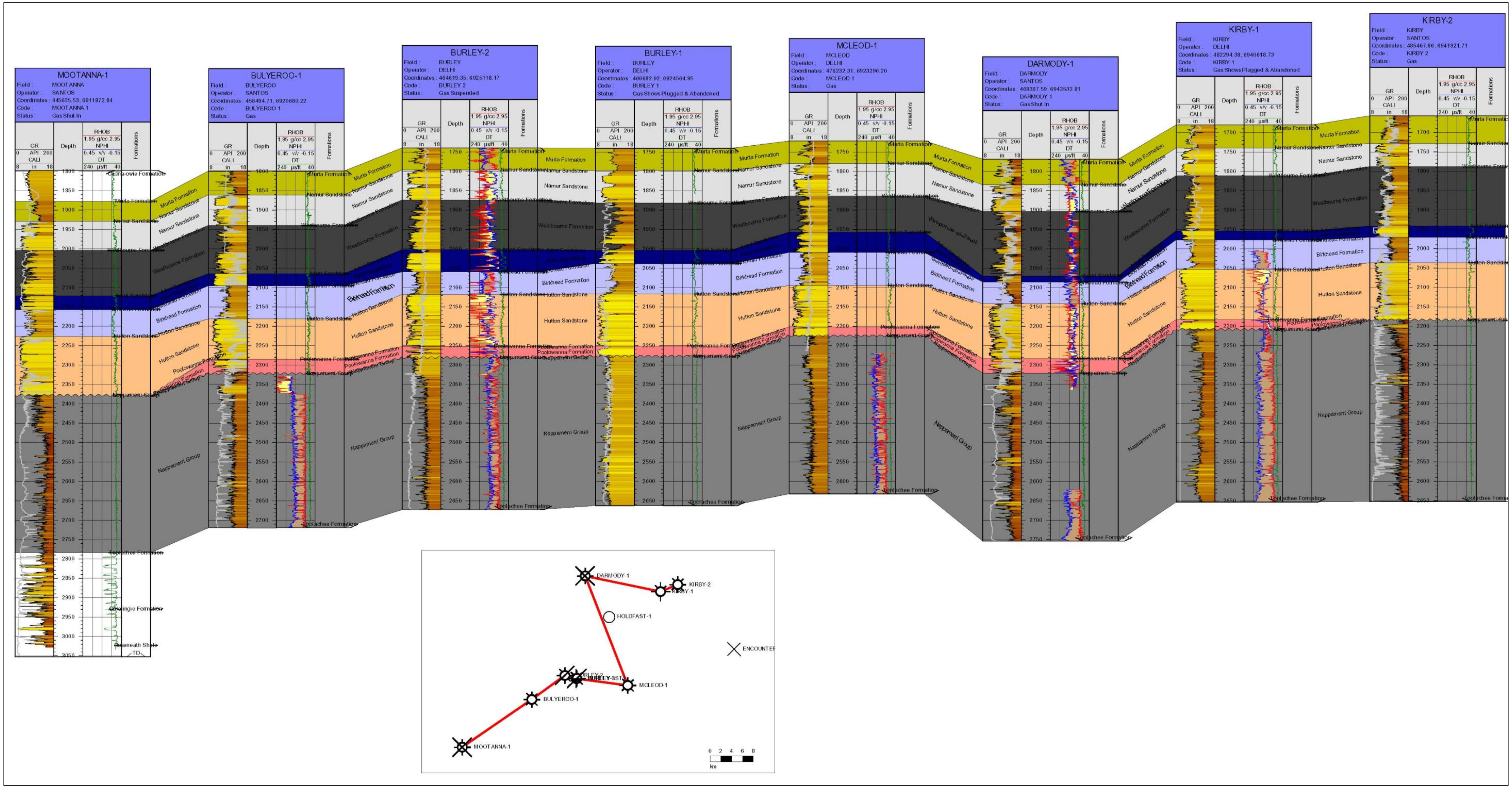


Figure 10: Jurassic cross-section showing the lateral continuation and relatively constant thickness of the Jurassic aquifers across the Central Nappamerri Trough area.

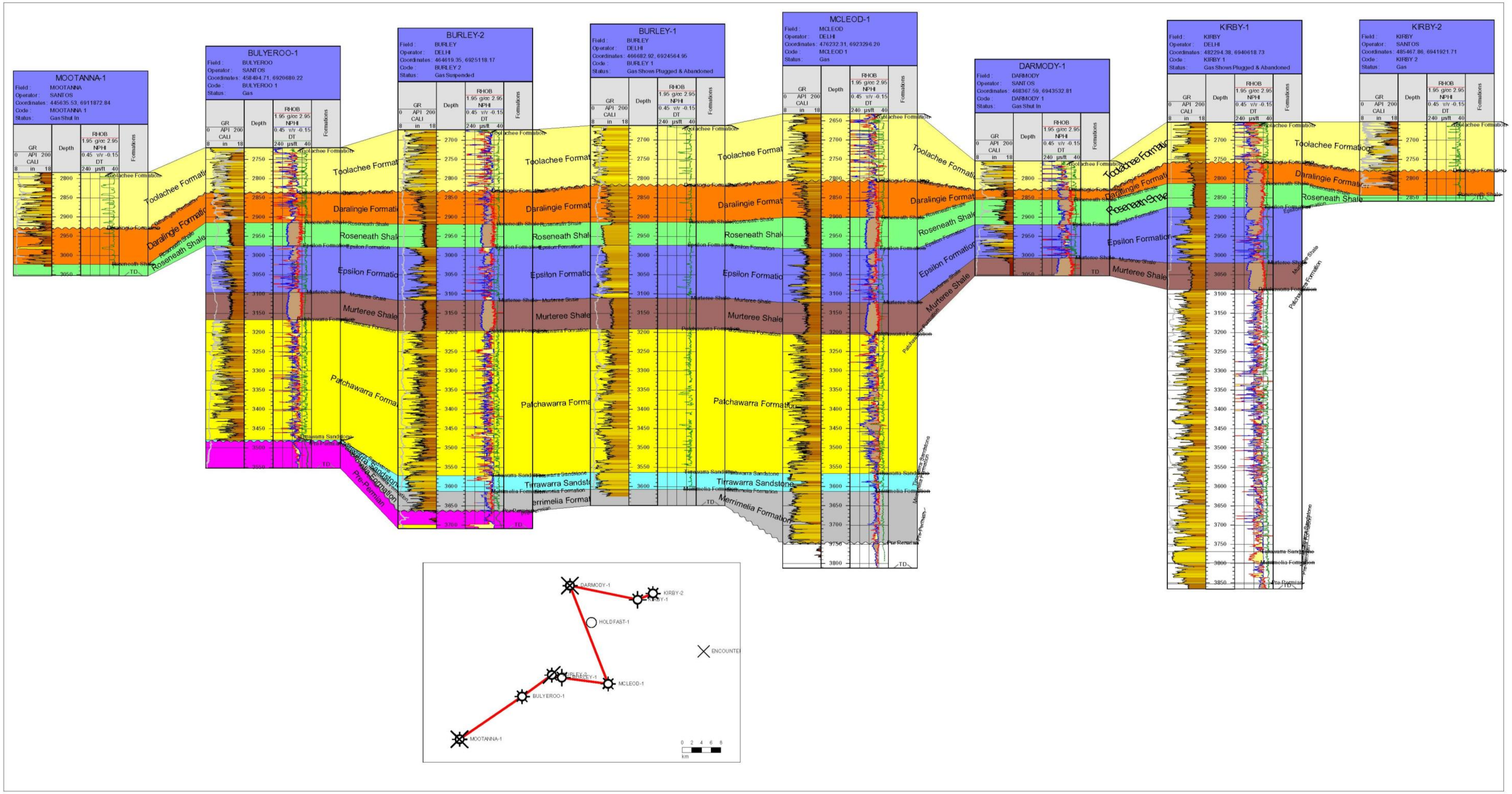


Figure 11: Permian formation cross-section showing the lateral continuation of the gas saturated target intervals across the PEL 218 area. Referenced to depth.

Unconventional Gas Potential

The potential for the Central Nappamerri Trough to contain large volumes of unconventional gas was recognised over a decade ago (Hillis *et al*., 2001). The recognition of significant overpressure in nine existing exploration wells in the Nappamerri Trough in combination with low permeability sands and thick source rocks set up the Central Nappamerri Trough as being a basin-centred gas play.

This play type can extend over a very large area and is believed to extend beyond the limits of the PEL218 permit. The extent is theorised to be controlled by the over-pressure of the Permian which is most likely caused by the difference in gas generation and expulsion/migration in the low permeability sand and shale reservoirs. Reservoir pressure up to 8,000 psi exists within the Permian formations. The over-pressure occurs not only in the sandstones but also within the shales and siltstones.

Characteristics of the Unconventional Gas Targets

The formations of interest as targets for gas production from Central Nappamerri Trough are Permian sediments: the Toolachee Formation (low permeability sands), Roseneath Shale (shale gas), Epsilon Formation (low permeability sands and shale gas), Murteree Shale (shale gas) and the Patchawarra Formation (low permeability sands). It is these formations that will be the focus of fracture stimulation activity. The Daralingie Formation (low permeability sands) is considered a secondary target at this stage. The unconventional gas targets are overlain by the Nappamerri Group, which in the Central Nappamerri Trough is a thick layer of relatively impermeable Triassic sediments.

All of the reservoir targets are laterally continuous across the Central Nappamerri Trough area with erosion and truncation of some of the Permian sediments occurring only towards the ridges which bound the greater Nappamerri Trough to the north (Gidgealpa-Merrimelia-Innamincka Ridge) and south (Murteree-Nappacoongee trend) (see Figure 11). The Permian strata appears to be gas saturated across the Central Nappamerri Trough and no formation water has been recovered from any of the drill stem tests in the exploration wells drilled in the trough.

The lithology of each of the Triassic-Permian target formations in the Central Nappamerri Trough is described in Table 8. Details on the lithology of the overlying sediments, which form the aquifers of the Great Artesian Basin and the shallower aquifers, are provided in the following section on hydrogeology (Section 4.2.5).

Table 8: Lithological characteristics of Triassic-Permian formations in the Central Nappamerri Trough

Formation	Lithological Characteristics
Nappamerri Group	The upper Nappamerri Group is dominated by sandstones of variable thickness and quality (Wimma Sandstone Member). When the upper Nappamerri Group does not have the sandstone present, lithology tends to be siltstone. In the Central Nappamerri Trough the remainder of the Nappamerri Group is dominated by siltstones and mudstones with the occasional thin sandstone bed (Paning and Callamurra Members).
Toolachee Formation	Mixed lithology formation with moderate to low permeability sandstones, siltstones, mudstone and coals up to 15 m thick. The middle and basal Toolachee Formation tends to contain more reservoir sands than the top portion of the formation.
Daralingie Formation	Dominated by siltstones and mudstones with the occasional thin interval of sandstones not easily correlatable across the Central Nappamerri Trough.
Roseneath Shale	Interval of consistent lithology dominated by mudstones and silty mudstones with occasional siltstone. Lithology consistent across Central Nappamerri Trough.
Epsilon Formation	Mixed lithology formation with minor thin coals generally in the middle of the formation. Interbedded sandstones, siltstones and mudstones with a more sandy package at the base of the Epsilon being common in all wells in the Central Nappamerri Trough.
Murteree Shale	Interval of consistent lithology dominated by mudstones and silty mudstones with occasional siltstone. Lithology consistent across Central Nappamerri Trough.
Patchawarra Formation	Mixed lithology formation with interbedded thin coals, mudstones, siltstone and low to moderate permeability sandstones. Variability in vertical occurrence of the sandstones between wells across Central Nappamerri Trough.
Tirrawarra/ Merrimelia Formation	Dominated by low permeability sandstones with sandstone packages being vertically separated by siltstone intervals.

Stress Regimes and Fracture Orientation

The stress orientations and magnitudes within the target rocks are important as they influence the orientation and growth of induced fractures during fracture stimulation. Stress studies using borehole data (caliper and image logs) indicated the average maximum horizontal stress (SHmax) orientation for the Cooper Basin was approximately east-west which is consistent with the maximum stress orientation interpreted in the Nappamerri Trough (Reynolds et al, 2004).

In general, fractures will propagate in the maximum horizontal stress direction and the fracture will open in the minimum stress direction. Geomechanical studies of early exploration wells in the Central Nappamerri Trough as well as recent studies using the Holdfast-1 and Encounter-1 data, indicated the Permian strata within the Central Nappamerri Trough is in a strike-slip stress regime where the vertical stress (Sv) is the intermediate stress. There is a possibility for the stress regime to become a reverse stress regime with depth. In this instance the vertical stress is the minimum stress. Hydraulic fractures in a strike-slip regime will tend to be vertical whereas a hydraulic fracture in a reverse stress regime will be horizontal.

In the recently drilled and fracture stimulated well, Holdfast-1, a tiltmeter array was installed to monitor the stimulation and determine whether horizontal or vertical fractures were being created. Tiltmeters are very sensitive tools which detect subtle deflections in the earth’s surface during the hydraulic fracture treatment and are used to interpret the fracture orientation and plane. The tiltmeter data from Holdfast-1 indicated that the fracture stimulation resulted in vertical fractures with only a minimal amount of horizontal component.

Stress Contrasts and Fracture Containment

The geomechanical studies discussed above have indicated that there is a significant variation in elastic properties and stress magnitudes between lithologies in the Central Nappamerri Trough, which will impact on the height growth of induced fractures during fracture stimulation.

The calculated minimum horizontal stress magnitude (shown as a black line in Figure 12), has a similar magnitude to the calculated vertical stress (shown as a sloping brown line in Figure 12). Where the minimum stress is less than the vertical stress, induced fractures are likely to be vertical. Where the minimum horizontal stress exceeds the vertical stress, induced fractures are expected to be horizontal.

Where all stresses come together, as seen in the Roseneath and Murteree shales, the induced fractures are likely to be controlled by a fabric or pre-existing natural fault system within the rock. The analysis of the tiltmeter data from Holdfast-1 has shown that the induced fractures in these zones were vertical.

Significant changes in the stress regime can result in containment of fracture growth. As seen in Figure 12, the minimum horizontal stress increases above the Roseneath shale into the Daralingie formation (3,100 – 3,075 m) by ~15% and again above the Toolachee formation into the Nappamerri formation (2,825 – 2,775 m) where it increases by ~25%. The minimum horizontal stress exceeds the vertical stress at these locations and the preferred induced fracture direction changes to horizontal. This change, together with the increase in stress, is likely to result in containment of fracture height growth at these points.

As a result, during fracture stimulation it is unlikely that induced fractures would propagate beyond the top of the Toolachee into the Nappamerri Group. In addition, the relatively impermeable nature of the Nappamerri Group sediments make the Nappamerri Group a very good geological barrier between the gas saturated target interval and the overlying Jurassic aquifers of the Great Artesian Basin.

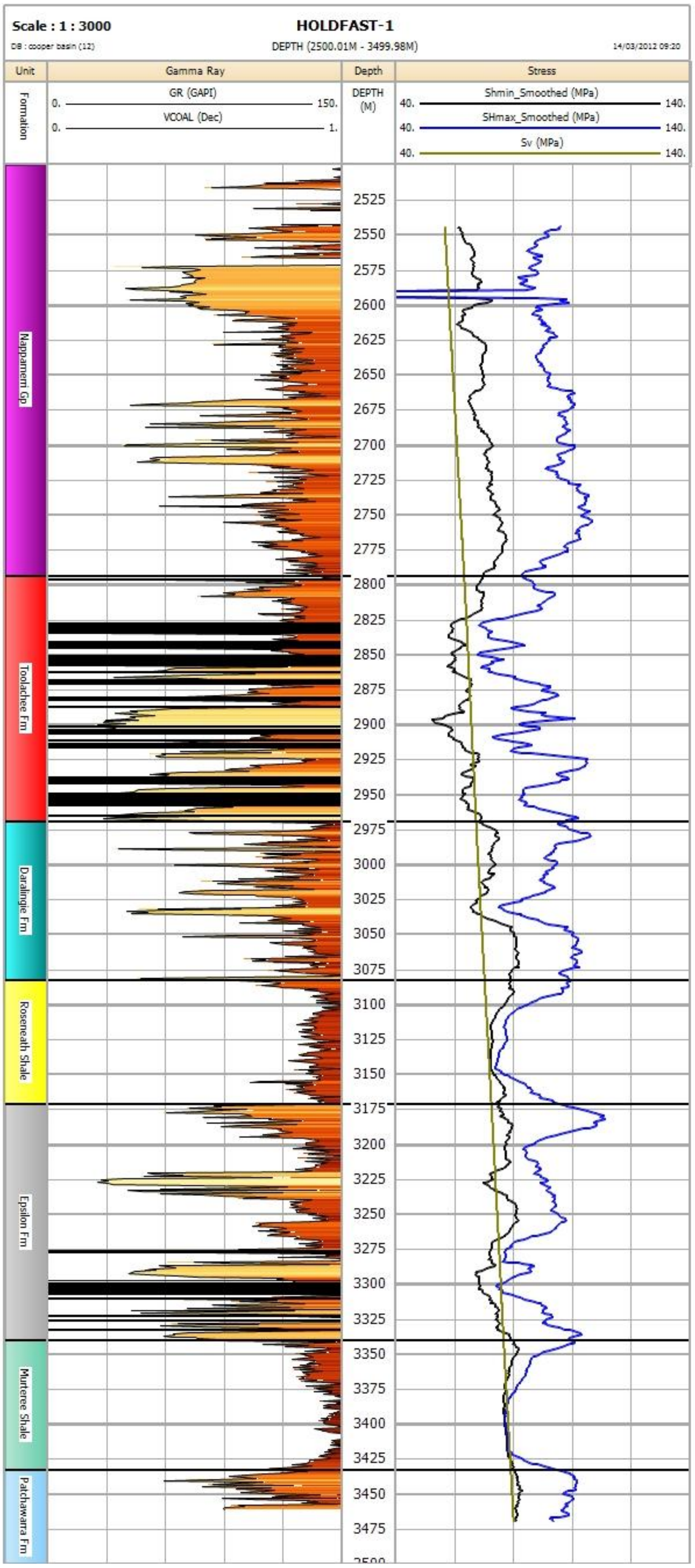


Figure 12: Calculated vertical and horizontal stresses

<u>Geothermal Gradient</u>

Geothermal gradients in the Cooper and Eromanga Basins range from 30°C / km on the margins to 60°C / km in the Nappamerri Trough. Here temperatures in the basal Cooper sediments reach approximately 250° C.

4.2.5 Hydrogeology

4.2.5.1 Regional Setting

Regional hydrogeology is dominated by the presence of the Great Artesian Basin, one of the largest multi-layer aquifer systems in the world. The Great Artesian Basin (GAB) comprises Jurassic and Cretaceous sediments of three large sedimentary basins, the Eromanga, Carpentaria and Surat Basins, of which the Eromanga Basin is the largest and most central. Only the south-western third of the Eromanga Basin extends into South Australia, with the Carpentaria and Surat Basins located in Queensland.

The groundwater flow in the GAB is generally to the south-west; with recharge occurring in northern Queensland and groundwater discharging as spring flow around Lake Eyre. Groundwater travel times can be of the order of 1 to 2 million years. In South Australia recharge also occurs along the western basin margin and a component of groundwater flow also comes from the eastern extension of the basin in New South Wales.

Throughout the GAB there are numerous permeable formations and a number of aquifers of regional significance. In central Australia the GAB sediments are overlain by the sediments of the Lake Eyre Basin. These sediments consist of Tertiary sands and often contain beds of lignite and clay. The sand units can host useful local aquifers that are often exploited for stock water. Localised aquifers can also be found in Quarternary alluvial sands and gravel. Depending on the location in the landscape, groundwater salinity in these shallow aquifers can range from fresh to saline.

Within the Eromanga Basin itself two major regional aquifer systems are identified, these being the Cadna-owie Formation and Algebuckina Sandstone (Cadna-owie–Algebuckina aquifer), and the upper confined aquifer consisting of sediments of the Winton and Mackunda Formations. The two aquifer systems are separated by the shales of the Bulldog Shale and Oodnadatta Formation. Aquifers of the Winton and Mackunda Formations are generally confined by clays and shale of the Winton Formation and Tertiary sediments of the Lake Eyre Basin. Both aquifer systems can be unconfined near the basin margins.

An intermediate aquifer exists between these two major aquifer systems and is hosted in the Coorikiana Sandstone, which forms a discrete aquifer of high salinity and low permeability in the southern and western Eromanga Basin. Although artesian pressures have been recorded in this aquifer it is generally not exploited due to its poor water quality and low yield. The Winton and Mackunda Formations, while generally confined, are not artesian and are not as widely utilised as the deeper and better quality artesian aquifers of the Cadna-owie–Algebuckina aquifer system.

The Cadna-owie–Algebuckina aquifer comprises the major source of groundwater in the Far North Prescribed Wells Area. To the east of the Birdsville Track Ridge, and overlying the Cooper Basin, the Cadna-owie–Algebuckina aquifer includes sediments of the Murta Formation and the Namur, Adori, Hutton and Poolowanna Sandstones. West of the Birdsville Track Ridge, the confining beds separating these sandstone units pinch out over the ridge and the individual sandstones merge into the Algebuckina Sandstone.

In various locations across the Cooper Basin, erosion of the Cooper Basin sediments and deposition of Eromanga Basin sediments over the top has resulted in contact or mixing between the two formations. As a result, over geologic time, hydrocarbons have migrated from the Cooper Basin into the Eromanga Basin. Indications of trace oil and gas are seen in the Jurassic (GAB) aquifers during drilling across the Cooper Basin because of this migration and in certain areas of the basin, the Eromanga Basin sediments (i.e. the GAB aquifers) are targets for oil exploration and production.

Table 9 summarises the characteristics of the formations which have either aquifer or hydrocarbon reservoir properties from surface through to the base of the Cooper Basin sediments. This is a general classification and can change in specific study areas. Figure 13 and Figure 14 show regional cross sections of the Cooper Basin and also indicate a number of the areas where mixing between Cooper and Eromanga fluids is known to occur. As noted in Section 4.2.4, within the Central Nappamerri Trough there are no known instances of communication between deeper Permian formations and shallower aquifer systems.

Table 9: Summary of salinity, pressure and permeability characteristics

Reservoir/ Aquifer	Use	Extent	Salinity	Pressure System	Permeability
Eyre Formation	Limited use for petroleum exploration (rig water)	Basin wide	Dept for Water Drillhole Enquiry System indicates 100-34,000 ppm	Uppermost aquifer, unconfined.	High
Winton Formation	Known aquifer and confining bed.	Basin wide	Brackish	Part of Winton-Mackunda aquifer system. Uppermost GAB aquifer. Generally confined, non-artesian. Confining layer to interbedded sands and underlying Mackunda Formation. Outcrops north of PEL218.	High
Mackunda Formation	Known aquifer	Basin wide	Brackish	Part of Winton-Mackunda aquifer system. Uppermost GAB aquifer. Generally confined, non-artesian.	High
Coorikiana Sandstone	Known aquifer. Potential reservoir	Restricted to more marginal southern and central areas of basin	Unclear, probably high (>9,000 ppm) dataset, may be high or low	GAB Aquifer between bulldog shale and Oodnadatta Formation. Confined aquifer, artesian in parts.	Generally low but local areas up to moderate
Murta Formation (multiple sands)	Known aquifer and reservoir	Basin wide, but sands may be limited in extent	Limited data (300-4,000 ppm) for Murta sands	Part of main GAB aquifer (Algebuckina Sandstone equivalent). Generally confined artesian, heads generally in excess of 50 m above ground in Nappamerri Trough area.	High - up to multiple darcy
Namur Sandstone (includes McKinlay member of Murta Fm)	Known aquifer and reservoir	Basin wide	300-4,000 ppm	Part of main GAB aquifer (Algebuckina Sandstone equivalent). Generally confined artesian, heads generally in excess of 50 m above ground in Nappamerri Trough area. May have local depleted zones	High - up to multiple darcy
Adori Sandstone	Known aquifer and reservoir	Restricted to northern and central part of basin	300-4,000 ppm	Part of main GAB aquifer (Algebuckina Sandstone equivalent). Generally confined artesian, heads generally in excess of 50 m above ground in Nappamerri Trough area. May have local depleted zones	High - up to multiple darcy
Birkhead Formation (multiple sands)	Known reservoir	Basin wide	300-4,000 ppm	Part of GAB. Generally a confining bed to the Hutton Sandstone. May have local depleted zones	Highly variable
Hutton Sandstone	Known aquifer and reservoir	Basin wide	300-4,000 ppm	Part of main GAB aquifer (Algebuckina Sandstone equivalent). Generally confined artesian, heads generally in excess of 50 m above ground in Nappamerri Trough area. May have local depleted zones	High - up to multiple darcy
Poolowanna Formation	Known reservoir	Basin wide?	3,000-4,000 ppm in Cooper Basin area, but in excess of 9000 ppm in northern areas	Unclear if part of GAB. May have local depleted zones	High - up to multiple darcy
Cuddapan Formation (multiple sands)	Known reservoir	Patchawarra Trough only	Unknown		High - up to multiple darcy
Nappamerri Group (multiple sands)	Known reservoir	Basin wide, but sands of local extent. Degree of interconnection across basin unclear	3,000-7,000 ppm. Local variations appear to depend on connection with GAB	May be same or greater or less than GAB. May have local depleted zones	Highly variable
Toolachee Formation (multiple sands)	Known reservoir	Basin wide, but sands of local extent. Complex interconnections across basin	1,500 to 15,000 ppm apparently depending on connection with GAB. Data set combined with Daralingie	Potential for very high pressures in centre of basin. May be same or greater or less than GAB. May have local depleted zones. Can prove connection with GAB in Munkarie Brumby area.	Highly variable
Daralingie Formation (multiple sands)	Known reservoir	As above	Data combined with Toolachee	Potential for very high pressures in centre of basin. May be same or greater or less than GAB. May have local depleted zones	Highly variable
Epsilon Formation (multiple sands)	Known reservoir	As above	Limited dataset, 2,000 to10,000 ppm apparently depending on connection with GAB	As above	Highly variable
Patchawarra Formation (multiple sands)	Known reservoir	As above	2,000 to 18,000 ppm. Low salinities in Weena / Tinga Tingana Trough	As above	Highly variable
Tirrawarra / Merrimelia Formation	Known reservoir	Basin wide except for south east and around local highs	Limited dataset for Tirrawarra 5,000 to 17,000 ppm no data for Merrimelia	As above	Highly variable
Pre Permian Basement	Known reservoir	Basin wide	Unknown	Potential for very high pressures in centre of basin. May be same or greater or less than GAB	Highly variable, may include natural fractures

Source: After Santos (2003)

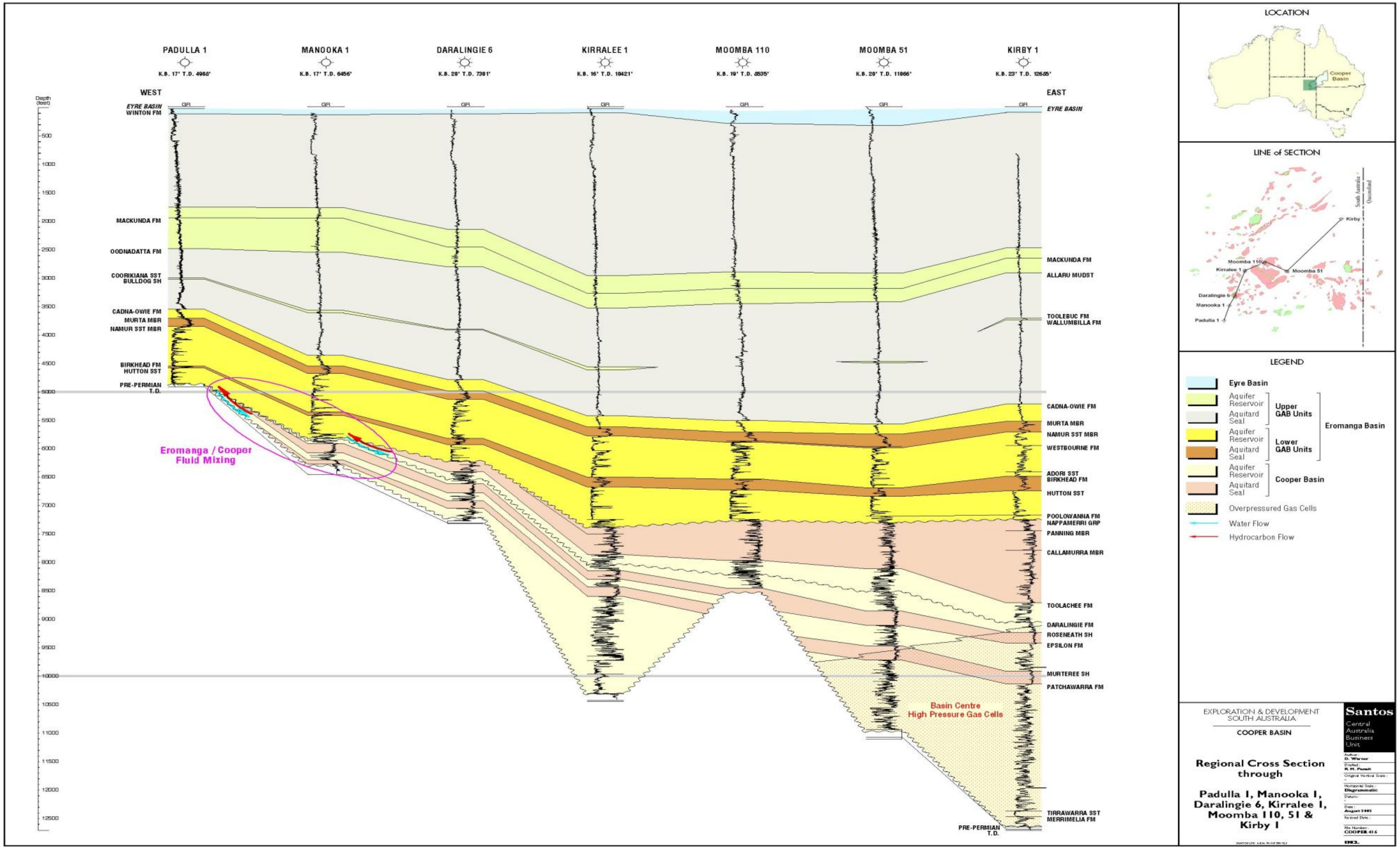


Figure 13: Regional geological cross-sections of the Cooper-Eromanga Basin (1). Note: Kirby-1 is in the Central Nappamerri Trough (Source: Santos 2003)

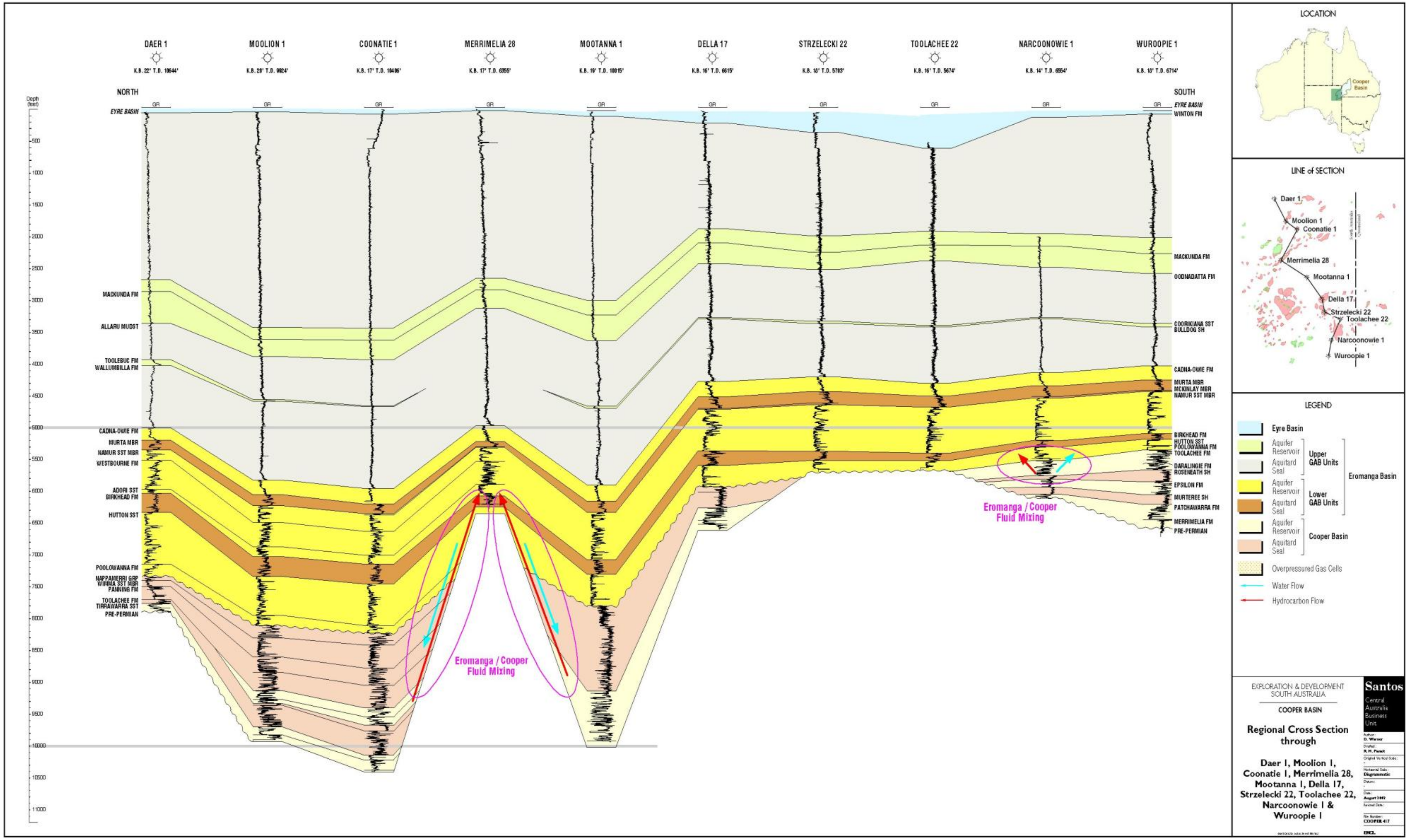


Figure 14: Regional geological cross-sections of the Cooper-Eromanga Basin (2). Source: Santos (2003)

4.2.5.2 Project Hydrogeology

The uppermost confined aquifer utilised in the Central Nappamerri Trough is the Winton Formation. Lithological information gathered in the recently drilled wells in PEL218 indicates variable amounts and depths of sandstone above 300 m. Common lithologies include sandstone, claystone, and siltstone. The Winton aquifers have been used as the source for water used in the drilling of Encounter-1 and Holdfast-1.

In the vicinity of the Nappamerri Trough, groundwater flow in the GAB (Cadna-owie–Algebuckina aquifer) is generally to the east and displays a steeper hydraulic gradient in comparison to the broader GAB aquifer. This is indicative of reduced aquifer permeability and lower groundwater flow velocities. Deeper burial depths and subsequent sandstone diagenesis has led to the Jurassic (GAB) aquifers being of lower permeability than is seen in other parts of the Eromanga Basin.

Artesian heads in the area are generally in excess of 50 m above ground from the Cadna-owie–Algebuckina aquifer. There are no natural artesian springs in the area.

The lithological characteristics of each of the Cretaceous and Jurassic aquifers in the Central Nappamerri Trough are shown in Table 10. An illustration of the depth of these aquifers and of the underlying Nappamerri Group and Permian targets in the Central Nappamerri Trough is shown in Figure 15.

Table 10: Lithological characteristics of the Cretaceous / Jurassic aquifers in the Central Nappamerri Trough

Formation	Lithological Characteristics
Winton Formation	The upper Winton Formation is dominated by thick sandstone intervals and the lower Winton Formation is dominated by siltstones with the occasional thinner sandstone package. The thinner sandstone intervals are variable in thickness and occurrence across the Central Nappamerri Trough.
Mackunda Formation	The interval within the Mackunda which contains the aquifer sands is predominantly the lower portion of the formation where thick sand intervals are present in most wells. The upper Mackunda Formation tends to be dominated by siltstones.
Cadna-owie Formation	Predominantly siltstone with the upper Cadna-owie having slightly less clay and the lower Cadna-owie increasing with clay content with depth. Overall formation is low permeability and not an aquifer in the Central Nappamerri Trough area.
Murta Member	Dominated by siltstone and mudstone with some interbedded thin coarse grained sandstones. There are typically three sandy cycles within the Murta Member with the middle portion having higher sand content and the very upper and lower Murta member tends to have thin sandstone beds.
Namur Sandstone	Predominantly sandstone in thick packages. Typically two main sand packages vertically separated by a thinner siltstone interval.
Westbourne Formation	Predominantly sandstone with thicker better quality sands towards the base of the formation. Clay content and grain size decreases in the upper Westbourne Formation. Occasional mudstone at the base.
Adori Sandstone	Dominated by a single thick sandstone package. Typically good quality sandstone but can be occasionally silty in some wells
Birkhead Formation	Dominated by siltstone and fine grained sandstone. Thin sandstone beds with better rock properties are typically found towards the lower portion of the Formation.
Hutton Sandstone	Dominated by stacked good quality sandstone packages with very little siltstone or mudstone in the overall formation. Occasionally the Hutton Sandstone interval will have sandstones increasing in clay content towards the base.
Poolowanna Sandstone	Predominantly thick clean sandstone intervals at the base of the formations with thinner sandstone interbedded with fine sandstone or siltstone in the upper half of the formation.

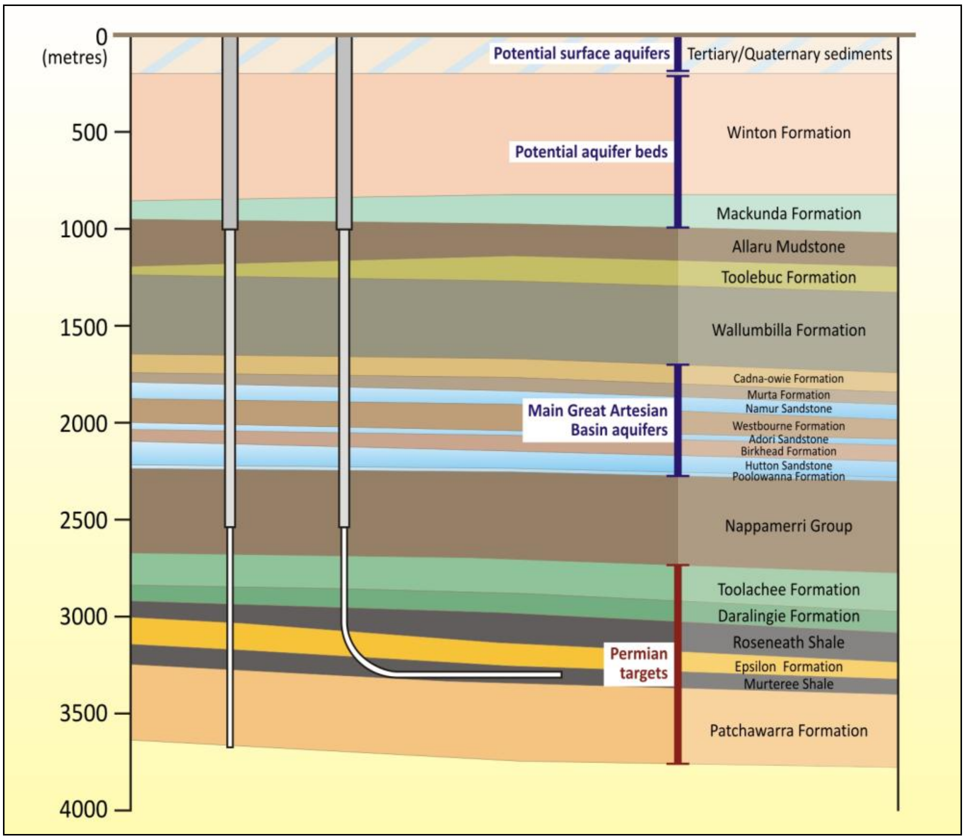


Figure 15: Illustration of the depth of aquifers, impermeable Nappamerri Group and Permian targets in the Central Nappamerri Trough.

The thickness of the Jurassic GAB formations stays relatively consistent across the Central Nappamerri Trough and the formations can be correlated between the exploration wells that have been drilled (see Figure 10 in Section 4.2.4). In most instances, individual sand packages can also be correlated from well to well.

As noted previously, minor indications of hydrocarbons have been intersected in the Jurassic GAB formations in many of the exploration wells in the Central Nappamerri Trough (Wakefield-1, Bulyeroo-1, Burley-2, Darmody-1, Kirby-1 and Kirby-2). Analysis of data from these wells indicated that the sands are either low permeability or have high water saturations. With limited potential for commercial oil production, standard oil industry flow testing has only once been conducted on a GAB sandstone interval in the Nappamerri Trough area. A test over the Murta Member in Burley-1 was attempted with no oil recovered. A lack of structural closures at the Jurassic level and perhaps a lack of migration pathways are most likely responsible for the Jurassic sandstones being water saturated. Elsewhere in the basin, where structures are present, oil accumulations have been found in the Jurassic GAB layers.

The underlying Permian formations appear to be gas saturated across the Central Nappamerri Trough and no formation water has been recovered from any of the drill stem tests in the exploration wells drilled in the trough.

<u>Aquifer Separation from the Permian Targets</u>

As illustrated in Figure 15 above, the Winton Formation is generally found between surface and 980 m in the Central Nappamerri Trough. The Mackunda Formation is found between 800 m and 1,030 m. Approximately 945 m separates the shallow aquifers from the Jurassic GAB aquifers which are generally found between 1,730 m and 2,380 m. The formations separating the shallow and GAB aquifer systems are non-prospective, as they contain no hydrocarbons and are generally low permeability sandstones or siltstones. Approximately 415 m then separates the Jurassic GAB aquifers from the gas saturated Permian formations.

The lateral continuity of all of the formations and aquifers, minimal variation in thickness, lack of structural complexity and major faulting and high variability in stress magnitudes between different lithologies ensures that there is a high degree of geological separation between the gas saturated Permian reservoirs and the Jurassic aquifers of the GAB and the shallow Winton and Mackunda aquifers.

Water Quality

The alluvium along some of the major streams is a frequent source of sub-artesian water across the broader region (Division of Land Utilisation, 1974). In particular, sandy sequences underlying the Cooper Creek provide a shallow aquifer, which provides baseflow to semi-permanent waterholes during extended dry periods. Water quality is good, although availability is inconsistent and reliant on infrequent flood recharge events.

The shallow (60-200m) unconfined aquifers of the Tertiary and Quaternary sediments in the greater region generally range from fresh to brackish (i.e. <1,000 to 10,000 mg/L) with some of these bores suitable for drinking or stock water supply. Water quality in shallow (water table) aquifers in the Moomba region is generally not suitable for stock watering purposes due to a high salt content (Santos 2003).

The salinity of the upper confined aquifer across the region is generally too high for use for stock or domestic purposes (Santos 2003). The salinity of the principal deep formations in the lower GAB aquifer are often in the range 600 – 2,000 mg/L in the eastern part of South Australia, which is acceptable for stock watering purposes, however they are generally too deep for widespread pastoral use. The use of artesian water in this central portion of the Cooper Basin is generally limited to converted petroleum wells due to the expense associated with drilling bores to the depth required to intersect freshwater aquifers.

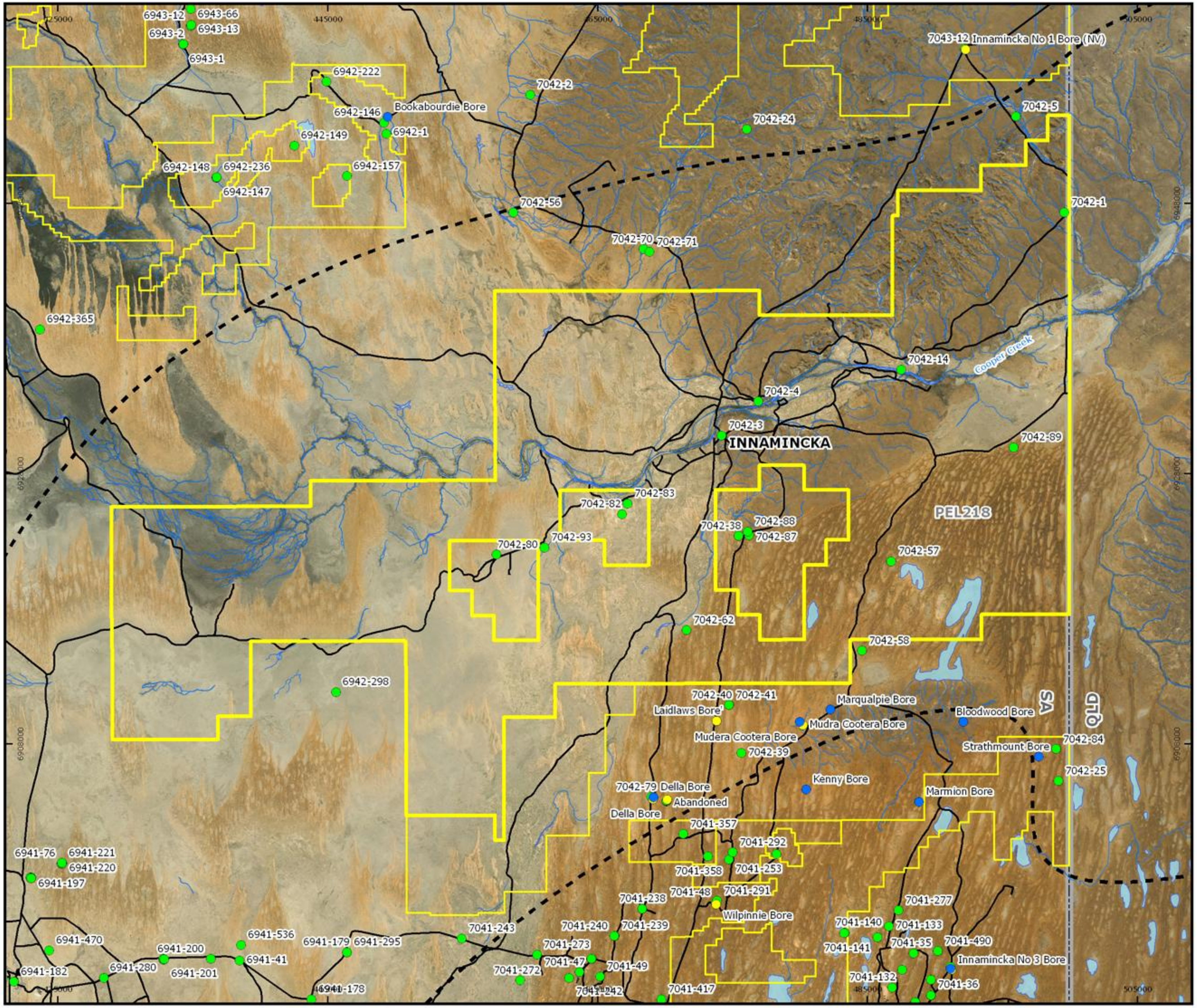
In the project area formation water has not been recovered from the exploration wells drilled in the Nappamerri Trough therefore the exact salinity and variation in salinity over the Central Nappamerri Trough is unknown. However, Pickett Plots (a graphic method of using log analysis to determine formation water salinity) from recent wells suggest the salinity of the Jurassic GAB aquifers in the Central Nappamerri Trough is closer to the low end of the range of salinities outlined in Table 9.

Groundwater Use and Well Locations

Use of groundwater across the Nappamerri Trough region is restricted to a number of scattered bores in shallow aquifers that are used for pastoral activities, road maintenance and petroleum/geothermal exploration, and several converted petroleum wells in deep formations of the GAB. Although they are few in number, these wells represent important sources of water for pastoral and other activities in the region.

Department for Water data (DfW 2012) and information supplied by S Kidman & Co indicate that there are in the order of 20 water wells in the Nappamerri Trough in the vicinity of PEL218. Most of these are shallow (ranging from 10 m to 180 m in depth). The Department for Water data shows one deep water well (2,416 m) in the vicinity of PEL218. The location of water wells in the vicinity of PEL218 is shown in Figure 16.

In the Cooper and Eromanga Basins, the petroleum industry also extracts water from the GAB and other aquifers as a result of petroleum production. The majority of oil producing reservoirs in the Cooper and Eromanga Basins are classified as 'water drive' reservoirs. The hydraulic head (pressure) from the water in the sandstone unit provides a source of pressure that flushes the oil through the pore space of the rock towards the wellbore. As a result water is produced with the oil. This water is separated from the oil stream at satellite stations and disposed of to surface evaporation ponds. These ponds present a potential source of water for fracture stimulation, however as there are no surface evaporation ponds in close proximity to the areas where Beach are planning to conduct fracture stimulation, it is not a practicable source of water for the exploration phase.



LEGEND

- Innamincka Additional Bore
- Innamincka Bore
- Water Well
- Localities
- Roads & Tracks
- Drainage
- State Boundaries
- Intermittent Lakes
- Nappamerri Trough
- Petroleum Exploration Licence PEL218
- Petroleum Exploration Licences

0 5 10
Kilometres
SCALE 1:400,000 @ A4
GDA 1994 MGA Zone 54

DATA SOURCES
DWLBC
Geoscience Australia
DENR
RPSAQT

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FIGURE 16:
Location of water wells

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4.3 Social Environment

4.3.1 Aboriginal Cultural Heritage

The Cooper Creek region is culturally significant to the Yandruwandha-Yawarrawarrka people. Evidence of long term occupation includes rock art, burial sites, trade and ceremonial sites scattered with grinding stones and other artefacts associated with habitation. Locations around the Cullyamurra Waterhole, upstream of Innamincka, are incorporated within the Innamincka/Cooper Creek State Heritage Area and contain significant sites listed on the Register of National Estate (Innamincka Historic Reserve).

Work Area Clearances are carried out with the Yandruwandha-Yawarrawarrka in advance of all activities to ensure that cultural heritage values and significant places are not impacted.

4.3.2 Non-Aboriginal Cultural heritage

Non-indigenous heritage in the region dates back to early exploration of the region in the mid to late 1800’s and the expansion of pastoralism. Many of the historical sites in the region are associated with the failed Burke and Wills expedition of 1860-61 (including the Dig Tree and grave sites) and the subsequent settlement of inland South Australia and Queensland and the establishment of transport routes and pastoralism (Planning SA 2009, AHPI 2009).

A number of sites in the region are listed on the State Heritage Register, including the Australian Inland Mission Nursing Home at Innamincka and the Innamincka / Cooper Creek State Heritage Area (a strip 1 km either side of the Cooper Creek channel from the Queensland border to 14 km west of Innamincka).

4.3.3 Native Title

There is an active native title claim over the region, the Yandruwandha/Yawarrawarrka Native Title Claim (Native Title Tribunal file number SC98/1).

4.3.4 Land-use

The current land uses in the area include pastoralism, oil and gas production and processing, conservation and tourism.

<u>Pastoralism</u>

Pastoralism, mainly in the form of cattle grazing, has a long history in the region, beginning in the late 1800s and continuing today. The floodplains surrounding the Cooper Creek in particular provide pasture and reliable water supplies in the form of permanent waterholes. While stocking rates are relatively low the region continues to support a substantial cattle production operation which is an important contributor to the local economy.

Pastoral operations in the region are certified under Quality Assurance systems such as the Livestock Production Assurance Program or Cattlecare, which places emphasis on minimising the risk of chemical contamination, bruising and hide damage and ensuring effective herd management and improvement.

Pastoral lease holders in the area are listed in Table 11.

Table 11: Pastoral lease holders in the area

Name	Registered Proprietor/ Lessee	Tenure
Gidgealpa	DOCE Pty Ltd	Leasehold
Innamincka Regional Reserve	Department for Environment and Heritage (Head Lessee) S Kidman & Co Ltd (Pastoral Lessee)	Leasehold

Oil and Gas

Oil and gas exploration in the Cooper Basin commenced in 1954 and the Cooper Basin has become a major supplier of oil and gas in Australia since the discovery of gas reserves at Gidgealpa, near Moomba, in 1963.

Santos (on behalf of the Cooper Basin joint venturers) operates the majority of the oil and gas fields and facilities in the Cooper Basin. In 2009 there were approximately 160 gas fields and 75 oil fields on production. These fields contained approximately 630 producing gas wells and more than 340 producing oil wells which feed into production facilities at Moomba and Ballera in Queensland. The production facilities are supplied through approximately 5,600 km of pipelines and flowlines via 15 major satellite facilities. Santos employs some 1,200 people living and working permanently or part-time at Moomba and Ballera in south-west Queensland. Beach Energy, through its acquisition of Delhi Petroleum, holds 20.2% interest in the South Australian Cooper Basin Joint Venture and 23.2% in the South West Queensland Joint Venture.

Beach Energy has two operational bases in the Basin, producing oil and gas, and is the second largest petroleum operator in the region. The Callawonga base, located approximately 90 km to the west of Moomba, is a permanently manned facility with an operational crew of 14 men, operating on a fly-in fly-out roster system. Beach operates approximately 35 wells in 10 producing oil fields and 2 producing gas fields from this location with a further 5 oil fields and 3 gas fields discovered but not yet on production. Oil production is transported via a Beach constructed and operated pipeline to Santos operated Cooper Basin oil gathering facilities. Fields that require trucking of oil are either trucked direct to Moomba or to the load in facility at Callawonga. Gas is piped from the well head via a Beach installed and operated metering and gathering network into a connection point on the Santos operated gas gathering system.

Beach also has a base at the Kenmore field, approximately 360 km north-east of Moomba in Queensland, with a permanent roster based crew of 10 men. From Kenmore, 8 oil fields with approximately 45 producing wells are maintained.

Senex Energy also operates several oil fields from which oil is trucked to Moomba or other Santos facilities. Beach is a joint venture partner in a number of these fields.

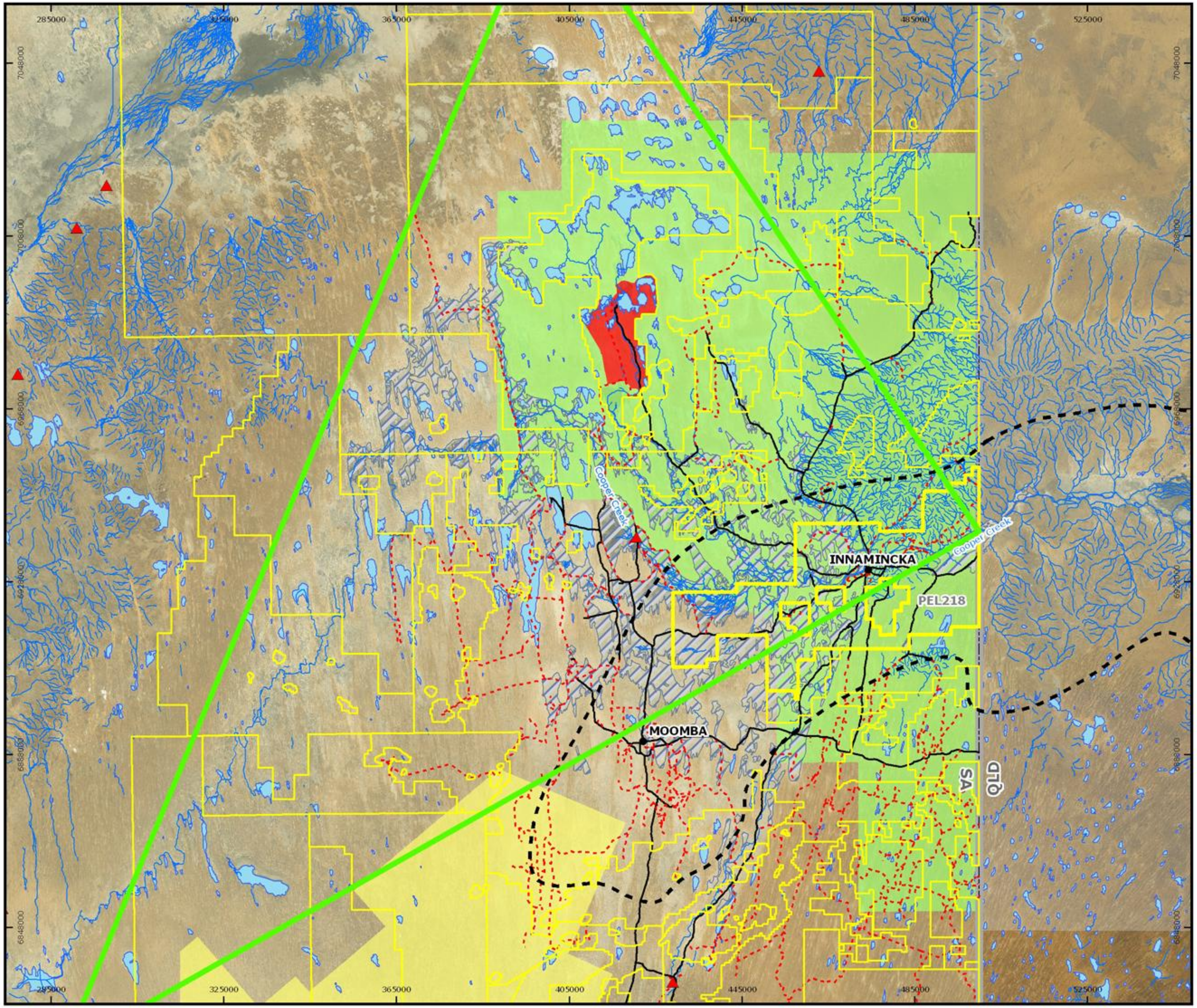
In recent years, exploration for geothermal energy has also been carried out in the region, and Geodynamics have established a pilot geothermal power station near Innamincka which is yet to be commissioned.

Conservation

Much of the central Nappamerri Trough region lies within the boundary of the Innamincka Regional Reserve, established under the *National Parks and Wildlife Act 1972*. This is a multiple use reserve, with the regional reserve category designed to enable areas to be managed under a conservation framework while permitting the sustainable use of resources (i.e. oil, gas, geothermal energy production and grazing). The western extent of the Nappamerri Trough also intersects the Strzelecki Regional Reserve south-west of Moomba.

The wetlands of the Cooper Creek, and the Coongie Lakes in particular, have been recognised as uniquely valuable due to their diverse, and in places unique, biota. The Coongie Lakes are now included in the Coongie Lakes National Park, which was proclaimed in 2005 and is located within Innamincka Regional Reserve. The Coongie Lakes are also listed under the Ramsar Convention as a Wetland of International Significance. The defined Ramsar wetland area is a triangle that covers a very large region and includes the Coongie Lakes themselves, the channels and floodplain of the Cooper Creek and large areas of dunefield land systems that have no hydrological connection to the Cooper Creek. Hundreds of petroleum wells and several oil and gas facilities are located within the designated Ramsar area.

The Nappamerri Trough region overlaps the south-eastern boundary of the Ramsar area while the Coongie Lakes National Park is located approximately 40 km north-west of the boundary of the Nappamerri Trough region (Figure 17).



LEGEND

- Localities
- Homestead
- Roads
- Tracks
- Drainage
- State Boundaries
- Land Subject To Inundation
- Intermittent Lakes
- Innamincka Regional Reserve
- Petroleum Exploration Licences
- Petroleum Exploration Licence PEL218
- Nappamerri Trough
- Coongie Lakes National Park
- Innamincka Regional Reserve
- Strzelecki Regional Reserve

N

0 20 40

Kilometres

SCALE 1:1,250,000 @ A4

GDA 1994 MGA Zone 54

DATA SOURCES

DWLBC
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RPS Aquaterra

FIGURE 17:
Location of Coongie Lakes Ramsar Wetland area

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Actions that will have a significant impact on the ecological character of a Ramsar wetland need approval under the EPBC Act. The EPBC Act guidelines (DEWHA 2009) state that this is the case if there is a real chance or possibility that the action will result in:

- areas of the wetland being destroyed or substantially modified
- a substantial and measurable change in the hydrological regime of the wetland
- the habitat or lifecycle of native species dependent upon the wetland being seriously affected
- a substantial and measurable change in the water quality of the wetland
- an invasive species that is harmful to the ecological character of the wetland being established.

As discussed in Section 6.3.1, with appropriate well site selection and mitigation measures in place, these criteria are not expected to be triggered.

The Strzelecki Creek wetland system, which is listed in the Directory of Important Wetlands in Australia (Environment Australia 2001) also overlaps the Nappamerri Trough region. It extends from the boundary of the Coongie Lakes wetland southwards down the Strzelecki Creek. The Strzelecki Creek is predominantly dry and only flows during large Cooper floods, for 200 km from the Cooper Creek at Innamincka south to Lake Blanche. When flooded, it provides significant habitat for large numbers of waterbirds.

Tourism

The Innamincka, Coongie Lakes and Cooper Creek regions in north-eastern South Australia have increased in popularity over the past 30 years as a destination for tourists seeking a bush exploration experience. It is estimated from available data that over 17,500 visitors travelled through Innamincka between July 2007 to January 2008 and that annual visitation exceeds 34,500 visitors (DEH 2008). Dillons Highway (Strzelecki Track) is a major tourist access route to the region and after connecting with the Adventure Way east of Innamincka, forms part of the outback tourist highway between South Australia and Queensland.

4.3.5 Socio-economic

The region is located in the unincorporated (i.e. out of councils) area of South Australia. Jurisdiction for the area falls under the responsibility of the Outback Communities Authority which provides limited local government-type support.

The major regional industries are pastoralism, oil and gas production and tourism.

The only township in the region is Innamincka, which has had a resident population in the order of 12 to 18 in recent years (Marree SCB 2004). The Innamincka Progress Association is responsible for managing many of the town’s public facilities, including the Town Common camping area, the airstrip and public amenities.

Moomba, Ballera and the satellite production facilities have accommodation and recreation facilities that house the petroleum industry workforce, which operates on a ‘fly-in, fly-out’ basis.

The closest pastoral station homesteads are Innamincka Station, which lies north of Innamincka township and the Cooper Creek, and Gidgealpa Station, which is north of Moomba.

Infrastructure in the region is minimal. Unsealed roads service the district, with the Adelaide-Moomba Road and Dillons Highway (which are generally referred to as the Strzelecki Track) being the major route through the region. The Old Strzelecki Track between Merty Merty Station and Innamincka is not maintained as a major road and carries relatively low traffic volumes. The oil and gas fields in the region are serviced by a network of unsealed roads and tracks, which are generally not available for public access. Other public roads in the region include the Adventure Way, east of Innamincka, the Cordillo road and Coongie Lakes track north of Innamincka and Fifteen Mile Track, west of Innamincka.

5 Description of Activities

5.1 Overview

As discussed in Section 3, basin centred gas and shale gas reservoirs have very low natural permeability. In order to assess the potential for production of gas from these targets it is necessary to improve connection of the pore space within the rock back to the well. This is achieved by the process of fracture stimulation.

Fracture stimulation involves the injection of fluid into the target rock interval at pressures sufficient to split the rock and create high conductivity flow paths to the well, as illustrated in Figure 18. The injected water is slightly modified with a gelling agent to enable proppant material (sand or ceramic material similar to sand particles), to be pumped into the rock to hold the induced fractures open. Further additives are used to control corrosion, friction, remove bacteria and assist with recovering the stimulation fluids from the interval when the well is flowed back to production.

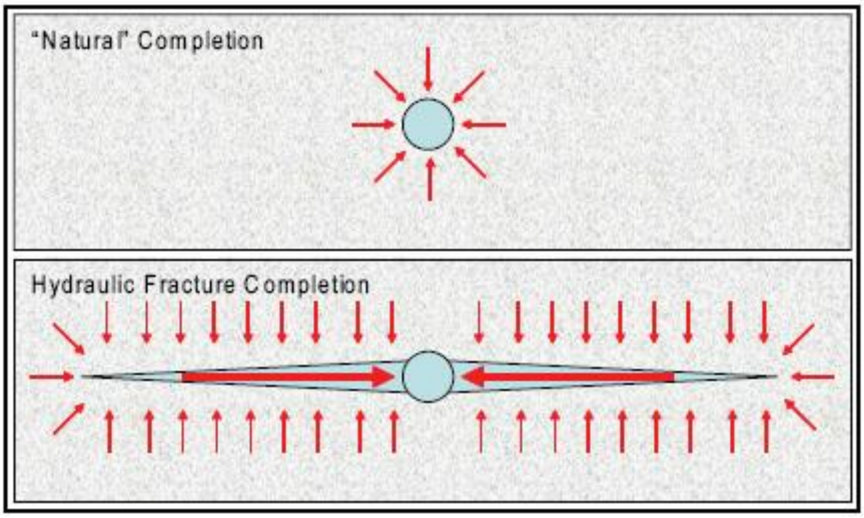


Figure 18: **Illustration of flow paths in a non-fractured and a fractured well (Source: API 2009)**

Fracture stimulation is not new to the Cooper Basin. It has been used for over forty years in several hundred wells to improve the commerciality of lower permeability zones in the same formations that Beach is exploring for basin-centred gas. However, fracture stimulation in the basin has historically been undertaken in development wells rather than during the exploration stage of evaluating resource potential.

This section describes the application of fracture stimulation to the exploration and appraisal of shale and basin-centred gas in the Nappamerri Trough. It outlines the principles of well design and construction (which ensure that injected fluid is contained in the well and injected into the target formation) and goes on to describe the fracture stimulation process, the fluids used, monitoring of stimulation, well completions, flowback and production testing, water use and other associated issues.

5.2 Well Design and Construction

It is not the intention of this EIR to revisit well design and drilling operations as these are covered under the existing Drilling and Well Operations SEO (Santos 2009). However, well design and construction is described here as it is important in ensuring well integrity under all the operating conditions that the well is expected to experience, and is particularly important during the high pressure fracture stimulation treatment and subsequent testing operations. Well design ensures that the wellhead, steel casing, cement and production tubing are suitable for:

- the high temperatures of the Nappamerri Trough
- the high pressures required to initiate fracture stimulation treatments deep underground

- the stresses induced when large volumes of cool fluids are pumped, at high pressure, into the well during stimulation
- the flow back of high temperature reservoir fluids
- the flow back of sour gases.

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

Beach Energy's current well design for the vertical exploration wells is shown in Figure 19. The layers of casing shown in the diagram are:

- the conductor pipe, which is installed at the surface and provides the initial stable structural foundation for the well.
- the surface casing string, which extends from the surface to approximately 900 m.
- the intermediate casing string, which is inside the surface casing and extends from the surface to approximately 2,600 m, past the level of the Great Artesian Basin aquifers.
- the production casing string, which is inside the intermediate casing and runs from the surface to the total depth of the well.

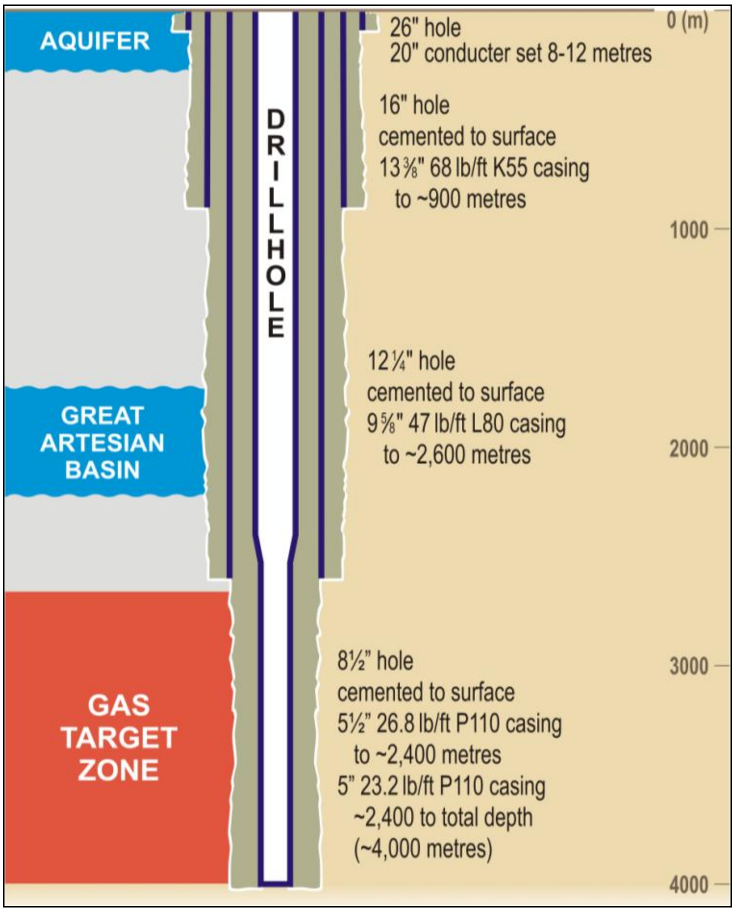


Figure 19: Indicative well design

The production casing design shown in Figure 19 is known as a tapered casing string, as it has larger diameter casing in the upper part of the well, a reducing coupling, then a smaller diameter casing to the bottom of the well.

Beach will also be drilling wells with horizontal sections within the target intervals to determine their potential for deliverability. These wells will have the same well construction as shown in Figure 19 except that approximately 300 m above the target zone (roughly 100-200 m into the 8 ½” production hole drilling) the well trajectory will be steered from vertical around an approximate 300 m radius bend to become horizontal in the target layer. Once in the target zone the well will be drilled a further 1,500 m giving a total measured length of the well of almost 5,000 m. 5” casing will be run back to the 5 ½” transition at 2,400 m as shown in Figure 19.

As indicated, each casing string in the well is cemented into the borehole. Cement integrity is important for isolating formations along the well bore. Cement integrity is verified by various means, including observation of the cement back to surface as per the cement design and cement bond logs of the production casing string, which use an acoustic tool to detect whether spaces are present behind the casing. Casing centralisation, cement design, volumes and pumping parameters are important in setting up a good seal between the casing and the well bore. The correct cement design and implementation prevents production fluids from migrating up the hole via the well bore - casing annulus eliminating potential cross flow into aquifers.

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

In order to connect the inside of the casing with the target formation, normally a technique known as perforating is used. Shaped charges, also known as guns, are lowered into the hole and detonated to create holes in the casing, cement and penetrate tens of centimetres into the rock.

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

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

5.3 Fracture Stimulation

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

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

Proppant stages Once the fracture has initiated proppant is introduced. In order to carry the proppant in suspension to the rock the fluid is viscosified with a gelling agent. Typically the higher the injection rate of fluid the less gel is required to carry the proppant. Additionally finer grained proppants require less gel to carry them. Gel breakers or surfactants are added during the stage to aid in later recovery of injected fluids from the fracture.

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

Plug/Perforate Once the stimulation treatment is placed, a wireline unit is rigged up to run a plug that will isolate the zone that was stimulated from the next interval to be stimulated. The wireline will also perforate the casing ready for the next stimulation treatment.

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

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

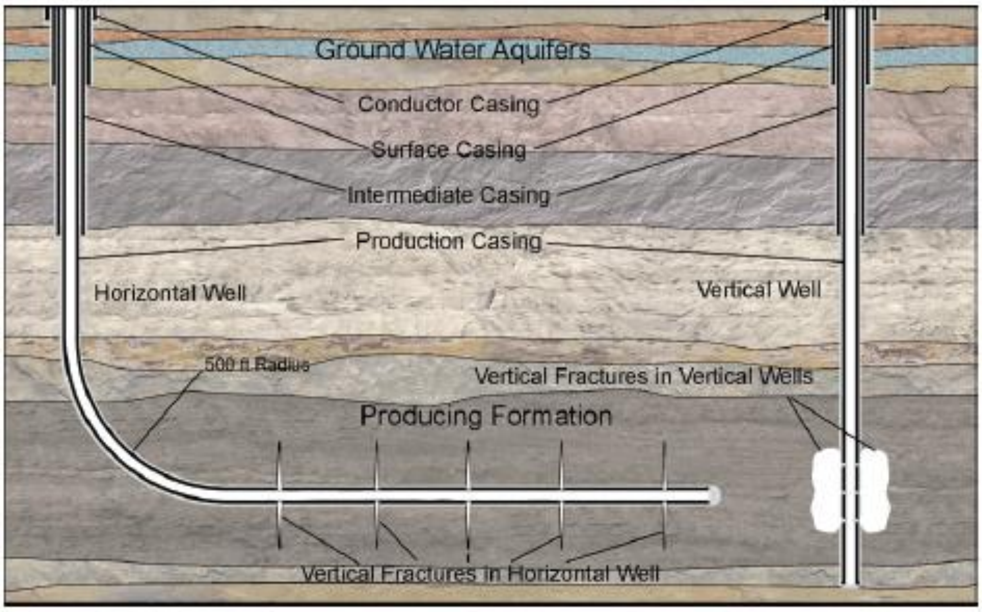


Figure 20: Example of fracturing in a horizontal and vertical well (Source: API 2009)

5.3.1 Fracture Stimulation Equipment

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

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

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

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

It is anticipated that the fracture stimulation equipment would operate for blocks of approximately 6-8 weeks in the exploration phase, during which 3-4 wells would be fractured. At each well, operations would typically involve a two day set-up, one day per zone stimulated and two days to rig-down and demobilise to the next well.

Plate 6: Fracture stimulation operations at Beach Energy's Holdfast-1 well in 2011

5.4 Fracturing Fluids

Water is the main component of fracture stimulation treatments and forms the vast majority of the fluid injected during fracturing operations, typically around 97%. The proppant is the next largest constituent. Proppant is a granular material, typically sand or small ceramic beads in the Nappamerri Trough where additional strength is required, which is mixed in with the fracturing fluids to prop open the fractures and allow gas to flow to the well.

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

The overall percentages of additives in a typical fracturing operation on a deep shale gas well in the Cooper Basin are shown in Figure 21.

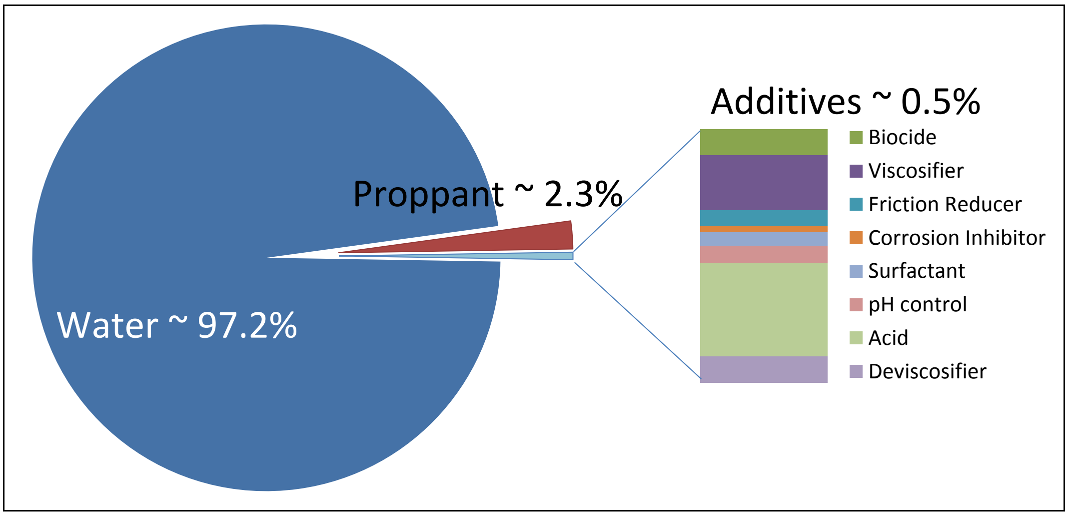


Figure 21: Example of overall percentages of additives in a deep shale gas well fracturing operation in the Cooper Basin (based on data from fracture stimulation of the Holdfast-1 well)

As discussed in Section 5.3, the fracturing fluid injected into the well is not uniform throughout the fracturing process. Each task performed during the fracturing operation will use fluid with additives specifically designed for the task. For example, acid is pumped in the initial acid injection phase to clean the well bore. In following phases, the fluid designed to propagate the fractures is injected, initially without proppant, and then proppant is added to the fluid to enter the fractures and hold them open. Gelling agents, or viscosifiers, are used during these phases to increase the viscosity of the fluid and help carry the proppant. Gel breakers and surfactants are added to aid in recovery of the injected fluids from the formation.

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

The types and purposes of additives expected to be used in the fracture stimulation of deep gas targets in the Cooper Basin are summarised in Table 12. This information is based on the fluid makeup for fracture stimulation of Beach's Holdfast-1 well that was undertaken in 2011 and information provided by the fracturing contractor. Further detail on these additives and their constituents is provided in Appendix A. Links to Material Safety Data Sheets (MSDSs), which contain detailed information about each additive are also provided in Appendix A. The MSDS information is important for the safe handling, storage and clean up of chemicals and fuels which is discussed further in Section 5.10.

Table 12: Additives in typical deep fracture stimulation fluids

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

At the time of writing this report there was only one stimulation service provider with the horsepower required to pump the shale and basin centred gas treatments in the Nappamerri Trough. The fluid additive information provided in Appendix A is from that provider. In the future, as the requirement for fracture stimulation increases for both conventional and unconventional targets, other fracture stimulation providers will have equipment capable of meeting the requirements for a Nappamerri Trough well and will provide their own suite of stimulation additives.

It is expected that the types, purpose, volume and concentrations used by other providers in the future are likely to be similar to those outlined in Appendix A. Fracture stimulation providers may have their own proprietary stimulation compounds, which are generally from the same group of chemicals but with different amounts of, or slightly different, active ingredients. Detailed additives proposed for use in fracture stimulation operations would be provided to DMITRE as part of the activity approval process (see Section 2.1.4), along with a demonstration that the level of risk posed by these additives is consistent with this EIR.

It is understood that fracture stimulation fluid additives are planned to be disclosed on an ongoing basis via the DMITRE website. A number of other websites also provide information on fracturing fluid additives and are listed in Appendix A, including websites for the fracture stimulation service providers currently operating in Australia.

Most of the chemicals used in fracture fluids are found within products that are used in the home or in industry, as indicated in Appendix A. While many of the additives used in the fracturing process are hazardous when in their concentrated product form, they are diluted by the water and are present in fracturing fluids in relatively low concentrations. However, even in low concentrations some of these additives need to be handled with care to avoid any potential for impacts on human health or the environment.

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

- Pumping as low a concentration of chemicals as is needed to perform the treatment
- Requiring that the material handling and safety aspects of these additives, as managed by the contractor, are in accordance with MSDSs and relevant standards and guidelines including AS 1940, EPA guidelines and the Australian Dangerous Goods Code (where relevant)
- Auditing the contractor’s management systems and conduct site inspections to assess the contractor’s compliance
- On-site supervision to monitor conduct of the treatments and ensure any spills are reported and remediated
- Containment of recovered flow back fluids in lined ponds, as discussed in Section 5.8, for evaporation of fluid
- Monitoring and sampling of returned fluids during the exploration stage. Once the treatment is placed, it is estimated that less than 50% returns to the surface (King 2012). Much of the fracture fluid remains trapped in the rock underground and some of the additives may become adsorbed to the surface of the rock.
- Management of ponds to ensure integrity of containment
- Removal of pond liner to a licensed waste facility following evaporation
- Rehabilitation of pond sites post activities.

Beach will investigate methods to further reduce chemical utilisation and incorporate findings during the monitoring of flow back fluids as part of Beach’s commitment to continuous improvement. Possible changes to fracture stimulation fluids that are being investigated include treatment with ultra-violet light to reduce the level of biocides that are required to control the growth of microbes.

<u>BTEX in Fracturing Additives</u>

Fracturing fluid additives containing the volatile aromatic compounds benzene, toluene, ethylbenzene and xylene (collectively referred to as BTEX) have been identified as a potential concern in some areas where fracture stimulation operations are carried out much closer to water supply aquifers. Although the level of risk posed by additives containing BTEX is relatively low in the Cooper Basin (e.g. the target petroleum reservoirs can naturally contain BTEX and are not near water supply aquifers), it is not proposed to use additives where BTEX is present in significant quantities. Some additives in the acid blend (e.g. hydrochloric acid, corrosion inhibitor and acid penetrating agent) can contain trace levels of BTEX, however the dilution of the acid blend by subsequent stages of the fracture stimulation would result in very low levels, which would be below drinking water guidelines. Suppliers and fracturing contractors have been working to ensure that levels of BTEX in fracturing fluids are reduced as far as practicable and are not at significant levels.

5.5 Fracture Height Growth and Fracture Monitoring

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

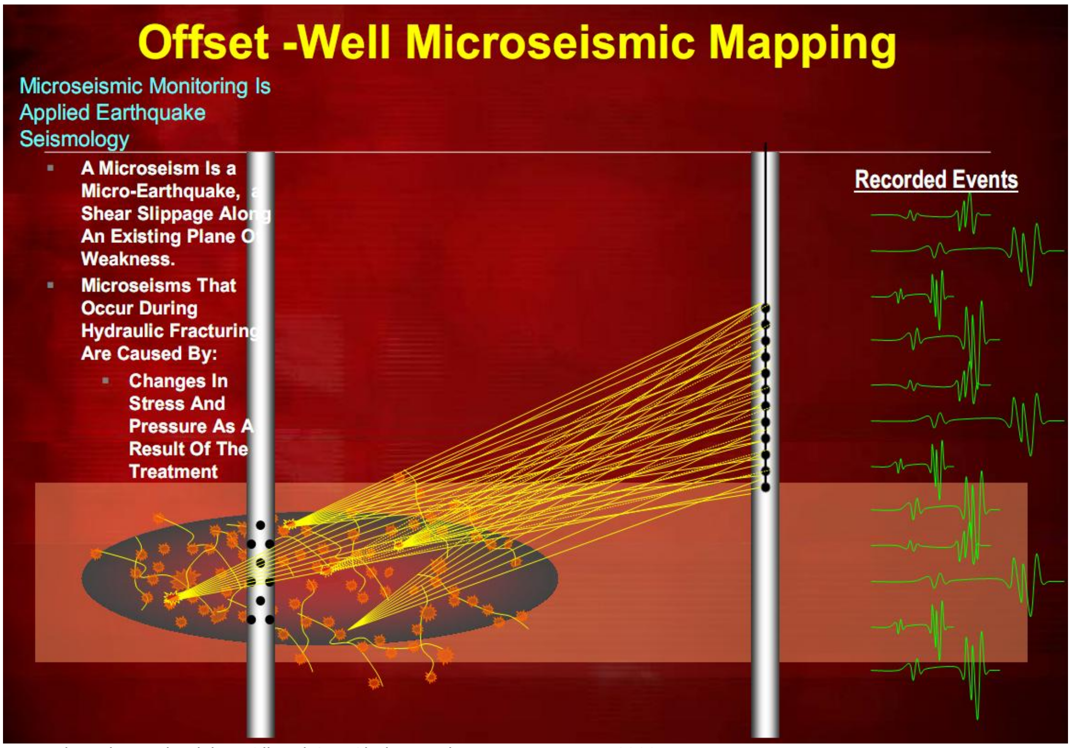
Due to the physical separation of the gas target intervals and the GAB aquifers by 400 m of low permeability sediment and stress contrasts associated with lithological changes, as described in Section 4.2.4.1 and shown in Figure 12, it is apparent that there is very low likelihood that fractures induced during stimulation will extend into the GAB.

However, Beach will be monitoring the fracture stimulation treatments in a variety of ways to understand the results and the impact on production and recovery from the wells. Some of the techniques that may be applied include micro-seismic monitoring, tiltmeter surveys and tracer injection.

Micro-seismic Monitoring

The technique used to monitor fracture growth is called micro-seismic mapping. The process, shown in Figure 22 involves placing a sensitive set of listening devices (geophones) in an adjacent monitoring bore (right hand well in the figure) during the stimulation of the target well (left hand well in the figure). During stimulation small movements of rocks are detected at the monitoring well and the location of those movements is determined by triangulation. The technique is accurate enough to assist geologists and engineers in understanding such things as the height of fracture growth of a treatment and whether the fracture treatment is breaking new rock or has grown back into a previously placed fracture treatment.

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



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

Figure 22: Schematic of micro-seismic monitoring of fracture stimulation treatment

Beach will undertake micro-seismic monitoring of at least two horizontal wells to gain understanding of how much of the rock has been stimulated. The geophone system for monitoring of stimulation treatment must be located in a well bore within 500 to 800 m of the target well. Beach is intending to drill a horizontal well immediately adjacent to both of the recently drilled Holdfast-1 and Encounter-1 bores, using the existing wells as the monitoring location. Subsequent micro-seismic monitoring will depend on further exploration and appraisal drilling.

Tiltmeter Surveys

Although not a technique used to understand fracture height growth, tiltmeters may be applied to understand the orientation of fracture stimulation growth in vertical wells where appropriate. Beach used tiltmeter surveys in the recent Holdfast-1 and Encounter-1 wells to determine whether fracture stimulation treatments were being placed horizontally or vertically and in what orientation the fractures were propagating. Further surveys may be required across the area to understand the preferred fracture orientation. This activity would be undertaken under the existing Drilling and Well Operations SEO or Geophysical Operations SEO (Santos 2009, Santos 2006) as it has been in the past.

Tracer monitoring

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

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

5.6 Post-Stimulation Completion

Immediately following fracture stimulation, dependent on the zone access and stimulation technique used, isolation plugs used to separate the fracture stimulation stages will be drilled out with coiled tubing or an equivalent. During this process excess well fluids will be directed to the lined pit, constructed adjacent to the flare pit.

The Cooper Basin gas stream includes varying amounts of carbon dioxide which requires appropriate casing material or isolation of the casing from the production stream through the use of a tubing string designed for this service.

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

The well design for the 2012 exploration activities requires that a tubing string is installed to isolate the majority of the production casing string from the production fluids. The material for the tubing, HP2, is appropriate for the combination of CO_2 typical in the Cooper Basin, low level H_2S and recovered stimulation fluid that is expected.

On-going monitoring of the gas composition from future wells will be undertaken to understand future equipment design requirements. As with well design, the design and selection of tubing and completion equipment and completion operations are covered by the existing Drilling and Well Operations EIR (Santos 2003a) and SEO (Santos 2009).

5.7 Flowback and Production Testing

Following installation of the tubing string the well will be opened and flow will commence. As the initial flow back will be predominantly recovered stimulation fluid, production will be directed to a lined pond adjacent to the flare pit (see Section 5.8 for a description of ponds). Once the well begins to recover

gas, the flow will be directed to the separator. The gas from the top of the separator is metered and sent to the flare where it is burnt. The water from the bottom of the separator is metered and directed to one of the lined temporary water storage ponds used to hold water for the fracture treatment.

The gas stream will be sampled for composition and contaminants. The recovered water will be sampled on a regular basis to evaluate the composition of the recovered fluid. Samples will also be obtained from lined storage ponds for analysis.

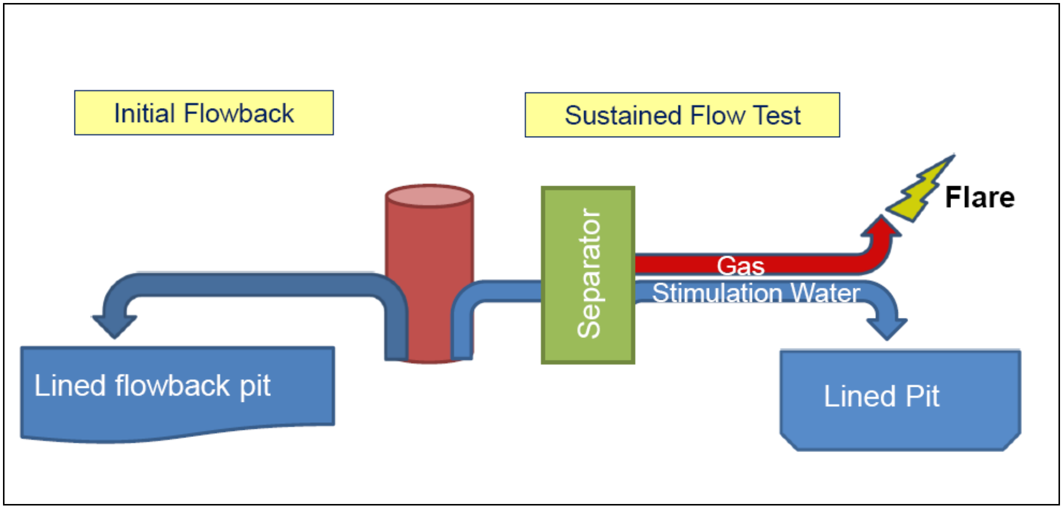


Figure 23: Flowback and production testing process

The exploration and appraisal wells are in areas with very few wells, which are located tens of kilometres apart. The wells will not be connected to gas gathering networks primarily due to the distance but also due to the untested flow capacity and gas composition and uncertainty in the volumes of gas that may be drained. As such, while the well is on production test the gas will be flared at the well site. Production testing may be carried out for up to 30 weeks. Production logging tools may be run to determine gas contribution from individual zones.

During the flow back period the rate of production of the recovered fracture fluid diminishes. It is expected that approximately 40-50% of the injected fluid will be recovered, based on experience from shales in the US which indicates that a significant proportion of the injected fluid remains trapped underground with generally less than 50% of the placed fluid returning to surface (King 2012). At the end of the test, the remaining fluid will be allowed to evaporate. Pond liners will be removed and disposed of to an appropriately licensed waste disposal facility.

If necessary for operational requirements, or due to potential flooding or potential issues with pond integrity, fluids may be transferred between ponds or removed from one location and transferred to another well site for further evaporation.

One or more operators will be assigned to the production testing and will visit the sites that are on production test daily.

The production of the wells, use of separation equipment, sampling and logging activities are regular production techniques that are covered by the existing Drilling and Well Operations SEO (Santos 2003 and 2009).

Additive Concentrations in Flowback

Chemicals returning from a well after a fracturing treatment are usually a fraction (usually 20% or less for chemicals and about 40% for polymers) of what was pumped down the well (King 2012, Friedman 1986, Howard 2009). Polymers decompose quickly at temperature, biocides are spent on organic demand and degrade, surfactants are adsorbed on rock surfaces and scale inhibitors precipitate and come back at 10 to 15 ppm (parts per million) over periods of up to several months (King 2012).

Hydrochloric acid used in initial cleanup is spent within a short distance of the entry point and no live acid is returned to the surface. Corrosion inhibitor is used in only the acid and is adsorbed onto the steel and then on the formation and only about 5 to 10% total returns to the surface (King 2012). Consequently, many of the compounds that are identified as potentially hazardous on their MSDS, such as acids, corrosion inhibitors or biocides, are effectively neutralised or present at significantly reduced concentrations in the flowback fluid. The flowback fluid may also contain salts that were dissolved from the geological strata underground. Monitoring of ion concentrations in the flowback fluids will be undertaken to understand the extent to which this is occurring.

5.8 Temporary Water Holding Ponds

All ponds that are to receive water for stimulation and recovered flowback fluids will be lined and fenced. The construction will utilise both excavation and bunding to raise the sides of the ponds above ground level to prevent surface water runoff into the ponds. The temporary water holding ponds will be constructed and start filling approximately one to two months in advance of the planned stimulation date.

A smaller lined pond will also be constructed, adjacent to the flare pit, to receive fluids associated with post stimulation clean-out and completion activities. Initial flow back of the well, prior to diversion of the well stream to the separator, will also be directed to this pond. If and as required, water from this clean up pond can be transferred to the larger temporary holding ponds with pumping equipment. It is expected that between 10% and 20% of the injected volume may flow back in this early clean out stage and the pond and transfer equipment will be designed for this load.

Once production is directed to the separator the flow back fluid will be sent, via a gauging tank or other metering device, to the temporary water holding ponds.

As discussed above, it is expected that that a significant proportion of the injected fluid will remain trapped underground and less than 50% of the placed fluid will returning to the surface.

Ponds for holding water at the fracture stimulation operations previously undertaken at Holdfast were approximately 50 m by 30 m and 2-3 m deep. Beach plans to construct up to four to six ponds of similar size at each well site. By constructing four to six ponds for water storage, some ponds can be rehabilitated relatively soon after the well has been fracture stimulated. Two or three ponds will be retained to contain recovered flow back fluids. Flow back may be required for approximately three to six months to understand longer term well performance.

Plate 7: Example of a temporary water holding pond

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

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

As part of Beach's commitment to continual improvement, Beach will investigate alternatives for water storage such as free-standing lined tanks. The challenge with alternative water storage options is that free-standing tanks are generally shallow and require a larger footprint, and use of truck mounted trailers would significantly increase traffic. The viability of committing to significant infrastructure during the exploration phase, prior to demonstrating commerciality of the resource, is also limited.

5.9 Water Use

To fracture stimulate the thick shale intervals and the low permeability basin-centred gas intervals the fracture stimulation treatments require 1.3 to 1.6 megalitres (ML) per treatment. In a vertical well, due to the multiple target horizons in the section and potential for approximately 1,300 m of gas bearing interval, it is anticipated that as few as five but potentially up to ten zones may be fracture stimulated. In a horizontal well, with a length of 1,500 m, stimulation treatments are likely to be placed every 100 m requiring 15 treatments in the well.

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

The exploration and appraisal wells are geographically spread, and are likely to be tens of kilometres apart. To minimise trucking of water, water will be obtained, where possible, from shallow water wells, drilled to a depth of approximately 200-250 m, within the lease area of each of the exploration wells. Drilling, productivity and water quality uncertainties encountered while drilling for water for previous exploration wells may make it necessary for Beach seek the landowner's permission to obtain water from existing bores. The opportunities for recycling of water from the exploration wells are being investigated, but they are likely to be limited due to the low number of wells and their geographic spread.

The drilling of water wells and extraction of groundwater in the region (which is within the Far North Prescribed Wells Area) is regulated under the Natural Resources Management Act. A licence is generally required to use groundwater, however some existing blanket authorisations apply for taking of groundwater for drilling, constructing or testing petroleum exploration wells. A well construction permit from the Department for Water will be required for any water well drilled, including bores installed to monitor aquifers, irrespective of licensing requirements.

Beach will liaise with the Department for Water to ensure that appropriate authorisations are in place for drilling and extraction of groundwater. Landowners will be consulted regarding water well locations and water use and proposed water supply wells will be reviewed to ensure that their use does not impact adversely on existing users of groundwater. As discussed in Section 4.2.5.2, there are relatively few water supply bores in the area and shallow aquifers are often unsuitable for stock or domestic use.

Water use for fracture stimulation will be in accordance with the Far North Prescribed Wells Area Water Allocation Plan, and applicable guidelines such as APPEA and API guidelines (APPEA 2011, API 2010).

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

5.10 Other Aspects of Fracture Stimulation Operations

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

Further aspects of drilling and well operations such as preparation of the well lease, drilling, casing and cementing of the well, camps, well operation and monitoring, well abandonment and well lease restoration are covered by the Cooper Basin Drilling and Well Operations Environmental Impact

Report (Santos 2003) and Cooper Basin Drilling and Well Operations Statement of Environmental Objectives (Santos 2009) and are not re-visited in this document.

5.10.1 Waste Management

A range of wastes are generated during fracture stimulation operations. Typical wastes are summarised in Table 13.

Table 13: Typical wastes and disposal methods

Waste	Disposal Method
Domestic Waste	
Sewage and grey water	Camp and sewage would be managed under the provisions of the Drilling and Well Operations SEO (Santos 2009). This requires the disposal method for wastewater to comply with the *Standard for the Construction, Installation and Operation of Septic Tank Systems in SA*, or be to the satisfaction of the Department of Health.
Food waste and paper	Collected (may be compacted) for disposal to approved landfill.
Plastic, glass and cans	Collected at the site for disposal to approved landfill or recycling where possible.
Industrial Waste	
Workshop waste (rags, filters)	Approved landfill.
Chemical bags and cardboard packaging materials	Compacted and collected at site for disposal to licensed facility.
Scrap metals	Collected in designated skip for recycling or to licensed facility.
Used chemical and fuel drums	Collected in designated skip for return to supplier or recycling.
Chemical wastes	Approved landfill or return to supplier.
Flowback fluids	Held in lined ponds for evaporation, with off-site disposal of liner to licensed facility.
Timber pallets (skids)	Recycled or to licensed disposal facility.
Vehicle tyres	Shredded and disposed to approved landfill.

Source: Adapted from Santos (2003)

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

Generation of domestic waste (e.g. food waste, paper, plastics, cans and glass) will be limited as most domestic waste handling would occur at the camp, which would be managed under the parameters of the Drilling and Well Operations SEO (Santos 2009). Any domestic waste at the well site would be stored on site in secure bins or skips. Recyclable materials will be segregated for transport to a recycling facility where practicable. Other materials will be transported to a licensed waste disposal facility.

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

5.10.2 Hazardous Materials Storage

Each stimulation treatment requires approximately 16,000 L of diesel and storage of sufficient fuel for four to five treatments will be on site. Fracturing additives required for the fracture stimulation

operation (see Section 5.4) will also be stored on site. Fuel and chemicals would be stored and handled, with appropriate secondary containment, in accordance with relevant guidelines and legislation (e.g. Australian Dangerous Goods Code, AS 1940 and EPA guideline *080/07 Bunding and Spill Management*).

5.10.3 Spills and Emergency Response

Appropriate spill containment and cleanup equipment would be maintained on site, including acid spill kits and hydrocarbon spill kits. Any spill that occurred would be contained, reported and cleaned up by treatment *in-situ* where appropriate, or removal off-site for treatment or disposal. A spill response and emergency response plan would be in place detailing actions to be taken to minimise the impacts of accidents and incidents (see Section 7 for further discussion).

5.10.4 Cleanup and Rehabilitation

Following the completion of fracture stimulation activities, all waste materials would be removed off site as discussed in Section 5.10.1. Once the ponds containing flowback fluids have had the contents and liner removed and the ponds are no longer required, they would be backfilled and re-profiled to match pre-existing surface contours, and the surface ripped to promote revegetation.

Site cleanup and rehabilitation and well abandonment (when required) would be carried out under the parameters established in the Drilling and Well Operations SEO (Santos 2003). Standard criteria have been established under the Petroleum and Geothermal Energy Act to measure the successful rehabilitation of abandoned well sites (PIRSA 2009).

6 Environmental Impact Assessment

This section discusses potential environmental impacts related to the fracture stimulation process in deep shale and tight gas reservoirs in the Nappamerri Trough. The discussion is supported by an environmental risk assessment, which is summarised in Section 6.6. This risk assessment quantifies the level of risk based on an assessment of the likelihood and consequences of hazardous events occurring.

Sections 6.1 to 6.5 provide a detailed discussion of aspects of the environment that are potentially (or commonly perceived to be) impacted by fracture stimulation activities. Reference is made to the results of the risk assessment where relevant throughout the discussion. The key aspects discussed are:

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

The risk assessment summary table (Table 14) in Section 6.6 provides a summary of the key hazards, management measures and resulting level of risk.

6.1 Aquifers

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

- Leakage to aquifers due to loss of well integrity
- Fracture propagation into overlying Great Artesian Basin (GAB) aquifers
- Leakage to GAB aquifers through geologic media
- Impact on Permian aquifer potential
- Lateral migration of injected fluid in the Permian section
- Fracture propagation between Permian pressure cells / aquifers that are normally isolated
- Groundwater impacts from water use.

6.1.1 Leakage to aquifers due to loss of well integrity

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

- The well design and construction provides the mechanical integrity that reduces this risk to as low as possible
- Pressure testing confirms that production casing meets designed pressure specification
- Cement bond logs confirm the integrity of cement that fills the casing-wellbore space and prevents migration
- Pressure safety trip out systems during the fracture stimulation prevent pressure limits of the surface pipework and downhole casing equipment being exceeded
- Pressure monitoring during the fracture stimulation provides confirmation that the stimulation has not resulted in a well integrity issue
- Installation of a tubing string, after stimulation, provides further isolation of production fluids from aquifers.

These items are discussed below.

Well design

As indicated in Section 5.2, the well design and construction process provides the mechanical integrity of the well bore for the operational conditions and life of the well. The process ensures that casing, well head and production equipment are designed to meet the stresses and loads associated with the temperature, pressures and fluids that may be pumped into and produced from the well.

The casing design outlined in Figure 19 was reviewed by an independent engineering firm to confirm that the selected production casing and tubing equipment met the operational requirements. Standard design safety factors of 10-30 % are applied to the pipe strength in this process to allow for the high temperature environment and the potential pressures and loads on the casing.

The design process ensures that the correct casing weight and grade and casing coupling is selected to meet the pressures and loads anticipated after application of the safety and temperature factors. For the well design shown in Figure 19, the maximum well injection pressure is 13,000 psi during the stimulation phase. Wellhead and surface piping equipment is rated to 15,000 psi.

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

Well construction

As detailed previously, during construction of the well the casing strings are cemented into the ground. As shown in Figure 19, the Jurassic GAB aquifers are isolated behind two strings of casing and cement and the surface aquifers in the Winton are behind three strings of casing and cement. In addition to anchoring the casing string into the bore, the cement provides a barrier to fluid migration between the casing and borehole isolating aquifers and hydrocarbon bearing intervals.

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

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

As outlined in Section 5.2 there have been several recent advances in well design for wells targeting low permeability gas that enable alternatives to traditional cementing and perforation options over the hydrocarbon bearing intervals. Beach will actively investigate the application of these technologies but will ensure that mechanical integrity of the well, as required to isolate the aquifers and meet the operational requirements, is maintained through the design and construction process.

Pressure testing and cement bond logs

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

Additionally a cement bond log is run prior to stimulation to characterise the quality of the cement behind the casing. The log may assist with understanding stimulation and production results in the event that unexpected production characteristics develop. The risks posed by poor cement bond quality are discussed below.

Should the cement bond log indicate poor cement isolation between formations below the Toolachee zone, this may result in poor separation between individual fracture stimulation treatments, which will have a negative impact on production but would not affect aquifers. This provides a commercial driver to ensure proper isolation of intervals, as discussed previously.

If there is a poor cement bond from the target gas bearing zones into the Nappamerri group, this would not pose a risk to aquifers, as the Nappamerri Group has very low potential of containing productive sands (whether these are gas or water bearing). Further, due to the stress regime in the Nappamerri group, fracture growth in a well with a poor cement bond into the Nappamerri would preferentially occur in the Toolachee formation, or potentially horizontal fractures would form if fracture initiation occurs in the Nappamerri Group (see Section 4.2.4.1). This would have a negative production outcome but no impact on the overlying aquifer zones.

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

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

Pressure protection during stimulation

In order to ensure that the pumping equipment does not generate pressures which exceed the design pressure of the casing and wellhead equipment, controls are fitted to the pumping equipment that will shut down the pumps once a pre-set operational maximum pressure is reached. For the well design discussed in this document this pre-set pressure is the 13,000 psi calculated after temperature and safety factors are allowed for.

Monitoring during fracture stimulation

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

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

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

Tubing string installation

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

Summary

The likelihood of aquifers being impacted by leakage during fracture stimulation of a properly constructed and operated well is very low. The level of risk to aquifers has been assessed as low (see Table 14).

6.1.2 Fracture propagation into overlying GAB aquifers

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

Based on extensive fracture height growth monitoring in shale gas plays in the United States and the stress contrasts observed in the formations intersected in the Cooper Basin (as discussed in Section 4.2.4), it is considered improbable that this type of connection can be established.

Monitoring of many fracture stimulation treatments in shale gas plays in the United States has shown that typical height growth of fractures is less than 200-300 m (Fisher and Warpinski 2011). Figure 24 is a plot of the upper extent of the fracture treatment, the perforation depth and lower extent of the fracture treatment plotted against target zone depth (decreasing depth to the right) for more than 300 wells in the Eagle Ford shale in Texas.

The Nappamerri Trough stratigraphic section and the location of the Great Artesian Basin aquifers and surface aquifers are shown on the figure to illustrate that a typical shale gas fracture treatment cannot reasonably be expected to have sufficient height growth to stimulate into the overlying aquifers. The Eagle Ford data shows no occurrence of height growth sufficient to intersect an aquifer located more than 400 m above the fracture stimulation zone in at least 250 treatments, representing less than a 0.5% chance of occurrence. Further, the significant increase in stress in the rocks observed at the top of the Toolachee formation (refer Section 4.2.4.1) reduces the chance of fracture growth into the overlying aquifers to a negligible level.

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

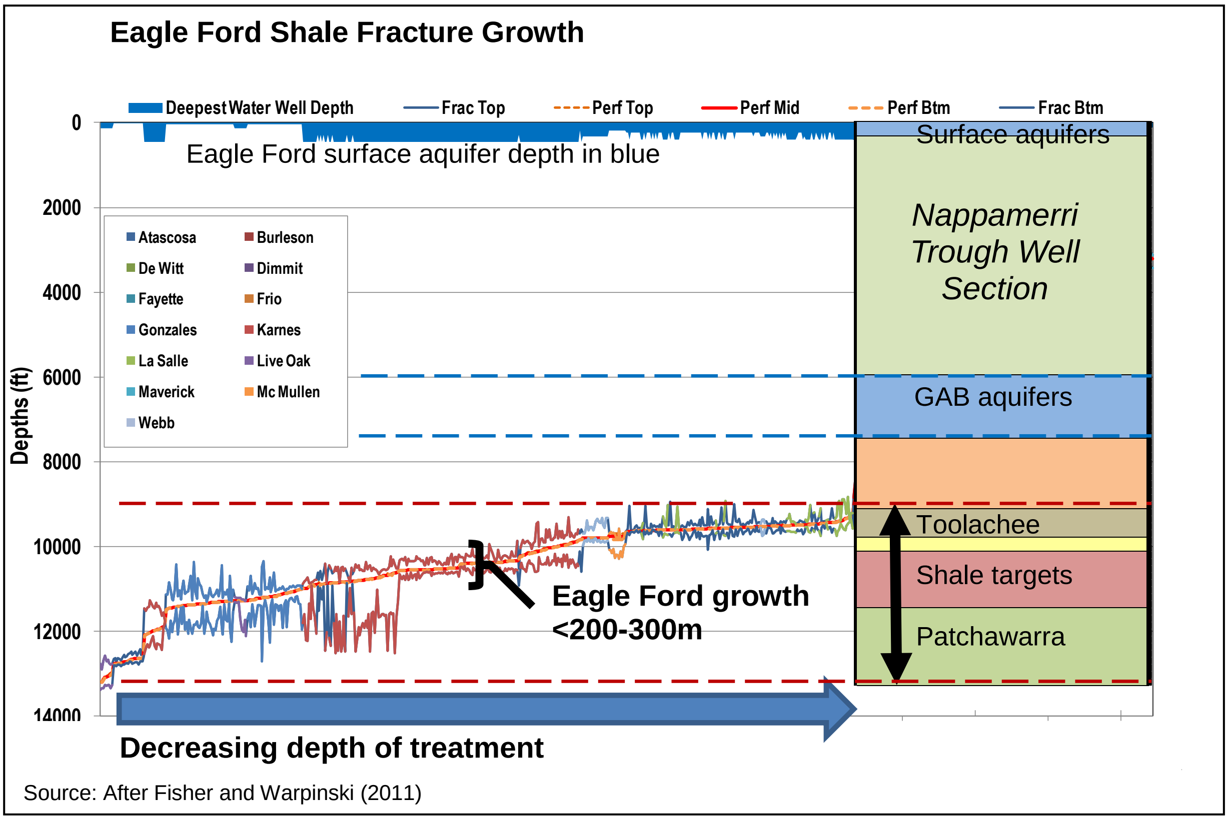


Figure 24: Typical fracture height growth measured during shale gas stimulation in the Eagle Ford (USA) with Nappamerri Trough well section superimposed

If it was considered that a fracture was able to grow 400 to 700 m or more into the GAB, it is not expected that the resultant impact would be significant, for the following reasons:

- Under production conditions, the flow will be from the aquifer to the well ensuring that further fluids do not cross flow into the aquifer.
- Flow from the aquifer production would be identified at the well by the elevated water production rates and analysis of the water chemistry.
- Any further fracture stimulation in the area would use micro-seismic monitoring equipment to ensure treatments are contained within the interval.
- When the well is shut-in or abandoned the aquifer will continue to flow to the lower gas zones until the pressure in the two zones equilibrates.
- Once equilibrated there is no pressure drive to enable gas or fluids to migrate towards the aquifer.
- Due to the low permeability of the GAB observed in the area and the very large distances to receptors, any contamination is likely to be significantly diluted over the many years that would be required before the water may come to surface.

The level of risk posed by fracture propagation into overlying freshwater aquifers has been assessed as low (see Table 14).

6.1.3 Leakage to GAB aquifers through geologic media

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

As discussed above, the nearest aquifers of any significance are the sandstone units of the Jurassic Great Artesian Basin. As shown in Figure 10 and Figure 11, and discussed in Section 4.2.4, the Permian target intervals are separated from the GAB by approximately 400 m of limited permeability Nappamerri Group siltstone. The slightly overpressured Toolachee gas reservoirs in Kirby, relative to the GAB pressure regime, suggest that there is very poor hydraulic conductivity through the overlying

Nappamerri Group siltstone in the Nappamerri Trough. It follows that if gas does not readily move through the Nappamerri Group siltstone, that a fracture stimulation fluid that is injected into the Permian Toolachee to Patchawarra sections is unlikely to migrate up to the GAB.

The presence of inter formation faults may result in migration of fluids but there is very low probability of this threat in the Nappamerri Trough. In particular:

- the pressure differential between the GAB and the Permian Formations indicates that the intervals are not currently connected by faults
- the seismic information, as discussed in Section 4.2.4 has not detected large scale faults that connect the GAB to the Permian section.

The level of risk posed by leakage into overlying GAB aquifers has been assessed as low (see Table 14).

6.1.4 Impact on Permian aquifer potential

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

The sandstone units of the Toolachee, Daralingie, Epsilon and Patchawarra Formations may be considered aquifers in other parts of the Basin where they are filled with water. This is not the case in the Nappamerri Trough where the units are evidently gas saturated:

- water salinity is unknown due to the lack of recovery of formation water during drill stem tests conducted in exploration wells on structural highs in the Trough; and
- there is still some uncertainty but indications are that, due to the low permeability in the Trough, gas has been trapped in the sands regionally without the need for conventional structural trapping and there may not be water in these zones off structure.

However, if it is considered that the Permian reservoirs are aquifers, the zones are not considered to be suitable for use for the following reasons:

- if water is present, it is expected that the salinity will be sufficient to preclude use of the water
- low permeability nature of the rocks results in insufficient yield for commercial use
- depth of the zones requires expensive drilling and pumping equipment and is not commercially viable.

The level of risk has been assessed as low (see Table 14).

6.1.5 Lateral migration of injected fluid in the Permian section

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

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

The level of risk has been assessed as low (see Table 14).

6.1.6 Fracture propagation between Permian pressure cells that are normally isolated

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

As described in Section 4.2.4.1, stress contrasts between layers in the Permian are likely to restrict growth between geological units. Evidence from pressure data in the area suggests that there are two

pressure systems in the Permian section with the Toolachee formation appearing to be normally pressured (i.e. pressure in the formation reflects a head of water from surface to the depth of the reservoir) and the Epsilon and Patchawarra formation which is observed to be overpressured, as described in the discussion on the basin-centred gas accumulation (Section 3). The contrast in the stress above the Roseneath shale is expected to be sufficient to prevent growth of induced fractures from the over pressured system into the normally pressured system and vice-versa.

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

The level of risk has been assessed as low (see Table 14).

6.1.7 Groundwater impacts from water use

Water extraction for fracture stimulation will be undertaken within the regulatory framework of the Natural Resources Management Act. As discussed in Section 5.9, Beach will liaise with the Department for Water to ensure that appropriate authorisations are in place for drilling and extraction of groundwater. Landowners will be consulted regarding water well locations and water use and proposed water supply wells will be assessed to ensure that their use does not impact adversely on existing users of groundwater. As discussed in Section 4.2.5.2, there are relatively few water supply bores in the area and shallow aquifers are often unsuitable for stock or domestic use.

The wells that will be fractured are expected to be geographically spread (several kilometres apart). They are also expected to be distant from existing water supply wells. A preliminary hydrogeological assessment was made to estimate an inferred zone of influence from extraction of water at fracturing locations. Where existing water wells are within approximately 1–5 km (dependent on aquifer properties) of an extraction point for a planned stimulation activity, there is potential for drawdown to be noticeable (e.g. greater than 5 m), if the fracturing water supply well is accessing the same aquifer or an aquifer in hydraulic connection to the existing well.

At such locations, further assessment of potential drawdown, consultation with the well owner and monitoring would be carried out, to ensure that significant drawdown or impacts are avoided or mitigated. If impacts were detected by monitoring, alternative water supply options would be pursued and any impact to existing users would be made good.

Extraction of large volumes of water from aquifers that provide baseflow to nearby waterholes (e.g. aquifers in sandy sequences underlying and adjacent to the Cooper Creek, as discussed in Section 4.2.5.2) could impact waterholes and the ecosystems that are dependent on them. Extraction of large volumes of water from aquifers such as these will be avoided (e.g. by assessing the location, depth, and aquifer properties of potential water supply wells to confirm they are not targeting such aquifers).

As discussed in Section 5.9, water use for fracture stimulation will be in accordance with the Far North Prescribed Wells Area Water Allocation Plan, and broadly applicable guidelines such as APPEA and API guidelines (APPEA 2011, API 2010). If the exploration and appraisal phase is successful and Beach is likely to progress to a development phase, alternative water sources are likely to be required. These may include recycling of recovered fracture stimulation fluids where practicable, recycling of produced formation water or extraction (under licence) of water from the Great Artesian Basin. In this case, detailed investigation and consultation regarding water sourcing would be carried out to ensure that significant impacts to water resources and other users are avoided.

The level of risk from water extraction for fracture stimulation in the exploration phase has been assessed as medium, based on minor level impacts being possible (see Table 14). The management procedures in place to assess and monitor possible impacts, cease extraction, if necessary, and make good, will ensure that significant impacts to existing water users are avoided.

6.2 Soil and shallow groundwater

Potential impacts to soil and shallow groundwater arise mainly from:

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

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

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

As discussed in Section 5.8, temporary storage ponds, lined with suitable UV stabilised polyethylene material (or equivalent), will be used to contain the water for fracture stimulation and the fluids recovered during flowback. Quality control during construction of the ponds is important in preparing a suitable base for the lining material to minimise risk of liner breaches. Fencing prevents large fauna and livestock from entering the ponds and damaging the liners. Regular monitoring of the pond and fence condition, operating the ponds below maximum fill levels (allowing freeboard for rain events and wave action) and construction with above-ground bunding to prevent surface runoff into the ponds all minimise the risk of seepage or release from the pond.

A water balance method, incorporating inflow rates, pond levels and evaporation (and the uncertainty associated with the measurements) can be used to identify potential seepage where the pond utilisation is short term. Where ponds are required for more than a year alternative leak detection methods may need to be employed.

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

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

The water table in much of the region, where present, is generally not close to the surface, and is expected to be predominantly saline. There is very low population density and very limited use of shallow groundwater. Many of the fracturing fluid additives are biodegradable and would be expected to break down over time if a spill or leak occurred. The rate of transport of any spilt contaminants to shallow groundwater (if present) is also likely to be limited by the low rainfall and high evaporation in the region. The relatively low permeability of the clay soils that are present at many of the potential exploration well locations would also limit the rate of transport of any spilt contaminants. Consequently, minor seepage from a pond, if it occurred, would be expected to have a low level, localised impact. A large release (e.g. due to pond failure) could affect a larger area and result in a moderate level consequence, but is considered unlikely given the construction, lining, operation and monitoring of the ponds that will be undertaken (as discussed above).

Fracture stimulation requires the injection of high pressure fluids into the wellbore. An equipment failure or leak could result in fracturing fluid being released to the lease area. Surface pipework, valving and pumping equipment required for the treatment must have a valid certification for the pressure rating. Once set up for the fracture stimulation the equipment is pressure tested to ensure integrity and pressure trip out devices are present to shut down pumps before equipment limitations are reached (Section 6.1.1). The design, pressure test and shut down systems reduce the risk of leaks to a very low level. In the unlikely event of a failure, the equipment is quickly shut down from the control van, reducing the volume of the spill to minor amounts.

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

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

Beach is establishing a monitoring program at well sites and water wells throughout the area to establish a baseline and monitor soil and groundwater quality on an ongoing basis. These studies will be used to assess impacts and success of any required remedial action.

Other potential impacts to soil (e.g. soil disturbance, erosion) are localised and generally short term. These are principally a result of well lease preparation activities that would be conducted under the Drilling and Well Operations SEO (Santos 2009). Site rehabilitation, including remediation of these impacts would also be carried out in accordance with the requirements of the Drilling and Well Operations SEO (Santos 2009), as discussed in Section 5.10.4.

The level of risk to soil and shallow groundwater has been assessed as low for most of these potential hazards. For a major leak or spill, while unlikely, the risk ranking is medium due to the assumed consequence (see Table 14).

6.3 Surface Water

Potential impacts to surface water arise mainly from:

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

Measures to ensure safe handling and storage of fuel, chemicals and flowback fluids will be implemented, as discussed in Section 6.2, including secondary containment, lining, spill response and cleanup. Similarly, secure storage and handling of waste will be implemented as discussed in Section 6.2.

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

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

Construction of the ponds with a polyethylene liner, operation with appropriate allowance for rain events and wave action, construction of pond walls higher than the surface grade to prevent surface water drainage to the pond, contouring surface drainage around the ponds and ongoing monitoring of pond condition reduce the risk of structural failure such that it is a very unlikely event. Selection of

appropriate well site and pond locations will also ensure that the consequences of a potential pond failure are minimised (e.g. ponds would not be located in close proximity to the Cooper Creek channel or other significant watercourses such that failure would result in direct release to these watercourses).

To mitigate the risk of fluid release due to flood inundation, well leases will not be located in areas where frequent flooding is likely. If well leases are to be located in areas where infrequent minor flooding may occur, measures will be undertaken to ensure that ponds are not vulnerable to flooding (e.g. ponds may be located on higher ground out of the floodplain and/or pond walls constructed higher above grade at these locations).

If there is a risk posed by floodwaters, flowback fluids can be removed to ponds on other leases that are not at risk. This transfer can be instigated at the completion of flow back operations, during flowback operations to minimise the fluid volumes on the lease at any given time, or if flood fronts in the Cooper Creek catchment area are identified that will impact on well operability and pond security. Broad scale flooding in the region is associated with heavy rainfall in the Cooper Creek catchment hundreds of kilometres upstream of the Nappamerri Trough. Gauging stations at various locations upstream monitor the level of the creek and the potential for flooding is understood several weeks or more in advance. If necessary, decommissioning and demobilisation activities can be planned and executed to minimise the impact of creek flooding.

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

Prior to undertaking fracture stimulation operations, site-specific assessments against the SEO will be submitted to DMITRE to demonstrate that the environmental objectives can be met, including the SEO requirement to avoid contamination of surface waters. The site specific assessments will indicate risks identified at individual well locations and management strategies required to mitigate these to meet the objectives.

The mitigation measures discussed above, particularly in regard to the location of ponds and well sites, indicate that the likelihood of release of flowback fluid to surface water can be reduced to a very low level. In addition, it is noted that the Coongie Lakes themselves are distant from the Nappamerri Trough region (approximately 50 km) and the large volumes of water that flow in the system would result in significant dilution if a release reached the Cooper Creek system, which further reduces the risk.

The level of risk to surface water has been assessed as low for most of these potential hazards. For a major leak or spill to surface water due to pond failure, while this is an unlikely event, the potential level of consequence has been assessed to be major, which results in a medium risk (see Table 14).

6.3.1 Coongie Lakes Ramsar Wetland Area

As indicated in Section 4.3.4, the Nappamerri Trough overlaps with the southern part of the Coongie Lakes Ramsar wetland 'triangle'. Wetland areas within the section of overlap include the Cooper Creek main channel and its extensive floodplain and the southern part of the North-West Branch of Cooper Creek (which eventually flows to Coongie Lakes) but not Coongie Lakes themselves.

As indicated previously, the designated Coongie Lakes Ramsar wetland site is a large area that includes extensive areas of dunefield and gibber tablelands with little or no hydrological connection to the Cooper Creek in addition to the channels, waterholes and floodplains of the Cooper Creek system. Hundreds of petroleum wells and several oil and gas facilities are currently located within the designated Ramsar area.

Well sites for fracture stimulation will not be established in locations that have significant wetland values and as discussed above, measures will be undertaken to ensure that surface water quality is not impacted, including appropriate siting of well sites and ponds. In addition, the Drilling and Well Operations SEO (Santos 2009) requirements that surface water flows are not altered by well lease and access track preparation will be met.

Consequently, it is not expected that fracture stimulation operations will trigger any of the criteria that would require EPBC Act approval (as discussed in Section 4.3.4). This will be confirmed on a site specific-basis. If individual wells appear likely to need approval, they would either be relocated or a referral submitted under the EPBC Act to determine whether approval is required.

6.4 Stock, Wildlife and Vegetation

Potential impacts to stock and native fauna arise mainly from:

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

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

The presence of temporary ponds for holding flowback fluids has the potential to attract birds. Due to the nature of the ponds (relatively steep sided and lined with plastic, with no ‘beaches’, vegetation or food sources) visitation by birds is expected to be restricted to relatively small numbers for relatively short periods of time. Concentration data for fracturing fluids to be injected and available toxicity information (e.g. MSDS information provided by the stimulation service provider) indicate that the concentration of additives of highest concern for fauna (e.g. biocides) is expected to be below levels that pose a significant risk for birds coming into short term contact with flowback fluids. As discussed in Section 5.7, many of the additives in the fracturing fluids are used or degraded in the process (including biocides) or remain in the formation and would return at a fraction of what was pumped down the well. The pH of the flowback fluids is expected to be relatively neutral, as acids are neutralised in the fracturing process (see Section 5.4). Water quality data from previous fracturing of the Holdfast-1 well support this, with recorded pH in the range of 6.2 to 7.7. Ponds will be temporary and will be rehabilitated following removal of liner.

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

Plastic lined ponds with relatively steep sides have the potential to trap stock and native fauna. As discussed above, fencing will prevent larger animals from entering the ponds. Based on experience with similar ponds used for holding raw water for drilling or fracturing or for treatment of produced formation water, entrapment of fauna in ponds in the Cooper Basin is a very rare occurrence. As noted above, the presence of these ponds is temporary.

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

to other holding ponds, and further assessment, rehabilitation and monitoring may be undertaken, as discussed in Section 6.2.

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

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

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

Based on the above discussion, impacts to native fauna and flora (including rare or threatened species) are expected to be minimal. Site-specific risks will be addressed in initial scouting and site assessment conducted under the Drilling and Well Operations SEO (Santos 2009) and in assessments submitted to DMITRE prior to undertaking fracture stimulation operations. These assessments must demonstrate that the objectives with respect to vegetation, stock and native fauna identified in the SEO will be met while undertaking the proposed work at the specific well location.

The level of risk has been assessed as low for most of these potential hazards. A medium risk is assigned for a major leak or spill; although it is unlikely to occur, the consequence is moderate (see Table 14).

6.5 Other Issues

6.5.1 Public Safety and Risk

Potential impacts to public safety and risk arise mainly from:

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

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

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

The population density in the area is very low. Fracture stimulation activities (and drilling activities in general) would not be carried out in close proximity to pastoral station residences, the Innamincka Township or campsites along the Cooper Creek.

Fires are generally not a frequent occurrence in the Cooper Basin, but heavy vegetation growth over 2010 and 2011 has resulted in an elevated fuel load and numerous grass fires have occurred from lightning strikes. In order to manage the risk of initiating fires, activities will be confined to the cleared well lease and combustible material will be cleared from around the flare pit. Fire fighting equipment will be maintained in the area as appropriate, and the requirements of the Fire and Emergency Services Act will be complied with.

Fracture stimulation operations may result in a short term and localised increase in traffic volumes. The existing road and track network in the Cooper Basin is already heavily used by the oil and gas industry and the incremental change is not likely to be significant. Measures to mitigate the risks to the public are already in place including signage, speed restrictions, monitoring of speeds in industry vehicles, education programs and ongoing maintenance of roads and tracks.

The level of risk to public safety has been assessed as low for most of these potential hazards. A medium ranking has been assessed for road use (see Table 14).

6.5.2 Cultural Heritage

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

Work Area Clearances with the native title claimant groups are carried out prior to undertaking any exploration or production activities in the Cooper Basin. Fracture stimulation operations are undertaken on a prepared well lease, within the area cleared by the Work Area Clearance party. Signage and fencing (where required) is installed to delineate approved areas and any restricted areas. If sites of cultural heritage significance are present in the vicinity they may be flagged and/or fenced off where necessary to prevent disturbance. In addition, procedures are in place to deal with the incidental discovery of cultural heritage material.

Consequently, significant impacts to cultural heritage are not likely to occur and the level of risk has been assessed as low (see Table 14).

6.5.3 Noise and Air Emissions

Potential impacts associated with noise and air emissions include:

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

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

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

Fugitive emissions from the flow testing equipment will be minimised by pressure testing of lines prior to use to ensure integrity. Due to the depth of stimulation treatment, the relatively small volume of rock that receives induced fractures from the treatments and testing conditions that draws gas towards the well, fugitive emissions through migration through geological strata to surface is not considered a plausible pathway. Migration along the well bore is a potential source of fugitive emissions and this is mitigated by well design and construction methods discussed in Section 6.1, particularly the presence of cemented casing strings, assessment of the cement quality with logging tools and monitoring the well and the lease during flowback.

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

The level of risk from noise and air emissions has been assessed as low (see Table 14).

6.5.4 Radioactivity

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

Based on previous experience with Cooper Basin petroleum operations, levels of radioactivity associated with NORM in flowback of fracture stimulation fluids are not expected to be significant and are expected to be well below any levels of concern. NORM are usually only a potential issue when they are concentrated (e.g. by the formation of mineral scales or sludges over time in tanks, piping and facilities). Beach are undertaking monitoring at current well sites and fracturing operations to confirm the expectation that the levels of radioactivity will be well below any levels of concern. In the unlikely situation that NORM above the natural background levels were to occur, appropriate measures for handling and disposal of pond liners and contents remaining after evaporation would be implemented.

The level of risk has been assessed as low (see Table 14).

6.5.5 Seismicity

The induction of seismic events (i.e. micro-earthquakes) as a result of fracture stimulation is sometimes perceived as a potential issue. It is not considered that a credible risk is presented by fracture stimulation of deep shale gas and tight gas targets in the Nappamerri Trough.

The region has low background seismic hazard and is mapped in the lowest category of earthquake hazard in Australia (McCue *et al.* 1993). As discussed in Section 4.2.4, there is a lack of major faulting in the central Nappamerri Trough. Fracture stimulation (using lower volumes of fluid) has been carried out in the Cooper Basin for over 40 years without any issues related to seismicity. Fracture stimulation of the Holdfast-1 well in PEL218 in 2011 did not register on the seismic monitoring equipment at Geodynamics' nearby Habanero site. Microseismic monitoring may be used at some well locations as part of the resource assessment and will be available to delineate seismic response.

In addition to the absence of significant risk posed by fracture stimulation operations, there is very low population density and little infrastructure that would be sensitive to small seismic events.

The level of risk has been assessed as low (see Table 14).

6.5.6 Cumulative Impacts

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

6.5.7 Economic Impact

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

- Noise (Section 6.5.3) has the potential to affect tourism. Activities will not to be undertaken in close proximity to residences and Innamincka to avoid affecting residents and tourists.
- Groundwater use (Section 6.1.7) for stimulation has the potential to impact on existing ground water users. Monitoring of water levels in supply wells and existing stakeholder bores will be used to assess the impact. As required, alternative water supplies will be utilised to reduce withdrawal from groundwater sources and 'make good' measures undertaken.
- Stock and vegetation (Section 6.4) may be affected by activities. Stock may attempt to access fluids or be exposed to fluids through spills. Ponds are fenced and design and construction minimises risk of breach. As may be required any spill affected areas will be fenced off, assessed, appropriately remediated or rehabilitated and monitored.

The potential economic benefits of the exploration and appraisal for shale and tight gas on owners of the land and other licensees are as follows:

- Improved understanding of shallow groundwater source and distribution with potential to assist landowner and Innamincka township in sourcing good quality water. Potential benefits to other licensees that may require water for activities.
- Well access routes would be rehabilitated in the event of an unsuccessful well but may be of use to landholders and may save construction costs to the landholder.
- Improved access routes, less affected by flood or heavy localised rain events, may be established and be beneficial to stakeholders.
- Increased utilisation of Innamincka food, fuel and lodgings which has direct impact to owners and potential indirect impact to users if services were to be expanded or augmented.
- Increased utilisation of indigenous land owner crews to undertake clearance surveys associated with activities.
- Potential for royalties to be paid if exploration and appraisal are successful and project economics favourable which benefits State and traditional land owners.
- Potential enhancements to infrastructure or increased maintenance such as roads, airstrips and communication, dependent on success and on-going activity.
- Potential installation of gathering systems and connection to gas lines may provide access to gas as an alternative fuel source for landowners and other licensees.
- Increased understanding of the geological zones under the ground provides information for other licensees in the area once data becomes open file.

6.6 Environmental Risk Assessment Summary

As discussed above, Beach has undertaken an environmental risk assessment of fracture stimulation of deep shale gas and tight gas reservoirs in the Nappamerri Trough. This section summarises the process and results of the assessment.

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

The risk assessment process involves:

- identifying the potential hazards or threats posed by the project
- categorising the potential consequences and their likelihood of occurring
- using a risk matrix to characterise the level of risk[2] .

The level of risk for fracture stimulation in the Nappamerri Trough has been assessed based on the assumption that management measures that are discussed in this EIR will be in place. The risk assessment was carried out by RPS and Beach Energy, based on knowledge of the existing environment, understanding of proposed operations and experience with similar operations, including Beach Energy, Santos and other companies oil and gas operations in the Cooper Basin.

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

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

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

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

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

A summary of the level of environmental risk for fracture stimulation activities is provided in Table 14 below. The level of risk has been assessed based on the assumption that the management measures outlined in this EIR will be in place.

Table 14: Risk assessment for fracture stimulation of deep shale gas and tight gas targets in the Cooper Basin, South Australia

<table>
<tr><th>Risk Event / Hazard</th><th>Potential Environmental Impacts</th><th>Key Management Measures / Comment</th><th>Consequence</th><th>Likelihood</th><th>Residual Risk</th></tr>
<tr><td colspan="6">Injection of fracture stimulation fluid</td></tr>
<tr><td rowspan="2">Loss of well integrity</td><td>Leakage to aquifers
Contamination of soil, groundwater and surface water
Emissions to the atmosphere</td><td rowspan="2">Aquifers isolated behind multiple casing strings, cemented to surface.
New casing and wellhead installed.
Casing and wellhead designed to meet pressure, temperature, operational stresses and loads.
Design reviewed by independent engineering firm where necessary.
Cement bond logs run to confirm quality of cement.
Well pressure tested prior to stimulation.
High pressure stimulation equipment has valid certifications, is properly secured and is pressure tested once set-up, prior to commencement of stimulation.
Stimulation pumping pressures do not exceed design safety factors.
Trip systems to shut off pumping units during stimulation.
Injection pressures are monitored and compared to expected fracture initiation pressure.
If significantly lower initiation pressure, stop job and assess for potential casing integrity failure.
Well control equipment used during coiled tubing, wireline and workover activities.
Installation of tubing string for production testing.
Ongoing well integrity monitoring.
Emergency response plan in place and drills conducted.</td><td>Moderate</td><td>Remote</td><td>Low</td></tr>
<tr><td>Injury / danger to health and safety of employees, contractors and possibly the public</td><td>Major</td><td>Remote</td><td>Medium</td></tr>
<tr><td>Fracture propagation into overlying GAB aquifers</td><td>Contamination of aquifers
Indirect adverse impacts to groundwater users</td><td>Significant physical separation between targets and overlying GAB aquifers (~400 m thick Nappamerri Group siltstone between Permian targets zones and the overlying GAB).
Fracture height growth in shales at similar depths in US is not more than 200-300 m.
Fractures unlikely to propagate beyond the top of the Toolachee into the Nappamerri Group due to stress contrast between these layers.
Microseismic monitoring to be used to monitor height growth, if required, due to thinning of geological strata or evidence of unsuitable geomechanical conditions.</td><td>Minor</td><td>Remote</td><td>Low</td></tr>
<tr><td>Leakage to GAB aquifers through geologic media</td><td>Contamination of aquifers
Indirect adverse impacts to groundwater users</td><td>Permian target intervals separated from overlying GAB aquifers by 400 m of limited permeability Nappamerri Group siltstone.
Low likelihood of migration of fluids along inter-formation faults – pressure differential between the GAB and the Permian Formations indicates that the intervals are not currently connected by faults, and seismic information has not detected large scale faults that connect the GAB to the Permian section.</td><td>Minor</td><td>Unlikely</td><td>Low</td></tr>
</table>

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures / Comment	Consequence	Likelihood	Residual Risk
Injection of fluid into Permian section	Impact on Permian aquifer potential	Sandstone units of the Toolachee, Daralingie, Epsilon and Patchawarra in the Permian thought to be gas saturated (i.e. can't be considered 'aquifers' as they may be in other parts of the Basin where they are filled with water). If Permian reservoirs are considered as aquifers, not suitable for use: ▪ if water is present, expected that the salinity will be sufficient to preclude use of the water ▪ low permeabilityof the rocks results in insufficient yield for commercial use ▪ depth of the zones requires expensive drilling and pumping equipment – not commercially viable.	Minor	Unlikely	Low
Lateral migration of injected fluid in the Permian section	Impact on Permian aquifer potential	Due to low permeability in the Permian intervals, fracture stimulation fluid highly unlikely to migrate any significant distance beyond the stimulation treatment. Once on production, pressure gradient underground will result in fluids moving towards the well rather than migrating either upwards or laterally away from the fracture stimulation.	Minor	Unlikely	Low
Fracture propagation between Permian pressure cells that are normally isolated	Crossflow between aquifers resulting in contamination / loss of quality Pressure depletion in hydrogeological cells	Stress contrasts above the Roseneath shale in the Permian are likely to restrict growth between the over-pressured Epsilon and Patchawarra formation and the normally pressured Toolachee formation. If induced fractures connect these two systems there will be a brief cross flow of the higher pressured gas into the lower pressure gas system until the well is flow tested. During production testing flow will be towards the wellbore. This can assist in improving recovery of gas but is not likely to have detrimental impact.	Negligible	Possible	Low
Water supply / use	Drawdown of artesian and sub-artesian aquifers Adverse impact on groundwater users Impact on groundwater dependent ecosystems	Water extraction in compliance with licensing and water allocations where applicable. Water supply wells reviewed to ensure that their use does not impact adversely on existing users of groundwater. Relatively few water supply bores in the area and shallow aquifers are often unsuitable for stock or domestic use. Wells to be fractured expected to be far apart (several kilometres). Impact on aquifer of once-off extraction for fracturing expected to be relatively short term and localised. Options for alternative water supplies investigated / used where possible (e.g. produced formation water, recycling, reuse). Monitoring of water extraction volumes. Extraction of large volumes of water from aquifers that provide baseflow to nearby waterholes (e.g. aquifers in sandy sequences underlying and adjacent to the Cooper Creek) will be avoided.	Minor	Possible	Medium

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures / Comment	Consequence	Likelihood	Residual Risk
Storage and handling of fuel, chemicals and fracturing / flowback fluids					
Leak of brackish or saline pre-stimulation water from holding ponds	Localised salinisation of soil, surface water and groundwater Indirect impacts to flora and vegetation	Quality control on pond construction and liner installation to minimise risk of compromised liner integrity. Pond liners prevent pond wall erosion. Maximum pond fill level not exceeded (allow for rain events and wave effects). Ponds with above-ground walls / bunds to prevent surface runoff into ponds. Pond operation monitored (e.g. pond wall integrity) and repair undertaken if required. Water balance method used for leak detection (incorporating inflow, evaporation, fluid levels and measurement uncertainty). No chemicals added to pre-stimulation water in ponds.	Minor	Unlikely	Low
Minor spill / leak from hazardous material storage and handling (e.g. several litres)	Localised contamination of soil, surface water and groundwater Access to contaminants by stock and wildlife Indirect impacts to flora and vegetation	Handling and storage in accordance with relevant International Standards Organisation standards, relevant MSDS and State regulatory requirements, as recommended by APPEA Code of Practice Guideline 4(2011). Fracturing additives contained in units with appropriate secondary containment. Emergency/spill response procedures in place with immediate clean up and remediation of spills. Personnel trained in correct procedures for use of materials, including refuelling and clean-up procedures. Bulk fuel storage with appropriate secondary containment system. Refuelling undertaken with appropriate drip capture systems. Suitable facilities present to contain potential spills when handling fuel and chemicals. Clean-up materials and wastes appropriately contained for off-site disposal to a licensed waste management facility.	Minor	Unlikely	Low
Major spill / leak from hazardous material storage and handling (e.g. entire contents of refuelling tank)	Contamination of soil, surface water and groundwater Access to contaminants by stock and wildlife Indirect impacts to flora and vegetation		Moderate	Unlikely	Medium

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

Note: Water table, where present, is generally not close to the surface and is expected to be predominantly saline, with very limited and scattered use of shallow unconfined groundwater. This further mitigates the level of risk.</td><td>Minor</td><td>Unlikely</td><td>Low</td></tr>
<tr><td>Major leak or spill to ground from surface handling / storage of flowback fluids (e.g. pond wall failure)</td><td>Contamination of soil and/or groundwater
Access to spilt contaminants by stock and wildlife
Indirect impacts to flora and vegetation</td><td>Moderate</td><td>Unlikely</td><td>Medium</td></tr>
</table>

<table>
<tr><th>Risk Event / Hazard</th><th>Potential Environmental Impacts</th><th>Key Management Measures / Comment</th><th>Consequence</th><th>Likelihood</th><th>Residual Risk</th></tr>
<tr><td>Minor leak or spill of flowback fluids to surface water</td><td>Localised contamination of surface water
Localised death or injury to aquatic fauna</td><td rowspan="2">Chemical utilisation during stimulation kept to the lowest possible to achieve necessary stimulation outcome.
Lower toxicity chemical additives used where practicable and suited to the stimulation design required.
Many of the fracturing fluid additives are used or degraded in the reservoir and at surface in the flowback pond.
Flowback fluid securely contained in lined ponds, as discussed above:
▪ Ponds lined with UV stabilised material
▪ Quality control during construction to minimise risk of compromise to integrity of liner
▪ Monitoring of pond operation (freeboard) to maintain pond integrity
▪ Water balance method used for leak detection (incorporating inflow, evaporation, fluid levels and measurement uncertainty)
▪ Spills / leaks cleaned up and remediated
▪ Ponds with above-ground walls / bunds to prevent surface runoff into ponds
▪ Pond liners prevent pond wall erosion.
Well sites and pond locations selected to ensure that the consequences of a potential pond failure are minimised (e.g. ponds would not be located in close proximity to the Cooper Creek channel or other significant watercourses such that failure would result in direct release to these watercourses).
Well leases located on higher ground as far as practicable.
Where well leases have potential for infrequent flooding, measures will be undertaken to ensure ponds are not vulnerable to flooding (e.g. ponds on higher ground, construction of higher pond walls, removal of flowback fluids off-site either during testing or at completion of operations).
Monitoring of Cooper Creek levels at gauging stations upstream of the Nappamerri Trough to enable implementation of flood response procedures if flood fronts are identified that are likely to impact on well operability and pond integrity.
Implementation of additional management measures as identified by site-specific assessments against the stated environmental objective to avoid surface water impacts.
Note: The Coongie Lakes are distant from the Nappamerri Trough region (approximately 50 km) and the large volumes of water that flow in the system would result in significant dilution if a release reached the Cooper Creek system, which further reduces the risk.</td><td>Minor</td><td>Unlikely</td><td>Low</td></tr>
<tr><td>Major leak or spill of flowback fluids to surface water
(e.g. if pond fails and contents reach surface water or flood overtops ponds)</td><td>Contamination of surface water
Death or injury to aquatic fauna</td><td>Major</td><td>Unlikely</td><td>Medium</td></tr>
</table>

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures / Comment	Consequence	Likelihood	Residual Risk
Flooding of well leases during fracture stimulation operations	Contamination of surface water Death or injury to fauna	Well leases located on higher ground as far as practicable. Fracture stimulation not carried out in floodplain areas if significant flooding is reasonably expected or predicted in the Cooper Creek system. Monitoring of Cooper Creek levels at gauging stations upstream of the Nappamerri Trough to enable implementation of flood response procedures prior to flooding (which can generally be predicted many weeks to months in advance). Handling and storage in accordance with relevant International Standards Organisation standards, relevant MSDS and State regulatory requirements, as recommended by APPEA Code of Practice Guideline 4(2011). Emergency/spill response procedures in place with immediate clean up and remediation of spills. Measures discussed above implemented to ensure ponds are secure from flooding. Flowback fluids will be monitored closely where ponds are located in areas where there is any potential of flooding.	Moderate	Unlikely	Medium
Interaction of stock or native fauna with storage ponds	Death or injury of fauna or stock	Ponds securely fenced to exclude stock and large native fauna. Pond construction to minimise attractiveness to birds i.e. relatively steep sides and lined with suitable polyethylene material, with no 'beaches' or vegetation. Many of the fracturing fluid additives are biodegradable. Routine surveillance monitoring will be undertaken to detect incursions. Ongoing inspection and monitoring of ponds would detect fauna mortality (if it occurred). Bird deterrent measures will be introduced if bird mortality incidents are observed. Ponds will be temporary and will be rehabilitated following removal of liner. Note: Historically there are very few reports of fauna (small or large) entrapment in similar ponds within the Cooper Basin.	Minor	Unlikely	Low
Personnel and third party access to storage ponds	Injury / danger to health and safety of employees, contractors and possibly the public	Ponds securely fenced. Signage in place to warn of access restrictions. Access to sites restricted during operations. Sites will be attended by an operator during and after fracturing operations.	Moderate	Remote	Low
Separator upset resulting in small volumes of flowback fluid going to flare pit	Contamination of soil and/or groundwater Access to spilt contaminants by stock and wildlife	Regular inspection and maintenance of equipment. Ongoing monitoring during flaring. Flare pit cleaned up and remediated as required following completion of operations.	Minor	Unlikely	Low

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures / Comment	Consequence	Likelihood	Residual Risk
General issues					
Activity outside designated / approved areas	Damage to significant vegetation Degradation of fauna habitat Damage to cultural heritage sites	Activities confined to existing cleared areas (e.g. access roads, prepared well lease) within area subject to environmental assessment and Work Area Clearance for cultural heritage. Approved work areas and restricted areas clearly delineated on site. Training and induction for all personnel to educate them on the importance of remaining within designated / approved areas. If flora with significant conservation value is present in the vicinity of the well site it will be flagged and/or fenced off where necessary to prevent disturbance. Cultural heritage sites or exclusion zones in the vicinity of the well site will be flagged and / or fenced off to prevent disturbance where necessary.	Minor	Unlikely	Low
Air emissions	Reduction in local air quality Generation of greenhouse gas emissions	Equipment operated and maintained in accordance with manufacturer specifications. Well flowback diverted to separator as soon as practicable to minimise gas not being captured and sent to flare. Flaring during production testing kept to minimum length of time necessary to establish resource and production parameters (consistent with APPEA Guideline 6 (2011)). Remote location of well sites. Uncertainty in production rates and gas composition prevents connection of exploration and appraisal wells to existing gathering system. Options to connect to the gathering network will be investigated once initial testing is complete and longer term testing is required for reserve definition. Fracturing would not be carried out in close proximity to Innamincka or pastoral station residences. Note: Greenhouse gas emissions recorded and reported in accordance with NGER requirements. Monitoring of well parameters during testing operations to check for potential for fugitive emissions at the wellbore.	Minor	Unlikely	Low
Noise emissions	Disturbance to native fauna Disturbance to local community	Equipment operated and maintained in accordance with manufacturer specifications. Remote location of well sites. Fracturing would not be carried out in close proximity to Innamincka or pastoral station residences. Landowners notified of location of operations and appropriate consultation and mitigation measures implemented, if required, to ensure that no reasonable complaints are received.	Minor	Unlikely	Low

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures / Comment	Consequence	Likelihood	Residual Risk
Bushfire (resulting from activities)	Loss of vegetation and habitat Disturbance, injury or death of fauna Atmospheric pollution Damage to infrastructure Disruption to land use Danger to health and safety of employees, contractors and possibly the public	Activities undertaken on cleared well lease. Combustible materials cleared from area surrounding flare. Fire fighting equipment available as appropriate for location and use. Fire and Emergency Services Act requirements will be complied with (e.g. permits for 'hot work' on total fire ban days).	Moderate	Remote	Low
Seismicity	Ground disturbance	Low background seismic hazard and lack of major faulting in the central Nappamerri Trough. Historical stimulation work in the Cooper Basin indicates low risk of induced seismicity. Microseismic monitoring may be used at some well locations as part of the resource assessment and will be available to delineate seismic response.	Negligible	Remote	Low
Radioactivity from Naturally Occurring Radioactive Materials (NORM) in flowback fluids	Danger to health and safety of employees, contractors and possibly the public Contamination of soil and/or groundwater	Flowback ponds polyethylene lined to prevent soil and groundwater contamination. Monitoring planned at current well sites and fracturing operations to confirm expectation that levels of radioactivity are within acceptable limits. If NORM above the natural background levels were to occur, appropriate measures for handling and disposal of pond liners and contents remaining after evaporation would be implemented.	Minor	Unlikely	Low
Light emissions	Disturbance to local community Disturbance to native fauna	Minimise lighting where possible. Flaring during production testing kept to minimum length of time necessary to establish resource and production parameters.	Minor	Unlikely	Low
Use of roads; movement of heavy machinery and vehicles along roads and access tracks	Injury or death of stock or fauna Dust generation Noise generation Damage to third party infrastructure Degradation of public roads and tracks Disturbance to cultural heritage sites	Existing access roads, cleared well lease and turn-arounds used. Dust control measures (e.g. water spraying) implemented if dust generation becomes a problem e.g. near sensitive sites. Equipment that has been operating outside the Cooper Basin or in areas of known weed infestation will be cleaned before arrival at the site. Speed restrictions and appropriate signage to reduce speed and increase awareness of hazards. Driver awareness training for all personnel. Traffic and journey management procedures followed. Liaise with road authorities regarding arrangements and responsibilities for road maintenance and undertake maintenance where required.	Minor	Unlikely	Low
	Introduction and/or spread of weeds		Moderate	Remote	Low
	Road hazard / disturbance to local road users		Major	Unlikely	Medium

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures / Comment	Consequence	Likelihood	Residual Risk
Storage of waste and transport to landfill	Localised contamination of soil, surface water and groundwater Damage to vegetation and habitat Attraction of scavenging animals (native / pest species) and access to contaminants by stock and wildlife Litter / loss of visual amenity	Waste generation minimised (e.g. reduce, reuse and recycle. Waste removed off-site and disposed of at appropriately licensed waste handling facility. High standards of 'housekeeping' implemented. Secure systems used for storage and transport of waste (e.g. covered bins in designated area for waste collection and storage prior to transport). Hazardous wastes handled in accordance with relevant legislation and standards. Licensed contractors used for waste transport.	Minor	Unlikely	Low

7 Environmental Management Framework

Fracture stimulation activities will be undertaken in accordance with Beach Energy's Health, Safety and Environment Management System (HSEMS). The HSEMS is a key tool in the management of Beach and associated contractors' environmental responsibilities, issues and risks. The HSEMS also provides a framework for the coordinated and consistent management of environmental issues by ensuring the:

- establishment of environmental policy (see http://www.beachenergy.com.au/)
- identification of environmental risks and legal and other requirements relevant to the operations
- setting of appropriate environmental objectives and targets
- delineation of responsibilities
- establishment of a structure and program to implement environmental policy and achieve objectives and targets, including the development of procedures or guidelines for specific activities and education and induction programs
- facilitation of planning, control monitoring, corrective action, auditing and review of activities to ensure that the requirements and aspirations of the environmental policy are achieved.

Key components of the HSEMS are discussed in the following sections.

7.1 Environmental Objectives

Environmental objectives have been developed based on the information and issues identified in this document. These objectives have been designed to provide a clear guide for the management of environmental issues and are detailed in the accompanying Statement of Environmental Objectives.

7.2 Responsibilities

Environmental management and compliance will be the responsibility of all personnel. The indicative organisation and responsibilities for personnel overseeing environmental management are detailed in Table 15. The exact nature and title of these roles may vary and positions may be amalgamated or the responsibilities shared under a modified arrangement.

The overall responsibility for environmental compliance lies with Beach Energy. Beach will maintain a high level of on-site supervision. The fracture stimulation contractor and individuals will also be responsible and accountable through their conditions of employment or contract. The training of all personnel will ensure that each individual is aware of their environmental responsibility.

Table 15: Indicative roles and responsibilities

Role	Responsibility
Beach Energy Executive Management	Licence holders Hold overall responsibility for Beach activities and environmental management
Beach Energy Project Manager	Responsible for co-ordinating the management of the activities, including all environmental aspects Responsible for overall implementation of EHS Responsible for the overseeing and fulfilling of commitments contained in EIR and SEO Overall responsibility for reporting on environmental performance and due diligence Co-ordinates environmental incident internal reporting and investigation Incident notification to Authorities
Beach Energy Environment Personnel	Oversees EIR and SEO implementation Monitors the activities of construction contractors and assesses compliance with the SEO Coordinates the monitoring and audit program Environmental internal reporting and incident investigation

Role	Responsibility
Beach Energy Site Representative	Directly responsible for on-site management, including all environmental aspects Responsible for the overseeing and fulfilling of commitments contained in EIR and SEO Reports to Beach Project Manager on environmental performance and due diligence Environmental internal reporting and incident investigation
Fracture stimulation contractor	Responsible for ensuring that works meet regulatory requirements and all environmental objectives contained in the SEO pertinent to the stimulation operations (e.g. not including sourcing water for stimulation, construction of lined ponds and flowback and testing operations) Directly responsible for the overseeing and fulfilling of commitments contained in relevant approvals, EIR and SEO Responsible for ensuring adequate resources are provided for constructing and maintaining environmental controls Inspection of work area to ensure appropriate environmental management Environmental internal reporting and incident investigation

7.3 Environmental Management Procedure

All Beach Energy employees and contractors are responsible for ensuring compliance with the Beach Energy Environmental Management Procedure (EMP) and associated environmental legislation. The EMP is comprised of a number of levels of documentation (including plans and procedures) that form the framework for the management of the environment in which Beach Energy operates. The EMP covers all activities undertaken by Beach Energy in Australia including: exploration, drilling and well operations, and production.

Beach Energy conducts periodic environmental audits to assess the appropriateness of the EMP to meeting Beach’s policy, legislative requirements and environmental objective commitments and whether the EMP has been properly implemented and maintained.

7.4 Job Safety Analysis and Permit to Work

Job Safety Analysis (JSA) is a process used to identify hazards associated with a job, by assessing the risks and implementing control measures to ensure the job can be conducted in a safe manner. Beach Energy conducts JSAs for tasks where a work procedure does not exist, where the task has not previously been conducted by the personnel assigned to the task, or where additional hazards are present.

Beach Energy operates a single use, multi-purpose Permit to Work (PTW) system covering all areas of operations. The purpose of this PTW procedure is to summarise the Beach safety control mechanism designed to identify hazards, assess risks and to prevent accidents associated with task specific activities requiring a Permit prior to the work commencing.

7.5 Induction and Training

Prior to the start of field operations all field personnel will be required to undertake an environmental induction to ensure they understand their role in protecting the environment. This induction will be part of a general induction process which also includes safety procedures. Site specific environmental requirements will be documented in the work program or work instruction.

A record of induction and attendees will be maintained.

7.6 Emergency Response and Contingency Planning

In the course of normal operations, there is always the potential for environmental incidents and accidents to occur. To manage these incidents, emergency response plans will be developed to guide actions to be taken to minimise the impacts of accidents and incidents. Emergency response plans will be reviewed and updated on a regular basis to incorporate new information arising from any incidents,

near misses and hazards and emergency response simulation training sessions. These plans will also include the facilitation of fire danger season restrictions and requirements.

Emergency response drills will also be undertaken at regular intervals to ensure that personnel are familiar with the plans and the types of emergencies to which it applies, and that there will be a rapid and effective response in the event of a real emergency occurring.

7.7 Environmental Monitoring and Audits

Ongoing monitoring and auditing of fracture stimulation operations will be undertaken to determine whether significant environmental risks are being managed, minimised and where reasonably possible, eliminated.

Monitoring programs will be designed to assess:

- compliance with regulatory requirements (particularly the Statement of Environmental Objectives)
- integrity of bunding and containment systems
- integrity of ponds and pond liners
- site contamination
- groundwater quality
- site revegetation following completion and any restoration
- potential future problems.

7.8 Incident Management, Recording and Corrective Actions

Beach and its contractors have a system in place to record environmental incidents, near misses and hazards, track the implementation and close out of corrective actions, and allow analysis of such incidents to identify areas requiring improvement. The system also provides a mechanism for recording 'reportable' incidents, as defined under the *Petroleum and Geothermal Energy Act 2000* and associated regulations.

7.9 Reporting

Internal and external reporting procedures will be implemented to ensure that environmental issues and / or incidents are appropriately responded to. A key component of the internal reporting will be contractors' progress and incident reports to Beach.

External reporting (e.g. incidents, annual reports) will be carried out in accordance with Petroleum and Geothermal Energy Act requirements and the SEO. Annual reports are available for public viewing on the DMITRE website.

8 Stakeholder Consultation

Effective consultation allows for an exchange of information and provides an opportunity to promote understanding and resolution of competing interests.

Beach Energy is committed to maintaining effective communication and good relations with all stakeholders. Beach has been undertaking a program of consultation with directly affected parties and other stakeholders, as outlined below. Issues raised to date have been integrated into this report where relevant.

8.1 Public Consultation

Following submission of this EIR, DMITRE undertook an Environmental Significance Assessment and determined that the EIR and draft Fracture Stimulation of Deep Shale Gas and Tight Gas Targets in the Nappamerri Trough (Cooper Basin) SEO required a 30 business day public consultation process. The public consultation period was open from 16 April 2012 until close of business 28 May 2012. The submissions received during the public consultation period are contained in Appendix C, along with Beach's responses. Beach will continue to consult with stakeholders as the fracture stimulation operations progress, to ensure that all potential concerns are identified and appropriately addressed. Stakeholder correspondence will be registered and documented to ensure that issues are appropriately addressed.

8.2 Key Stakeholder Consultation

Beach held meetings with relevant stakeholders to present a description of the project and discuss potential environmental impacts and mitigation strategies. Stakeholders were invited to attend meetings in either Adelaide and/or Innamincka on 17 and 20 February 2012 respectively.

The following table identifies the key stakeholders and number of attendees at the meetings. Stakeholders were given two weeks to submit any comments on the presentation to be addressed in the EIR and SEO prior to formal submission to DMITRE. A written response was received from Conservation Council of SA.

Issues raised at the stakeholder meetings, and the sections of the EIR which relate to these topics, are provided below.

Well integrity:
- Section 5.2 (p.44)
- Section 6.1.1 (p.58)
- Table 14 (p.74)

Aquifer and groundwater quality:
- Table 9 (p.33)
- Section 4.2.5.2 (Water Quality p.38)

Aquifer use and future beneficial use of Beach bores by third parties:
- Section 4.2.5.2 (Groundwater Use and Well Locations, p.38)
- Figure 16
- Section 5.9 (p.55)
- Section 6.1.7 (p.64)
- Section 6.5.7 (pp.71 &72)
- Table 14 (p.75)
- Use of bores by third parties is beyond the scope of the EIR and will require discussion with the appropriate regulator.

Monitoring frequency, processes and procedures for ponds and groundwater:
- Section 5.8 (p.54)
- Section 6.1.7 (p.64)

- Section 6.2 (p.65)
- Section 6.5.7 (p.71)
- Table 14 (pp.76, 77 and 79 - ponds, p.75 - groundwater)

Chemicals in fracture stimulation fluids:

- Section 5.4 (p.48)
- Appendix A (p.97)

Contractor accommodation in Innamincka and secure storage of equipment:

- Section 5.3.1 (p.47 – Contractors camps on site)
- Section 6.5.7 (p.72) increased utilisation of Innamincka – expect occasional use from sampling and monitoring crews and visits by Beach representatives.

Frequency of crew movements / flights:

- Section 5.3.1 (p.48) stimulation campaign for 3-4 wells will take 6-8 weeks. Discussed at meeting: 1 flight per week either into Moomba or Innamincka during stimulation work. Break between stimulation campaigns for 3-4 months. Flights associated with ongoing drilling activities will continue during the break between stimulation activities.

Unsuitability of Innamincka airstrip for wet weather:

- During wet weather alternative arrangements are made utilising Moomba all-weather strip and helicopter services where required.
- Section 6.5.7 (p.72), potential for improved infrastructure if successful.

Impacts of traffic on roads:

- Section 6.5.1 (p.70) and Table 14 (p.81)

Greenhouse gas emissions and NGER reporting methods

- Section 6.5.3 (p.70) and Table 14 (p.80)

Fencing of ponds and potential impacts on fauna:

- Section 5.8 (p.54)
- Section 6.2 (p.65)
- Section 6.4 (p.68)
- Section 6.5.7 (p.71)
- Table 14 (p.79)

Table 16: Summary of stakeholder consultation

Organisation / Agency	Consultation method(s)	Accepted Invitation
State Government Departments		
Department for Manufacturing, Innovation, Trade, Resources and Energy (DMITRE)	Adelaide Meeting 17 February 2012	Yes, 7 attendees
Environment Protection Authority (EPA)	Adelaide Meeting 17 February 2012	Yes, 2 attendees
Department for Environment and Natural Resources (DENR)	Adelaide and Innamincka 17 & 20 February 2012	Yes, 3 attendees
Department for Water (DFW)	Adelaide Meeting 17 February 2012	Yes, 2 attendees
Aboriginal Heritage Branch, Aboriginal Affairs & Reconciliation Division of the SA Department of the Premier and Cabinet (DPC)	Adelaide Meeting 17 February 2012	Yes, 1 attendee
Department for Planning and Local Government (DPLG)	Adelaide Meeting 17 February 2012	No
Department of Planning, Transport and Infrastructure (DPTI)	Adelaide Meeting 17 February 2012	Yes, 1 attendee

Organisation / Agency	Consultation method(s)	Accepted Invitation
Other Government Bodies		
SA Arid Lands (SAAL) Natural Resources Management Board	Adelaide Meeting 17 February 2012	Yes, 2 attendees
Outback Communities Authority	Adelaide Meeting 17 February 2012	No
Lake Eyre Basin Community Advisory Committee	Adelaide Meeting 17 February 2012	Yes, 1 attendee
Cooper Creek Catchment Committee	Adelaide Meeting 17 February 2012	Yes, 1 attendee
Great Artesian Basin Coordinating Committee	Adelaide Meeting 17 February 2012	Yes, 1 attendee
Landholders		
Innamincka Station	Innamincka Meeting 20 February 2012	Yes, 1 attendee
Kidman and Co. Ltd	Adelaide and Innamincka 17 & 20 February 2012	No. Beach met with Kidman and Co. to discuss future shale gas projects on 11 January 2012.
Gidgealpa Station	Adelaide and Innamincka 17 & 20 February 2012	Yes, 1 attendee
Cordillo Downs Station	Innamincka Meeting 20 February 2012	Yes, 1 attendee
Local Community		
Innamincka residents and Innamincka Progress Association	Innamincka Meeting 20 February 2012	Yes, 8 attendees
Native Title / Heritage		
Yandruwandha/Yawarrawarrka Native Title Claimants	Adelaide Meeting 17 February 2012	No. Planning to present at next Yandruwandha/Yawarrawarrka meeting.
SA Native Title Service	Adelaide Meeting 17 February 2012	Yes, 1 attendee
Petroleum, Pipeline and Mining Tenement Holders / Operators		
Santos	Adelaide Meeting 17 February 2012	Yes, 3 attendees
Epic Energy	Adelaide Meeting 17 February 2012	No
Geodynamics Ltd	Adelaide Meeting 17 February 2012	No
Clean Energy Australia	Adelaide Meeting 17 February 2012	No
Origin Energy	Adelaide Meeting 17 February 2012	No
TC Development Corporation	Adelaide Meeting 17 February 2012	No
Osiris Energy Ltd	Adelaide Meeting 17 February 2012	Yes, 1 attendee
Other		
Conservation Council of South Australia	Adelaide Meeting 17 February 2012	Yes, 1 attendee
Wilderness Society	Adelaide Meeting 17 February 2012	No
Nature Foundation SA	Adelaide Meeting 17 February 2012	Yes, 1 attendee

Organisation / Agency	Consultation method(s)	Accepted Invitation
SA Farmers Federation	Adelaide Meeting 17 February 2012	No
SA Chamber of Mines and Energy	Adelaide Meeting 17 February 2012	Yes, 1 attendee

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10 Abbreviations and Glossary

ADG Code	Australian Dangerous Goods Code
aeolian	Carried, deposited or eroded by the wind.
ANZECC	Australian and New Zealand Environment and Conservation Council
aquitard	A bed of low permeability adjacent to an aquifer
AS 1940	Australian Standard *AS 1940 Storage and Handling of Flammable and Combustible Liquids*
basin-centred gas	Regionally pervasive gas accumulation in the centre of a hydrocarbon-rich basin that exhibits low permeability, abnormal pressure and gas saturation
bbl	Barrels (1 bbl = 159 litres)
BDBSA	Biological Databases of South Australia
biocide	Chemical compound that can kill living organisms (typically targeted at microorganisms)
BoM	Bureau of Meteorology
borehole	A narrow shaft bored into the ground
borrow pit	Surface excavation for the extraction of materials such as sand or clay.
BTEX	Benzene, toluene, ethylbenzene, xylene
bund	An earth, rock or concrete wall constructed to prevent the inflow or outflow of liquids.
casing annulus	Space between the casing and any piping, tubing or casing surrounding it
casing string	A long section of connected oilfield pipe that is lowered into a wellbore and cemented into place
cement bond log	The output from an acoustic tool that is lowered down an oil or gas well to evaluate the integrity of the bond of the cement to the casing and formation
coring	The process of cutting out a long cylindrical section of rock, known as a core sample or core, from a geological formation by core drilling
coiled tubing	A long, continuous length of pipe wound on a spool. The pipe is straightened prior to pushing into a wellbore and rewound to coil the pipe back onto the transport and storage spool
coiled tubing unit	The package of equipment required to run a coiled tubing operation. Basic components include the coiled tubing reel to store and transport the coiled tubing string, the injector head to provide the tractive effort to run and retrieve the coiled tubing string, the control cabin and the power pack that generates the power required by the other components.
continuous play	A gas reservoir where the reservoir rock is charged with gas everywhere, rather than being concentrated in conventional traps
conventional gas	Natural gas trapped in underground structures in highly permeable sandstones
ºC	Degrees Centigrade
DEH	Department for Environment and Heritage (South Australia) (now DENR)
DENR	Department for Environment and Natural Resources (South Australia) (known as DEWNR from 1 July 2012)
DEWHA	Department of the Environment, Water, Heritage and the Arts (Commonwealth) (now DSEWPC)
DEWNR	Department of Environment, Water and Natural Resources (South Australia)
DFW	Department for Water (South Australia) (part of DEWNR as of 1 July 2012)
DMITRE	Department for Manufacturing, Innovation, Trade, Resources and Energy (formerly PIRSA)
DSEWPC	Department of Sustainability, Environment, Water, Population and Communities
EIR	Environmental Impact Report prepared in accordance with Section 97 of the South Australian *Petroleum and Geothermal Energy Act 2000* and Regulation 10

EMP	Environmental Management Plan
EMS	Environmental Management System
EPA	Environment Protection Authority (South Australia)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
ephemeral	Existing for only a short time, often dependent upon climatic influences.
flowback	Fluids that are injected during fracture stimulation and flow back up the well from the reservoir to the surface after the pressure is released
forb	A herbaceous flowering plant (not including grasses, sedges or rushes)
fracturing fluids	The mixture of water and additives injected into a well during fracture stimulation
Gathering line	A pipeline used to relay fluids such as raw gas, condensate or oil from a well to a processing plant.
GAB	Great Artesian Basin
Gibber	Small to medium weathered rounded stones that form a relatively flat extensive pavements on plains and gentle slopes. The narrow spaces between stones have soil infill. The stones are concentrated on the surface by their gradual downward movement as the soil that once separated them in the vertical dimension has been removed by wind and gentle water erosion.
GIS	Geographic Information System
GL	gigalitre (10^9 litres)
H	hour
ha	hectares
kL	kilolitre (10^3 litres)
km	kilometre
km/h	kilometres per hour
L/s	litres per second
lithology	Description of the physical characteristics of a rock such as colour, texture, grain size or composition
LPG	Liquified Petroleum Gas
m	metre
m^3	cubic metre (=10^3 litres or one kilolitre)
ML	megalitre (10^6 litres)
microseismic monitoring	The passive observation of very small-scale seismic events which occur in the ground as a result of human activities or industrial processes such as mining, oil and gas production, enhanced geothermal operations or underground gas storage
Native Vegetation Council	A council established under the South Australian *Native Vegetation Act 1991* to assess vegetation clearance applications.
NGER Act	*National Greenhouse and Energy Reporting Act 2007* (Cth)
NGERS	National Greenhouse and Energy Reporting System
NORM	Naturally Occurring Radioactive Materials
NPW Act	*National Parks and Wildlife Act 1972* (South Australia)
over pressure	Subsurface pressure that is abnormally high, exceeding hydrostatic pressure at a given depth
PEL	Petroleum Exploration Licence
perforating	The process of punching holes in the casing or liner of an oil or gas well to connect it to the reservoir
permeability	A measure of the ease of flow of fluids through a rock
Permian	And all other geological age terms

PFW	Produced Formation Water
PIRSA	Primary Industries and Resources, South Australia (now DMITRE)
ppm	Parts per million
production fluid	The mixture of oil, gas and water that flows to the surface of an oil or gas well from a reservoir
proppant	Particles (e.g. sand grains, resin-coated sand or high-strength ceramic material) mixed with fracturing fluid to hold fractures open after a fracture stimulation treatment
psi	Pounds per square inch (a unit of pressure)
Ramsar wetland	A Wetland of International Importance listed under the Ramsar Convention (held in Ramsar, Iran 1971).
ripping	The use of machinery to rake or shallow plough soil to relieve compaction and aerate soil.
RNE	Register of the National Estate
SEO	Statement of Environmental Objectives
stimulation	Fracture stimulation of a well, which involves pumping fluid, largely water, at high pressure to create or enhance fractures in the rock and increase permeability in the reservoir.
stratigraphy	The study of rock layers and layering (stratification)
tectonic	Relating to, causing, or resulting from structural deformation of the earth's crust
tight gas	Natural gas which is difficult to access because of the low permeability of the rock containing the gas
tiltmeter	An instrument used to measure slight changes in the inclination of the earth's surface
unconventional gas	Natural gas that is trapped in lower permeability reservoirs, rather than on underground structures such as anticlines and highly permeable sandstones
viscosifiers	An additive that increases the viscosity of a fluid. Viscosity of a fluid is its resistance to flow, or in everyday terms, its “thickness”
wellhead	The part of an oil or gas well which terminates at the surface, where oil or gas can be withdrawn.
wireline unit	The equipment used to lower a wire or cable into an oil or gas well to conduct operations in the well
zone	An interval or unit of rock differentiated from surrounding rocks on the basis of its fossil content or other features, such as faults or fractures. Often used to describe a layer of reservoir rock that contains oil or gas

Appendix A

Listing of Fracturing Additives and Constituents

1 Introduction

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

As discussed in Section 3 of the EIR, Halliburton information is used to exemplify the makeup of a typical fracturing fluid. Detailed information on additives that may be used by other fracture stimulation providers in deep fracturing operations in Australia in the future is not available at this stage.

2 Typical Deep Fracturing Formulation (Halliburton Australia)

The following information has been obtained from Halliburton[3], and is based on a typical fracture stimulation formulation for deep wells in the Cooper Basin.

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

2.1 Fracturing Fluid Additives

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

Table A1: Fracturing fluid additives

Product Name	Additive	Purpose	Concentration (within stage injected)	Indicative overall % in total fracturing fluid (Holdfast-1)
100 Mesh Sand, 100 Mesh Premium, 30/50 Premium, 40/70 Premium	Proppant	Holds open fracture to allow oil and gas to flow to well	0.25 - 10 lbs/gal	2.3%
15% Hydrochloric Acid (HCl)	Acid/Solvent	Removes scale and cleans wellbore prior to fracturing treatment	1000-5000 gal run ahead of frac treatment	0.19%
Acetic Acid	Buffer/Acid Additive	Acid used to adjust the pH of the base fluid and Iron control additive in acid	<0.2 gal/ 1000 gal and 5 - 20 gal/1000 gal of acid	0.02%
BE-6™	Biocide	Prevents or limits growth of bacteria that can cause formation of hydrogen sulfide and can physically plug flow of oil and gas into the well	0.15 lbs/1000 gal	0.0001%
BE-9™	Biocide	Prevents or limits growth of bacteria that can cause formation of hydrogen sulfide and can physically plug flow of oil and gas into the well	0.25 - 0.75 gal/1000 gal	0.05%
Caustic Soda	Buffer	Used to adjust the pH of the base fluid	0.2 - 2 gal/1000 gal	0.01%

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

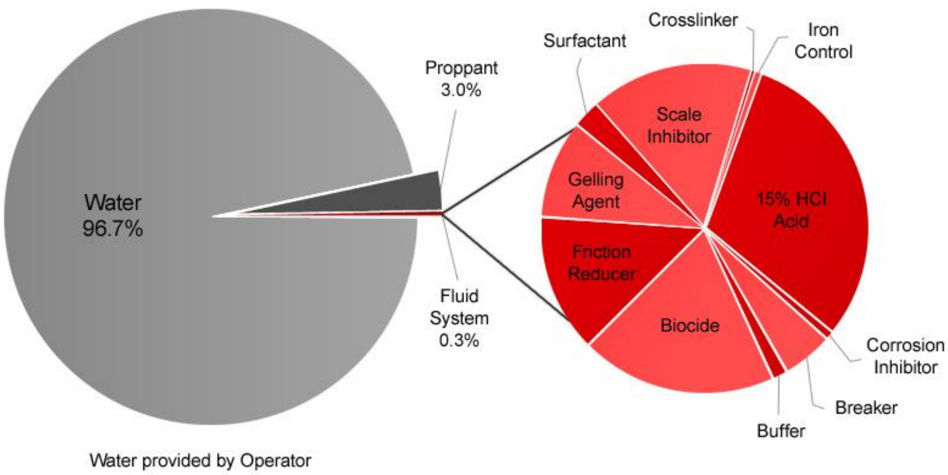
Product Name	Additive	Purpose	Concentration (within stage injected)	Indicative overall % in total fracturing fluid (Holdfast-1)
CL-28M™	Crosslink Agent	A delayed crosslinker for the gelling agent.	0.3 -1.1 gal/1000 gal	0.03%
FE-2™	Iron Control Agent	Helps to sequester dissolved iron in spent acid	5 -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

* Not used in the Holdfast-1 fracturing

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

2.2 Indicative Overall Percentage of Additives

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



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

2.3 Constituents

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

Table A2: Halliburton listing of constituents in fracturing additives

Constituent Name	Generic Name	CAS Number	Common Use	Hazardous as Appears on MSDS
1-(Benzyl) quinolinium Chloride	Quaternary Ammonium Salt	15619-48-4	Industrial and Commercial Disinfectant	Yes
2-Bromo-2-nitro-1,3-propanediol	Bronopol	52-51-7	Anti-Bacterial Soap, Skin Cleansing (Wipes), Hand Wash and Body Shampoo	Yes
Acetic Acid	Organic Acid	64-19-7	Processed Fruit, Cheese, Meat and Poultry	Yes
Acid Red 1	Red Dye	3734-67-6	Aloe and Olive Oil Cream, Stainless Steel Polish, FDA Approved Colorant, Industrial Buffer Solution	No
Acid Red 27	Red Dye	915-67-3	Laboratory Dye, Industrial Buffer Solution	No
Acid Violet 12	Violet Dye	6625-46-3	Air Freshener, Commercial pH Indicator Solution	No
Acrylate Polymer	Acrylate Polymer	*	No Common Product Uses Identified	No
Alcohol	Alcohol	*	Commercial Defoamer	No
Alcohols, C12-C16, Ethoxylated	Alcohols, Ethoxylated	68551-12-2	Car Wash Liquid, Laundry Stain Remover, Air Freshener	No
Aldehyde	Aldehyde	*	Non-Alcoholic Beverages, Ice Cream, Candy, Baked Goods, Chewing Gum	Yes
Alkylphenols	Alkylphenols	*	Metal Soldering Flux, Commercial/Industrial Cleaners and Degreasers	No
Amines, Coco Alkyl, Ethoxylated	Ethoxylated Amine	61791-14-8	Commercial Bathroom Cleaner, Medical Rinsing Solution, Photography Printer Ink	No
Ammonium Phosphate	Inorganic salt	7722-76-1	Milk Products	No
Ammonium Sulfate	Inorganic Salt	7783-20-2	Lawn Insecticide, Fertilizer, Fire Extinguishing Agent, Insulation, Body Wash, Caramel Food Coloring Agent	Yes
Borate Salt	Borate Salt	*	Agricultural Plant Food/Fertilizer, Industrial Glass Manufacturing Additive	Yes
Chlorous Acid, Sodium Salt	Inorganic Salt	7758-19-2	Food Additive	Yes
Citric Acid	Organic Acid	77-92-9	Fruit Juice, Dishwasher Cleaner, All Purpose Cleaner, Hand Soap	Yes
Crystalline Silica, Quartz	Silica	14808-60-7	Cat Litter, Tile Mortar, Arts & Crafts Ceramic Glaze	Yes
Disodium Octaborate Tetrahydrate	Inorganic Salt	12008-41-2	Wood Preservative, Agricultural Pesticide	Yes
Ether Compound	Ether Compound	*	Air Freshener, Food Flavoring Agents	No
Ethylene Glycol Monobutyl Ether	Glycol Ether	111-76-2	Paint Removal Gel, Citrus Household Cleaner, Sterilizing Wipes, Commercial Lubricating Oil	Yes
Fatty Acids, Tall Oil	Fatty Acids, Tall Oil	61790-12-3	Car Polish, Industrial Hand Cleaner	No

Constituent Name	Generic Name	CAS Number	Common Use	Hazardous as Appears on MSDS
Glycerine	Glycerine	56-81-5	Laundry Stain Remover, Antimicrobial Soap, Toothpaste, Lipstick	No
Guar Gum Derivative	Guar Gum Derivative	*	Fabric Softener, Hair Straightening Aid, Shampoo, Body Lotion, Shaving Cream	Yes
Hydrochloric Acid	Inorganic Acid	7647-01-0	Table Olives, Unripened Cheese, Cottage Cheese	Yes
Isopropanol	Alcohol	67-63-0	Tape Head Cleaner, Hops Extract used for Beer, Air Freshener	Yes
Methanol	Alcohol	67-56-1	Furniture Refinisher, Liquid Hand Soap, Windshield Washer Concentrate, Hops Extract	Yes
Naphthenic Acid Ethoxylated	Cyclo Alkyl Acid Ethoxylate	68410-62-8	No Common Product Uses Identified	No
Polyacrylamide Copolymer	Polyacrylamide Copolymer	*	Mulch Binder/Dust Control Agent, Moisture Control Agent for Gardens, Emulsion Agent in Industrial Water Treatment	No
Polyacrylate	Polyacrylate	*	Laundry Detergent, Glass Cleaning Solution, Dishwashing Detergent	Yes
Polyacrylate	Polyacrylate	*	Paint Hardener, Detergent, Children's Bathwater Additive, Food Defoaming Agent	No
Polyethoxylated Fatty Amine Salt	Ethoxylated Amine	61791-26-2	Toilet Bowl Cleaner, Car Glass Polish	No
Proprietary	Proprietary	*	Hair Colorant, After Shave, Fabric Softener, Deodorant, Air Freshener	No
Proprietary	Proprietary	*	Floor Soap, Shampoo, Car Shampoo, Nail Polish Remover, Insect Repellent	No
Proprietary	Proprietary	*	Air Freshener, Fragrance, Scent for Soap and Household Cleaning Products	No
Proprietary	Proprietary	*	Medical Disinfectant, Automotive Rust Remover, Commercial Floor Cleaner	No
Proprietary	Proprietary	*	All-Purpose Household Cleaner, Fabric Softener, Pool Algae Control, Disinfecting First Aid Wipes	No
Proprietary	Proprietary	*	Laundry Detergent, Dishwashing Liquid, Toothpaste, Pool pH Adjustment Liquid	No
Proprietary	Proprietary	*	Air Freshener, Perfume Oil, Flea Repellant, Insect Repelling Candle	No
Proprietary	Proprietary	*	Deodorant, Body Hair Bleach, Leather Cleaner, First Aid Burn Treatment	No
Proprietary	Proprietary	*	Hydraulic Clutch Fluid, Brake Fluid	No
Quaternary Ammonium Salt	Quaternary Ammonium Salt	*	Industrial and Commercial Water Acidity Neutralizing Solution	Yes
Silicate	Silicate	*	Industrial Joint Compound, Industrial Construction Thickening Agent	No
Silica Gel	Silica	112926-00-8	Mouthwash, Toothpaste, Powdered Sugars	No
Sodium Carbonate	Carbonate	497-19-8	Laundry Detergent, Dishwashing Liquid, Toothpaste, Pool pH Additive	No
Sodium Chloride	Inorganic Salt	7647-14-5	Concentrations greater than 1%: Food Grade Salt, Laundry Detergent, Aquarium Fish Medication, Ice Melting Product	Yes
Sodium Hydroxide	Caustic Soda	1310-73-2	Laundry Detergent, Toothpaste, Cocoa, Milk Products , Chocolate	Yes

Constituent Name	Generic Name	CAS Number	Common Use	Hazardous as Appears on MSDS
Sodium Iodide	Inorganic Salt	7681-82-5	Light Bulbs, Infant Food	No
Sodium Sulfate	Sulfate	7757-82-6	Dishwasher Detergent, Laundry Detergent, Liquid Hand Soap, Toothpaste	No
Terpene	Terpene	*	Laundry Soap, Furniture Oil, Thickened Stripper for Grease, Paint, Ink, and Gum Removal	Yes
Tributyltetradecylphos-phonium Chloride	Organic Phosphonium Salt	81741-28-8	Industrial Water Treatment Agent	Yes
Water	Water	7732-18-5	Water Present in Additives (Not Water Used as Carrier Fluid)	No

Notes:

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

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

2.4 Material Safety Data Sheets

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

2.5 Further Information

Additional information on fracture stimulation additives relevant to Nappamerri Trough fracture stimulation activities is available from the following sources:

Government web sites:

DMITRE	http://www.petroleum.dmitre.sa.gov.au
DERM (for Coal Seam Gas)	http://www.derm.qld.gov.au/environmental_management/coal-seam-gas/fraccing.html

Fracture stimulation providers:

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

Industry bodies:

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

Appendix B

Environmental Risk Assessment Tables

Environmental Risk Assessment Tables

The risk assessment that is summarised in the EIR (Section 6.6) uses Beach Energy's risk matrix and definitions for consequences and likelihood, as defined in Beach Energy HSE Procedure 04 – F04. The risk matrix and the consequence and likelihood definitions are outlined below.

Definition of Consequences

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

Table 1: Consequence definition

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

Definition of Likelihood

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

Table 2: Likelihood definition

Likelihood of the Consequences selected occurring

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

Characterisation of Risk

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

Table 3: Environmental risk matrix

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

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

Risk Assessment Summary Table

A summary of the level of environmental risk for fracture stimulation activities is provided in Table 14 in the EIR. The level of risk has been assessed based on the assumption that the management measures outlined in the EIR will be in place.

Appendix C

Public Consultation Comments and Responses

Note: Where 'EIR' and 'SEO' are used through this Appendix, unless otherwise specified, EIR refers to the *EIR Fracture Stimulation of Deep Shale and Tight Gas Targets in the Nappamerri Trough (Cooper Basin), South Australia* (this document), and SEO refers to the *SEO Fracture Stimulation of Deep Shale and Tight Gas Targets in the Nappamerri Trough (Cooper Basin), South Australia* (Beach 2012).

Table C1: Environmental Impact Report – Public Consultation Comments and Responses

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	Beach Comment / Change
Title of Document	Department for Water (DFW)	*Comment 1: Include Nappamerri Trough in the title of the document*	Amended.
Generic	DFW	*Comment 2: Number and specific location of exploration and appraisal wells and distance to existing bores and groundwater dependent ecosystems*	The EIR identifies risks associated with fracture stimulation activities in the Nappamerri Trough area. The SEO documents environmental objectives and assessment criteria, based on the risks identified in the EIR. These objectives are common to fracture stimulation activities throughout the area and provide the environmental framework to conduct environmentally responsible activities. The number of wells, and their locations, has not been specified in these documents as the extent and location of exploration and appraisal will be dictated by drilling and stimulation results. As identified in Section 1.3 and further in Section 2.1.4, site specific technical and environmental details for individual well sites are provided under activity notification and approval requirements of the Act and Regulations (Section 74(3), Reg 18 and 19). These submissions must demonstrate compliance with the objectives identified in the relevant SEO. DMITRE receive the notification and review to ensure compliance. Figure 16 identifies the location of existing bores and the Cooper Creek. Assessment of specific well activities against the SEO will address location of proposed groundwater withdrawal in relation to existing bores and groundwater dependent ecosystems (SEO Table 1, Objective 2).
Section 6.1.7	DFW	*Comment 3: Drawdown on aquifers may be 1-5 m, assumptions and radial extent not provided*	The preliminary hydrogeological calculations discussed in Section 6.1.7 identify that if water bores were located within 1 to 5 km of an existing stakeholder bore and were to access the same aquifer interval then there may be potential for drawdown to be noticeable. If water bores are to be drilled within 5 km of an existing bore, further detailed assessment of drawdown potential, together with strategies to avoid / monitor / mitigate these impacts, will be undertaken and reviewed with the owner of the bore in question. This is identified in Table 14 in the EIR (p. 75 Water supply / use) where water supply wells are to be reviewed to ensure that use does not impact on existing users and Objective 2 of Table 1 in the SEO where further clarification has been added.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	Beach Comment / Change
			As per comment 2, the site specific assessment against the SEO will identify instances where impacts may occur and DMITRE will be advised during the activity notification process of the strategies employed to avoid / monitor / mitigate impacts.
Section 6.1.7	DFW	*Comment 4: Provide contingency measures where existing users impacted*	Section 6.1.7 of the EIR outlines that where impacts are identified, alternative water supply options would be pursued and impacts on existing users would be made good. Alternative water could be sourced from existing water bores and make good measures could include providing an interim alternative water source, setting pumps deeper for land holders (if appropriate and possible) through to providing a new bore. The appropriate solution would be discussed between Beach and the affected stakeholder and approvals sought from the appropriate regulator as required.
Section 5.9	DFW	*Comment 5: Any water well or water monitoring bore will require a well construction permit*	The following sentence has been incorporated in Section 5.9, *'A well construction permit from the Department for Water will be required for any water well drilled, including bores installed to monitor aquifers, irrespective of licensing requirements.'* The SEO has also been amended (Table 1 Objective 2 'Comments').
Figures 10, 11, 13 and 14	DFW	*Comment 6: Figures too small to be read*	The figures are sized at A3 in the PDF document and can be read if printed at full size or when zoomed in on-screen.
Section 4.2.4.1	DFW	*Comment 7: Volume of co-produced water to be reported and may require licence*	Produced hydrocarbons and co-produced water are reported to DMITRE. If water is co-produced from the target intervals it is likely to indicate a non-prospective outcome at that depth in the well or in that area of the permit. In this eventuality, testing or production would be ceased and the zone and / or well isolated and abandoned.
Table 9	DFW	*Comment 8: Salinity range of Eyre Formation*	Table 9 of the EIR has been adjusted to incorporate DFW indicated range.
General	DFW	*Comment 9: Misnumbered – no Comment 9 provided*	No response required.
General	DFW	*Comment 10: Multiple wells may be drilled per year with requirement for 15-24 ML per well*	Section 6.1.7 documents that the exploration and appraisal wells envisaged in the EIR will be many kilometres apart. Beach is emplacing a baseline water bore monitoring program to understand current fluid levels in water bores across the area, water compositions (refer SEO Table 1 Objective 3 'Guide to How' - Monitoring) and confirm that the objective to minimise impact on groundwater use is achieved. As indicated in Section 5.9 of the EIR, if exploration is successful, alternative water sources including recycling of recovered stimulation water, recycling of produced water from other hydrocarbon production activities in the basin, or licensing of water from the GAB is likely to be required for the development of the resources.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	Beach Comment / Change
		Water bore locations, lithology and aquifer details to be provided	Water bore details (including monitoring bores) will be provided to the Department for Water through the well construction permit process .
General	Conservation Council	<u>*Bullet point 1*</u>*: Environment and increase in global greenhouse emissions*	It is not the purpose of this EIR to put forth a general discussion on the environment and global greenhouse emissions. This is well covered in literature. The specifics of reducing greenhouse emissions related to fracture stimulation are covered in Section 6.5.3, Table 14 and in the SEO Table 1 Objective 8. These include: ▪ Production testing (flaring) to be kept to the minimum length of time necessary to establish resource and production parameters. ▪ Flowback to be directed to separation equipment as soon as practicable to minimise venting of gas. ▪ Pressure testing of surface flowlines to ensure integrity of pipework. ▪ Monitoring well site for potential fugitive emissions.
Section 6.5.3	Conservation Council	<u>*Bullet point 2*</u>*: Greenhouse gas pathways*	Refer Section 6.5.3. Well bore design, construction and integrity (further discussed in Sections 5.2 and 6.1.1) are important in isolating gas bearing intervals from aquifers and prevent gas migration along the wellbore. Emissions associated with flowback will be minimised by diverting to separation equipment as soon as practicable. Once diverted to the separator, recovered gas is flared to minimise greenhouse gas intensity. Due to the exploration and appraisal nature of these wells, connection to gas gathering systems during early testing is not a viable solution (Section 5.7).
Section 6.5.3	Conservation Council	<u>*Bullet point 3*</u>*: Techniques to estimate greenhouse gas emissions*	Beach will report on its greenhouse gas emissions for those activities for which it has operational control in accordance with the National Greenhouse Reporting System (NGERS), the requirements of the *National Greenhouse and Energy Reporting Act 2007* (Cth) and the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* (Measurement Determination). Where Beach engages a contractor to undertake work, such as drilling and / or fracture stimulation activities, and that contractor is deemed under the NGERS to have operational control, that contractor will be required to report on the greenhouse gas emissions associated with those activities in accordance with the NGERS and the Measurement Determination. The techniques used by Beach in measuring its greenhouse gas emissions arising from those activities for which it has operational control are derived from and comply with the Measurement Determination, as amended from time to time.
Section 5.7	Conservation Council	<u>*Bullet point 4*</u>*: Metering during the flow back period*	Refer Section 5.7. The initial flowback is predominantly fracture stimulation fluid and this is directed to the lined pit. As there may be some proppant or sand in the flow that may block metering equipment, the initial flowback production to the lined pit is typically estimated with coarse measurement methods.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	Beach Comment / Change
			Beach is investigating application of downhole gauges to assist in further refining estimates of gas and liquid components in the early time (trialled in the Holdfast-1 well in 2011, investigating gauge options for the current well design). Once gas is apparent, the well production is diverted to the separator where accurate flow measurements are made and samples are collected for the remainder of the production test.
Section 4.2.5.1	Conservation Council	*Bullet point 5: Changes to levels of natural gas detected in GAB aquifers due to cumulative natural gas activities*	As described in Section 4.2.5.1, gas and oil fluorescence is observed in the GAB aquifers in the area of interest. Gas readings obtained during the drilling of petroleum exploration wells in the area, indicate background gas readings, indicative of gas that has migrated from deeper source rocks through the geological strata as part of the natural hydrocarbon generation and accumulation process that occurs over geologic time. The wells drilled in the area date back more than 40 years, to the early years of exploration and development in the basin, through to the most recent 5 wells which were drilled between 2009 and 2012. Interpretation of this data would be inconclusive in relation to the extent or source of any variation.
Section 6.4	Conservation Council	*Bullet point 6: Fauna escape from lined pits*	Section 6.4 and Table 14 outline that fencing is erected around ponds to prevent stock and larger fauna from entering the ponds. In the pit construction process, the immediate area is cleared of vegetation reducing attraction of the area for smaller fauna. The slope of the internal wall is approximately 1 m fall per 2.5 m travel (roughly 22 degrees) which is sufficient to reduce attractiveness to birds (EIR Section 6.4 and Table 14). It is anticipated that smaller fauna will be able to ascend this grade of pond wall. Monitoring of the ponds for incursions is discussed in response to bullet point 7.
Table 14	Conservation Council	*Bullet point 7: Frequency of routine surveillance of ponds to detect incursions*	As identified in Section 5.7, describing flowback and production testing operations, one or more operators will visit sites on production test on a daily basis. These operators will also be responsible for visiting the sites during filling of the ponds on a daily basis to ensure water bores are pumping. Once testing is complete the operators will monitor the ponds and lease condition on a less frequent basis, initially weekly, but less frequently as pond levels reduce. It is not expected that leases would be visited less frequently than once per month unless the lease has been rehabilitated.
Table 14	Conservation Council	*Bullet point 8: Current fauna entrapment reporting procedures*	As indicated in Section 6.4 and Table 14, fauna entrapment in ponds is a very rare occurrence. Beach does not currently have a written procedure in place to specifically report faunal entrapment but has an incident reporting system to capture safety and environmental incidents which will capture fauna entrapment in ponds. A statement to this effect has been added to the SEO in Table 1 Objective 5 'Guide to How'.
Section 5.8	Conservation Council	*Bullet point 9: Area of footprint for each site*	As indicated in Section 5.8, four ponds roughly 50 m x 30 m x 3 m would be required. Allowing for sloping of the sides and bunding at the surface, the foot print of the four ponds would be roughly 200 m x 80 m or approximately 1.6 hectares per well site. Together with the drilling pad requirement of 1.3 hectares (130 m x 100 m) the area required will potentially be less than 3 hectares, 75% of the amount indicated in the EIR.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	Beach Comment / Change
Table 13	Conservation Council	*Bullet point 10: Flowback fluid disposal*	As described in Table 13 and Section 5.7, recovered fracture stimulation fluids will naturally evaporate in the lined ponds. Once the fluids have evaporated and the ponds dried, the liners will be recovered and disposed of at a licensed facility.
Table 14, Greenhouse Gas Emissions	Conservation Council	*General commentary: NGER reporting is not a management measure* *Greenhouse gas emissions monitoring and assessment discussion lacks meaningful content and should be addressed in a step by step manner* *Recent USA Green Completion requirements and objectives to minimise flaring*	Noted. Table 14 of the EIR (p.80) has been modified to make clear that this is a comment rather than a management measure. The EIR methodically outlines well design, construction and integrity (Section 5.2), fracture stimulation activities (Section 5.3) and monitoring (Section 5.5) to confirm that treatments are placed where desired, completion design (Section 5.6) and flowback and production testing (Section 5.7) which is flared as soon as possible to minimise emissions. In Section 6, the potential impacts associated with the activities are systematically addressed capturing the importance of the well design and construction and treatment monitoring in minimising potential for fugitive emissions to aquifers. Finally in Section 6.5.3 all these aspects are summarised, capturing that flow testing (and associated flaring) will be conducted for the minimum amount of time necessary to establish resource and production parameters. This flaring is the largest emission source of the activities and is accurately assessed. As discussed (response to bullet point 3 and 4) some gas is vented but techniques are applied to estimate the potential volumes and methods are adopted to minimise the length of time the well is produced to the lined pit prior to separation. The Green Completion objective is to have wells flow back to separation equipment from which gas is then directed to adjacent gathering networks rather than flared. The USA is fortunate to have a much more extensive legacy gathering network than Australia which enables ready connection of wells. Additionally, unconventional shale and tight gas fields in the USA are typically well beyond the exploration and appraisal stage and the practices being suggested are to mitigate emissions during larger scale development where many hundreds of rigs across the USA are developing shale gas. We neither have the infrastructure nor the scale of development that prompted the USA EPA to drive towards Green Completions. Although we are in the early stages of assessment, the practice of using separation equipment to capture gas is a first step and enables the gas to be flared rather than vented which significantly reduces greenhouse gas emissions. However, as discussed in Section 5.7, due to the exploration and appraisal nature of stimulating the deep shale and tight gas targets, there is uncertainty in gas productivity, recovery and composition. These need to be understood prior to constructing and installing pipelines and any necessary surface facilities such as metering, compression and processing that may be required to enter gas gathering pipelines in the region. In recognition of the comments put forward a management measure has been added to the EIR (Table 14 p.80) and the SEO (Table 1 Objective 8 'Comments') to investigate potential for connection to gas gathering systems once initial testing is complete and further testing is required for reserve definition.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	Beach Comment / Change
Table 14	Department of Environment and Natural Resources (DENR)	*Comment 1: Recommend bird deterrents employed to reduce risk of death or injury*	As described in Section 6.4, deterrent measures would be implemented to discourage bird presence at the pond sites. Table 14 (p.79 Interaction of fauna with storage ponds) has been modified to reiterate by incorporating, '*Bird deterrent measures will be introduced if bird mortality incidents are observed*.'
Section 4.2.4.1	Environment Protection Authority (EPA)	*Comment 1: Condensate production contingency plan*	Production and testing operations are covered by the Drilling and Well Operations SEO (Santos 2009) which covers storage and handling of petroleum liquids.
Section 4.2.5.2	EPA	*Comment 2: Report to DMITRE on investigation of alternative water sources*	Beach is actively investigating water management options. As indicated in Section 5.9 of the EIR, should exploration and appraisal be successful and the project moves to the development stage, alternative water sources are likely to be required. Beach and DMITRE have quarterly meetings to discuss activities in Beach operated areas and these present a forum for discussing the alternatives.
Section 5.4	EPA	*Comment 3: Disclosure of composition of fluid additives to DMITRE at activity notification stage, providing justification if BTEX present in additives*	Beach provides the details of volumes, pump rates, additives, concentrations and material safety data sheets to DMITRE as part of the notification of activity. As indicated in Section 5.4, in the context of the complete stimulation treatment stage, BTEX levels are below the levels that are required for drinking water guidelines. However suppliers and fracture stimulation contractors are working to ensure that levels of BTEX in fracturing fluids are reduced as far as practicable.
Section 5.5	EPA	*Comment 4: Review of microseismic results of monitoring fracture stimulation of horizontal wells before permitting ongoing horizontal drill and stimulation*	As indicated in Section 5.5, microseismic monitoring in the Cooper Basin will be largely utilised to optimise well orientation and understand production performance. The geological setting, stress properties in the rocks (as detailed in Section 4.2.4.1 and Figure 12) and separation of aquifer zones from the target reservoirs indicate that growth of induced fractures is likely to be confined to the Permian section, well below GAB aquifers. While Beach is keen to utilise microseismic to understand fracture orientation and well performance, there will be challenges in using this method in the Nappamerri Trough associated with: ▪ high downhole temperatures, exceeding current maximum tool temperatures if the gauges are set in close proximity to the target interval ▪ lack of sensitivity, if tools are hung higher in the observation well to avoid temperature they may be too distant from the generated fractures, and coals in the Toolachee Formation may limit transmission of seismic event waves to the tools ▪ lack of resolution, if analogue tools that are less temperature sensitive are used rather than digital tools (only 2 tools versus 8-16 tools, older technology).

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	Beach Comment / Change
			Beach will use best efforts to develop and implement microseismic diagnostics but re-asserts that due to the geomechanical properties and the separation distance the risk of fracture height growth towards sensitive receptors is low. DMITRE will be kept informed of our fracture monitoring program to determine the success of accessing resources in the strata but further drilling and stimulation should not be decided on this information, which may or may not be successfully obtained.
Section 5.5	EPA	*Comment 5: Disclosure of proprietary information on tracers to DMITRE*	Beach discloses the information available to it from the supplier. The service provider indicates that the chemicals are non-hazardous and, as outlined in Section 5.5, these are injected into the formation at trace concentration levels, less than 1 part per million. The returning concentration is typically less than a third of the injected concentration (Section 5.5 EIR, based on experience at Holdfast-1). The returning fluids are contained within the lined evaporation ponds.
Section 5.6	EPA	*Comment 6: Unexpected variation in gas composition may impact on well construction material and design posing a risk to well integrity*	The EIR and SEO are specific to the environmental risks and associated objectives identified from stimulation of deep shale and tight gas targets in the Nappamerri Trough. Well design and material selection have been carefully considered, as outlined in these documents, but are more appropriately covered under the Drilling and Well Operations SEO (Santos 2003 and 2009). A third party engineering firm and a corrosion consultant have been used to design the wells and select the appropriate casing and tubing material for the range of production streams that may be encountered in these wells based on observed gas compositions throughout the Nappamerri Trough.
Section 5.8	EPA	*Comment 7: Pond construction with suitable UV stabilised polyethylene liner, installed to manufacturer's recommendations, water balance and visual inspection of ponds*	As outlined in Section 6.2, a suitable UV stabilised polyethylene material will be used. It is recognised in the document that quality control during the construction phase is important for pond integrity and this aspect is identified in both the risk assessment and the SEO. Section 6.2 of the EIR has been modified to incorporate comments on the water balance approach for the short term ponds as follows, '*A water balance method, incorporating inflow rates, pond levels and evaporation (and the uncertainty associated with the measurements) can be used to identify potential seepage where the pond utilisation is short term. Where ponds are required for more than a year alternative leak detection methods may need to be employed.*' Table 14 (pp.76, 77, 78) has been adjusted to incorporate '*Water balance method used for leak detection (incorporating inflow, evaporation, fluid levels and measurement uncertainty)*' where management issues relate to pond operations.

Table C2: Statement of Environmental Objectives – Consultation Comments and Responses

SEO Section / Table	Stakeholder	Issues Raised or Comments Made	Beach Comment / Change
Title	Department for Water (DFW)	*Comment 1: Include Nappamerri Trough in the title*	Amended.
Table 1, Objective 2	DFW	*Comment 2: Impact on ground water dependent ecosystems*	Assessment criteria '*No impact on groundwater dependent ecosystems resulting from extraction of groundwater*' has been added to Objective 2. Comments in the 'Guide to How' have been expanded to incorporate options to access deeper aquifer sands and install a monitoring bore where water bores are close to waterholes.
Table 1, Objective 2	DFW	*Comment 3: Impact on existing bores within 5 km*	See DFW Comment 3 on EIR (concerning Section 6.1.7 of the EIR). Objective 2 'Guide to How' has been clarified to identify that new water bores drilled within 5 km of existing water bores are to require further assessment of potential impact to existing users and may require monitoring of the existing bore to confirm no adverse impacts.
Table 1, Objective 2	DFW	*In response to DFW EIR comment 5: Water well and aquifer monitoring bores require well construction permit*	A statement has been added to Objective 2 'Comments' to reflect the requirement for a well construction permit to be obtained for any water well and aquifer monitoring bore (as identified in EIR comments). A statement has also been added to Objective 2 'Comments' - '*Liaise with DFW to ensure appropriate authorisations are in place*' as identified in Section 5.9 of the EIR.
Table 1, Objective 2	DFW	*Comment 4: Location of exploration wells to be provided and approved*	Approval for exploration wells is regulated by DMITRE. The site specific activity notification process must demonstrate that the activity complies with this SEO which specifies that DFW well construction permits are required. The SEO outlines strategies to mitigate / avoid / monitor impacts when water bores are planned in proximity to other users and water holes.
Table 1, Objective 3	DFW	*Comment 5: Groundwater monitoring program to be reviewed*	Beach has consulted with independent ground water monitoring companies to develop a monitoring program for the area. Beach has discussed the program with bore owners in the area and is undertaking baseline fluid level and water chemistry assessments. Beach submits annual licence review documents where monitoring and surveys are reported. In addition DMITRE and Beach conduct quarterly reviews to discuss activities within Beach operated permits.
General	Conservation Council	*Bullet point 1: Include objective for open and transparent reporting*	Annual reports of activities are submitted to DMITRE and are on the public record. The annual report details where the licence holder has not complied with the objectives set out in the applicable SEO for the activities. Production information, subject to confidentiality periods is also available on the public record.
General	Conservation Council	*Bullet point 2: Actions that contribute to sustainability of SA*	The SEO outlines objectives related to specific petroleum activities such as drilling wells, fracture stimulation and production operations.

SEO Section / Table	Stakeholder	Issues Raised or Comments Made	Beach Comment / Change
			Broader company actions with respect to community and the environment are contained within our annual report to shareholders, are presented at our AGM and are maintained on our website. Beach's strategy is to fund programs that support children, the communities and environment in which we work and indigenous communities.
Table 1, Objective 8	Conservation Council	_Bullet point 3 and general comment:_ *Actions taken to prevent release of fugitive emissions* *Continual assessment of emissions*	Table 1 Objective 8 outlines how the objective to minimise greenhouse gas emissions can be achieved. Objective 8 has been modified to reflect that National Greenhouse and Energy Reporting (NGER) is not a method to reduce emissions and is not a specific assessment criterion. The NGER reference has been moved to 'Comments' and the 'Assessment Criteria' for air pollution and gas emissions now incorporate: ▪ No reasonable stakeholder complaint left unresolved ▪ No unplanned gas releases ▪ Well production diverted to flare as soon as practicable ▪ Well testing curtailed when test objectives are satisfied Additional "Guide to How" points in Objective 8 have been incorporated to minimise the period that flowback is not occurring through separation equipment and investigate potential for connection to facilities once initial testing is complete and further testing is required for reserve assessment. NGER requires continual assessment of emissions.
Table 1, Objective 8	Conservation Council	_Bullet point 4_: *The use of Green Completion practices*	Addressed in EIR commentary, Table 14, Greenhouse Gas Emissions, General Commentary. Specifically, the use of separation equipment to capture and flare gas, as detailed in the EIR and SEO, is consistent with the Green Completion process. As discussed, the context of the Australian industry as compared to the US needs to be understood. The green practices in the US are targeting reduction of emissions for development projects with much higher level of activities, where gas composition, resource and reserve potential are understood and gathering infrastructure is in place and readily accessible.
Table 1, Objectives 1 and 8	Conservation Council	_Bullet point 5_: *Proactive identification, monitoring and remedial action to stop fugitive emissions*	As identified in Objective 1, monitoring of stimulation injection pressures, where appropriate microseismic surveys and production volumes are noted as guides for picking up undesired flow between geological units. Objective 8 'Guide to How' addresses well monitoring during production testing to assess well and pipework integrity. Operators use gas detectors, for safety reasons, to alert them to the presence of fugitive gas. If present the operation is shut down and the leak is repaired.

SEO Section / Table	Stakeholder	Issues Raised or Comments Made	Beach Comment / Change
			Although not discussed in the EIR and SEO Beach is investigating emerging fibre optic technology to measure temperature along the length of the well bore (distributed temperature sensing). If appropriate trials will be run on vertical and horizontal wells that may assist further in determining where stimulation treatments are place and monitor for potential fugitive emissions along the wellbore behind pipe.
Table 1, Objective 8	Conservation Council	*Bullet point 6: Weekly inspection of facilities with infra-red equipment to observe potential leaks*	Beach is aware of using thermal imaging as an equipment monitoring technique and has two portable thermal cameras at its operating facilities in the Cooper Basin. The statement in Objective 8 'Guide to How' referring to monitoring well parameters captures options such as thermal techniques to identify sources of emissions.
Table 1, Objective 5	Conservation Council	*Bullet point 7: Reporting procedure for fauna entrapment*	A sentence has been added to Objective 5 'Guide to How' to indicate that fauna mortality in ponds is to be captured in the incident reporting system
Table 1, general	Conservation Council	*Bullet point 8 and general Reporting discussion: Seeking commitment to increased reporting of resource utilisation, emissions and environmental data*	SEOs outline objectives related to specific petroleum activities such as drilling wells, fracture stimulation and production operations. In this instance the SEO is specific to fracture stimulation. It identifies the objective to reduce emissions and guides comments / actions for achieving reduced emissions. Discussing broader company-wide environmental reporting policies is outside the scope of the document. Our commitment to conducting environmentally responsible exploration and production is contained within our corporate policies which are maintained on our website. Beach complies with all reporting requirements.
Table 1, Objective 5	Department for Environment and Natural resources (DENR)	*Comment 1: Recommend bird deterrents used around ponds*	Objective 5 'Guide to How' has been modified to incorporate the following, '*Bird deterrent measures introduced if bird mortality incidents are observed.*'
Table 2, Objective 3 bullet point 4	DENR	*Comment 2: Footnote 4 to identify impacts to listed flora, fauna and ecological communities under EPBC Act 1999 as a serious incident*	Rather than modify the footnote Beach has changed bullet point 4 in the table to expand the 'environmental risk' to 'risk of serious damage to environmental values whether or not those values are referred to in State or Commonwealth legislation' such that it now reads: *Any well incident or failure that threatens or poses an imminent risk to safety or a risk of serious damage to environmental values whether or not those values are referred to in State or Commonwealth legislation.*
Table 1, Objective 3	Environment Protection Authority (EPA)	*Comment from EIR: Water balance for pond seepage monitoring*	Objective 3 'Guide to How' 'Pond Integrity' has been modified to incorporate water balance model to monitor for potential seepage as follows: '*Water balance method used for leak detection (incorporating inflow, evaporation, fluid levels and measurement uncertainty)*'.

SEO Section / Table	Stakeholder	Issues Raised or Comments Made	Beach Comment / Change
Table1, Objective 1	Department for Manufacturing, Innovation, Trade, Resources and Energy (DMITRE)	*Comment 1: Geological / geomechanical risk assessment for stimulation to assess potential fracture extension*	Table 1, Objective 1 ‘Guide to How’ has been modified such that Fracture Stimulation Monitoring is now Fracture Stimulation Planning and Monitoring and incorporates the following: *Assessment of geological and geomechanical setting is undertaken during design of fracture stimulation treatments to avoid growth into undesired strata.*

STATEMENT OF ENVIRONMENTAL OBJECTIVES

Fracture Stimulation of Deep Shale Gas and Tight Gas Targets in the Nappamerri Trough (Cooper Basin), South Australia

Prepared by:

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and:

Beach Energy

[redacted]

A273B-Cooper Basin Fracture Stimulation SEO; Rev 1 / July 2012

Document Status

Version	***Purpose of Document***	***Orig***	***Review***	***Review Date***	***QA Review***	***Release Approval***	***Issue Date***
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Rev B	*Revised draft for review*	*MP/SM*	*SM*	*16 Mar 2012*			*16 Mar 2012*
Rev C	*Revised draft to accompany EIR RevG*	*RPS/Beach*	*SM*	*26 Mar 2012*			*26 Mar 2012*
Rev D	*Draft for issue to DMITRE*	*RPS/Beach*	*MP*	*27 Mar 2012*	*BW/SM*	*MP*	*27 Mar 2012*
Rev E	*Restructured by Beach & RPS*	*Beach/RPS*	*SM*	*2 Apr 2012*			
Rev F	*Revised draft for issue to DMITRE*	*Beach/RPS*	*MP*	*3 Apr 2012*	*SM*	*MP*	*3 Apr 2012*
Rev G	*Minor Beach edits*	*Beach*		*3 Apr 2012*			
Rev0	*Prepared for formal issue to DMITRE*	*Beach/RPS*	*SM/MP*	*5 Apr 2012*	*BW/SM*	*MP*	*5 Apr 2012*
Rev1	*Comments incorporated from public consultation period and document finalised*	*Beach*	*MP*	*5 Jul 2012*	*BW/SM*	*MP*	*5 Jul 2012*

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1 Introduction

1.1 Purpose

This Statement of Environmental Objectives (SEO) has been prepared to meet the requirements of Sections 99 and 100 of the *Petroleum and Geothermal Energy Act 2000* and Regulations 12 and 13 of the *Petroleum and Geothermal Energy Regulations 2000.*

The intent of the SEO is to outline the environmental objectives to which fracture stimulation activities in shale gas and tight gas targets in the Nappamerri Trough in the Cooper Basin will conform, and the criteria upon which the achievement of these objectives will be assessed.

The objectives of this SEO have been developed on the basis of the information provided in the Environmental Impact Report (EIR) (Beach Energy 2012), and are in keeping with the objectives of the Petroleum and Geothermal Energy Act, which include:

- to minimise the environmental damage from exploration for, or recovery or commercial utilisation of, resources to which the Act applies
- to establish appropriate consultative processes involving people directly affected by regulated activities and the public generally
- to protect the public from risks inherent in regulated activities.

Environment is broadly defined in the Petroleum and Geothermal Energy Act to include natural, social, cultural and economic aspects. The environmental objectives outlined in this SEO incorporate these aspects.

1.2 Scope

This SEO applies to fracture stimulation operations in deep shale gas and tight gas targets in the Nappamerri Trough in the Cooper Basin in South Australia. These operations are described in the EIR (Beach Energy 2012).

Activities associated with Cooper Basin operations that are not addressed in the EIR or covered by this SEO include:

- drilling and well operations other than fracture stimulation; these are covered by the Cooper Basin Drilling and Well Operations SEO (Santos 2009)
- seismic exploration activities (covered by Santos 2006)
- petroleum production operations (covered by Beach 2009)

This document and the accompanying EIR focus on the fracture stimulation process carried out after the well has been drilled. Other aspects of drilling and well operations such as preparation of the well lease and access, drilling, casing and cementing of the well, camps, well operation and monitoring, well abandonment and well lease restoration are covered by the Cooper Basin Drilling and Well Operations Statement of Environmental Objectives (Santos 2009) and are not re-visited in the EIR or this SEO.

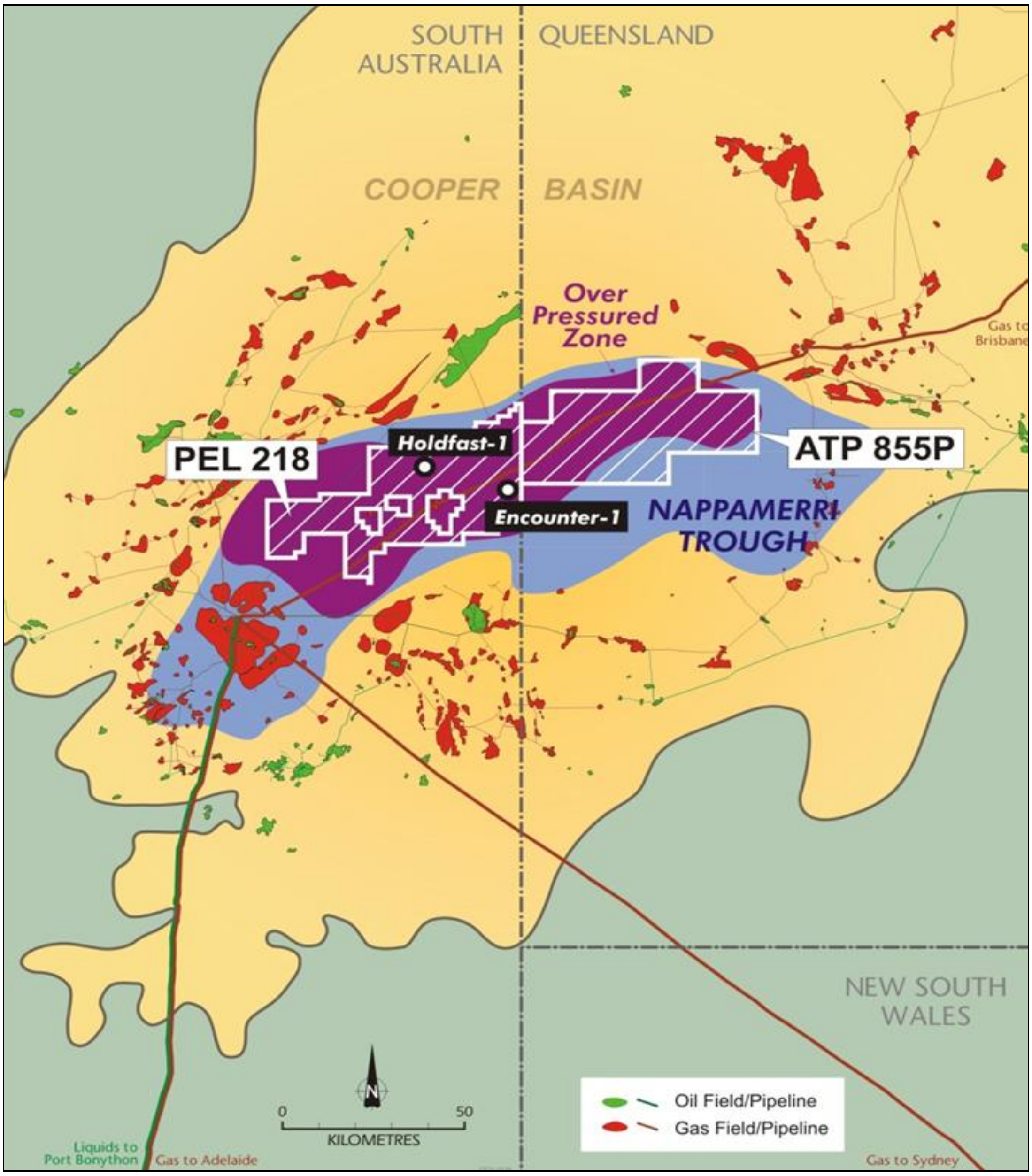

Figure 1: The South Australian Cooper Basin and Nappamerri Trough

2 Environmental Objectives and Assessment Criteria

2.1 Objectives

Potential environmental hazards and consequences associated with fracture stimulation activities in shale gas and tight gas targets in the Nappamerri Trough have been identified in the Environmental Impact Report (Beach Energy 2012). Beach is committed to achieving a range of environmental objectives in regard to these potential hazards.

The environmental objectives for fracture stimulation operations are:

1. Avoid aquifer contamination.
2. Minimise impacts of groundwater use.
3. Avoid contamination of surface water and shallow groundwater.
4. Minimise disturbance and avoid contamination to soil.
5. Minimise disturbance to native vegetation and native fauna.
6. Avoid the introduction or spread of pest plants and animals and implement control measures as necessary.
7. Avoid disturbance to sites of cultural and heritage significance.
8. Minimise air pollution and greenhouse gas emissions.
9. Minimise risks to the safety of the public, employees and other third parties.
10. Avoid or minimise disturbance to stakeholders and / or associated infrastructure.
11. Optimise (in order of most to least preferable) waste avoidance, reduction, reuse, recycling, treatment and disposal.
12. Remediate and rehabilitate operational areas.

2.2 Assessment Criteria

The environmental objectives identified above are subject to an assessment to measure the level of achievement. The assessment criteria for each objective are set out in Table 1 and include:

- Defined conditions – In many cases the achievement of an objective can be assessed through ensuring defined conditions are met or carried out. Such conditions include:
  - Prohibitions that achieve the objective through the prevention of unacceptable actions
  - Requirements to carry out certain actions in accordance with approved procedures or industry accepted standards.

- Scientific studies / monitoring - In some cases assessment of the environmental objectives may not be possible in the shorter term and may require longer term monitoring and scientific evaluation. In such cases, the assessment criteria may be in the form of longer term data and information gathering.

Table 1 also outlines the controls that are planned to be implemented to ensure that environmental objectives are achieved, in the “Guide to How Objectives Can be Achieved” column.

Table 1: Environmental Objectives and Assessment Criteria

Environmental Objectives	Assessment Criteria	Guide to How Objectives Can be Achieved	Comments
1. Avoid aquifer contamination.	No undesired flow between geological units or to surface. No contamination of aquifers as a result of fracture stimulation operations.	Well Integrity Casing and wellhead designed to meet pressure, temperature, operational stresses and loads. Well pressure tested prior to fracture stimulation. Monitoring programs implemented (e.g. through well logs, pressure measurements, casing integrity measurements and corrosion monitoring programs) to assess condition of casing and cross-flow behind casing. Trip systems installed to shut off stimulation pumping units if pre-set operational maximum pressure is reached. Fracture Stimulation Planning and Monitoring Assessment of geological and geomechanical settings undertaken during design of fracture stimulation treatments to avoid growth into undesired strata. Injection pressures monitored and compared to expected fracture initiation pressure. If initiation pressure is significantly lower, injection is stopped and casing integrity is assessed. Investigation undertaken if unexpected water flows occur during production testing, to determine source (e.g. may indicate communication with aquifer). Microseismic monitoring to be used to monitor height growth, if required, due to thinning of geological strata or evidence of unsuitable geomechanical conditions.	Significant physical separation between targets and overlying GAB aquifers (approx. 400 m thick Nappamerri Group siltstone between Permian targets zones and the overlying GAB). Fractures are unlikely to propagate beyond the top of the Toolachee into the Nappamerri Group due to stress contrast between these layers. Low likelihood of migration of fluids along inter-formation faults – pressure differential between the GAB and the Permian Formations indicates that the intervals are not currently connected by faults, and seismic information has not detected large scale faults that connect the GAB to the Permian section.
2. Minimise impacts of groundwater use.	No reasonable stakeholder complaints left unresolved. No impact on groundwater dependent ecosystems resulting from extraction of groundwater.	Potential impacts to existing bores assessed where new water bores are to be drilled within 5 kilometres of existing water bores. Options to access deeper aquifer sands and to undertake monitoring of existing bores (where applicable) investigated to confirm that water extraction does not impact adversely on existing users. Water extraction for fracture stimulation in accordance with licensing and water allocation plan where applicable. Options for alternative water supplies investigated / used where feasible (e.g. produced formation water, recycling, reuse). Extraction of large volumes of water from aquifers that provide baseflow to nearby waterholes (e.g. aquifers in sandy sequences underlying and adjacent to the Cooper Creek) avoided. For water bores proposed in close proximity to waterholes - location, depth and aquifer properties assessed and, where necessary, deeper intervals targeted or water wells relocated (where appropriate). Requirement for monitoring bore near the waterhole addressed.	Relatively few water supply bores in the area and shallow aquifers are often unsuitable for stock or domestic use. Wells to be fractured are expected to be far apart (several kilometres). Impact on aquifer of once-off extraction for fracturing expected to be relatively short term and localised. Liaise with DFW to ensure appropriate authorisations are in place. Any water well or aquifer monitoring bore will require a well construction permit.
3. Avoid contamination of surface water and shallow groundwater.	No leaks / spills outside of areas designed to contain them. No overflow or escape of flowback fluids from temporary ponds. No water (surface or groundwater) contamination as a result of fracture stimulation operations.	Pond Location Well sites and pond locations selected to ensure that consequences of a potential pond failure are minimised (e.g. ponds not located in close proximity to the Cooper Creek channel or other significant watercourses such that failure would result in direct release to these watercourses). Well leases located on higher ground as far as practicable. Where well leases have potential for infrequent flooding, measures undertaken to ensure ponds are not vulnerable to flooding (e.g. ponds on higher ground, construction of higher pond walls, removal of flowback fluids off-site either during testing or at completion of operations).	Fracture stimulation will not be carried out in floodplain areas if significant flooding is reasonably expected or predicted in the Cooper Creek system. Any additional management measures identified by site-specific assessments will be implemented to avoid surface water impacts.

Environmental Objectives	Assessment Criteria	Guide to How Objectives Can be Achieved	Comments
		Pond Integrity Flowback fluids securely contained in ponds lined with UV stabilised material. Ponds with above-ground walls / bunds to prevent surface runoff into ponds. Quality control on pond construction and liner installation to minimise risk of compromised liner integrity. Maximum pond fill level not exceeded (allow for rain events and wave effects). Water balance method used for leak detection (incorporating inflow, evaporation, fluid levels and measurement uncertainty). Pond operation monitored (e.g. pond wall integrity) and repair / remediation and / or decommissioning / rehabilitation undertaken where appropriate (e.g. if leak evident, recover excess fluid where practicable, repair or decommission / rehabilitate pond). Monitoring Program established to monitor shallow aquifers that are accessed by regional stakeholders. Monitoring of Cooper Creek levels at gauging stations upstream of the Nappamerri Trough (e.g. Durham Downs, Windorah, Stonehenge and Blackall) to enable implementation of flood response procedures if flood fronts are identified that are likely to impact on well operability and pond integrity. Refer to Objective 4 for criteria relating to fuel and chemical storage and handling.	
4. Minimise disturbance and avoid contamination to soil.	No overflow or escape of fluids from temporary ponds. No soil contamination as a result of fracture stimulation and flowback operations. Fuel and Chemical Storage and Handling No spills / leaks outside of areas designed to contain them. Level of hydrocarbon and other contaminants continually decreasing for in situ remediation of spills. Also refer to Objective 12 for remediation of contaminated sites.	Routine inspections of storage ponds, general lease area and equipment. Flowback lines from wellhead rated and pressure tested to appropriate pressure and emergency shut-down system installed on well-head. Spills / leaks cleaned up and remediated. Flare pit cleaned up and remediated as required following completion of operations. Refer to Objective 3 for criteria related to pond integrity. Refer to Objective 9 for pressure integrity of fracture stimulation pumping equipment. Fuel and Chemical Storage and Handling All fuel, oil and chemical storage, handling and secondary containment in accordance with the appropriate standards and guidelines e.g. Australian Standard AS 1940, EPA guideline *080/07 Bunding and Spill Management* and product MSDSs. Refuelling undertaken with appropriate drip capture systems. Spill response equipment maintained on site. Spills or leaks immediately reported and clean up actions initiated. Spill Response / Contingency Planning Results of emergency response procedures carried out in accordance with Regulation 31 show that emergency response plan in place in the event of a spill is adequate and any necessary remedial action needed to the plan is undertaken promptly. Personnel trained in correct procedures for use of materials, including refuelling and clean-up procedures.	Chemical utilisation during stimulation will be kept to the lowest possible to achieve necessary stimulation outcome. Lower toxicity chemicals will be investigated and used where practicable and suited to the stimulation design required. ERP exercises conducted by Operator on a regular basis.

Environmental Objectives	Assessment Criteria	Guide to How Objectives Can be Achieved	Comments
	<u>Waste Disposal</u> Refer to Assessment Criteria for Objective 11.	<u>Waste Disposal</u> Refer to Objective 11.	
5. Minimise disturbance to native vegetation and native fauna.	No unauthorised clearing of vegetation. Activities confined to cleared areas (e.g. access tracks and prepared well lease). Fauna casualties reduced to as low as reasonably practicable. <u>Waste Management</u> Refer to assessment criteria for Objective 11. <u>Fuel and Chemical Storage and Handling</u> Refer to assessment criteria for Objective 4.	Impacts to flora and fauna minimised by well lease siting, scouting and preparation in accordance with the Drilling and Well Operations SEO. Activities confined to existing cleared areas (e.g. access roads, prepared well lease) within area subject to environmental assessment. If flora with significant conservation value is present in vicinity of well site it will be flagged and / or fenced off where necessary to prevent disturbance. Ponds securely fenced to exclude stock and large native fauna. Pond construction to minimise attractiveness to birds i.e. relatively steep sides and lined with suitable polyethylene material, with no 'beaches' or vegetation. Routine surveillance monitoring will be undertaken to detect fauna incursions. Ongoing inspection and monitoring of ponds would detect fauna mortality (if it occurred). Fauna mortality to be captured by incident reporting system. Bird deterrent measures introduced if bird mortality incidents are observed. <u>Fauna Management</u> No domestic pets allowed at camps or worksites. Feeding of wildlife (e.g. dingoes) is not permitted. <u>Waste Management</u> Refer to Objective 11. <u>Fuel and Chemical Storage and Handling</u> Refer to Objective 4.	
6. Avoid the introduction or spread of pest plants and animals and implement control measures as necessary.	No weeds or feral animals are introduced to, or spread in, operational areas as a consequence of activities.	Operations and equipment confined to existing cleared areas (e.g. access roads, prepared well lease). Equipment that has been operating outside the Cooper Basin or in areas of known weed infestation cleaned before arrival at the site.	
7. Avoid disturbance to sites of cultural and heritage significance	Well lease and access tracks have been surveyed and any sites of Aboriginal and non-Aboriginal heritage identified. Any identified cultural and heritage sites have been avoided.	Activities confined to existing cleared areas (e.g. access roads, prepared well lease) within area subject to Work Area Clearance for cultural heritage. Training and induction for all personnel to educate them on the importance of remaining within designated / approved areas. Where necessary, cultural heritage sites or exclusion zones in the vicinity of the well site flagged and / or fenced off to prevent disturbance.	

Environmental Objectives	Assessment Criteria	Guide to How Objectives Can be Achieved	Comments
8. Minimise air pollution and greenhouse gas emissions.	No reasonable stakeholder complaint left unresolved. No unplanned gas releases. Well production diverted to flare as soon as practicable. Well testing curtailed when test objectives are satisfied.	Equipment operated and maintained in accordance with manufacturer specifications. Well flowback diverted to separator as soon as practicable to minimise gas not being recovered and sent to flare. Flaring during production testing kept to minimum length of time necessary to establish resource and production parameters. Options to connect to gathering network investigated once initial testing is complete and longer term testing is required for reserve definition. Dust control measures (e.g. water spraying) implemented if dust generation becomes a problem e.g. near sensitive sites. Appropriate emergency response procedures are in place for the case of a gas leak. Monitoring of well parameters during testing operations to check for fugitive emissions at the wellbore.	Greenhouse gas emissions are estimated, recorded and reported in accordance with NGER requirements.
9. Minimise risks to the safety of the public, employees and other third parties.	Reasonable measures implemented to ensure no injuries or health risks as a result of the activities.	<u>Fracture Stimulation Activity</u> All employees and contractor personnel complete a safety induction prior to commencement of work in the field. All employees and contractor personnel undertake a regular refresher induction. Signage in place to warn third parties of access restrictions to operational areas, with particular warnings when potentially dangerous operations are being undertaken. Contractor equipment has valid certifications, is properly secured and pressure tested prior to commencement of stimulation at each site and trip systems are installed to shut off stimulation pumping units if pre-set operational maximum pressure is reached. All appropriate PPE (personnel protective equipment) is issued and available as required in accordance with company operating requirements and applicable standards. Monitoring undertaken to confirm / ensure that levels of radioactivity are within acceptable limits. Safety management plans prepared as required for the activity. Permit to work systems in place for staff and contractors as required. Effective Emergency Response Plan (ERP) and procedures are in place. Traffic and journey management procedures followed. <u>General Area</u> Speed restrictions and appropriate signage to reduce speed and increase awareness of hazards for public, employees and third parties. Fire and Emergency Services Act requirements complied with (e.g. permits for 'hot work' on total fire ban days). Fire fighting equipment available as appropriate for location and use.	Fracture stimulation activities will be undertaken in accordance with the Operator's Health, Safety and Environment Management System.

Environmental Objectives	Assessment Criteria	Guide to How Objectives Can be Achieved	Comments
10. Avoid or minimise disturbance to stakeholders and / or associated infrastructure.	No reasonable stakeholder complaints left unresolved.	Induction for all employees and contractors covers pastoral, conservation, tourism, legislation and infrastructure issues. Relevant stakeholders notified prior to undertaking operations (pursuant to Regulations). Fracturing not carried out in close proximity to Innamincka or pastoral station residences. Ponds securely fenced to exclude stock and large native fauna. Landowners notified of proposed operations. If, and as required, consultation undertaken and mitigation measures implemented to ensure that no reasonable complaints are received. Potential sources of contamination fenced as appropriate to prevent stock access. System is in place for logging landholder complaints to ensure that issues are recorded, addressed as appropriate and complaints are resolved in a timely manner.	Planned activities are presented to the local community in advance. Liaison with appropriate regional land management committees and boards.
11. Optimise (in order of most to least preferable) waste avoidance, reduction, reuse, recycling, treatment and disposal.	Wastes to be disposed of at an EPA licensed facility in accordance with EPA licence conditions. No waste material disposal to sumps and flare pits with the exception of drilling fluids, drill cuttings, other fluids disposed during well clean-up (under the Drilling and Well Operations SEO).	Waste generation minimised (e.g. reduce, reuse and recycle). Waste streams segregated on site to maximise opportunities for waste recovery, reuse and recycling. Chemical utilisation kept to the lowest level possible. Waste removed off-site and disposed of at appropriately licensed waste handling facility. Secure systems used for storage and transport of waste (e.g. covered bins in designated area for waste collection and storage prior to transport). Hazardous wastes handled in accordance with relevant legislation and standards. Licensed contractors used for waste transport. Pond liners removed off-site following evaporation, for disposal at an appropriately licensed waste disposal facility. Spill clean-up materials and wastes appropriately contained for off-site disposal to a licensed waste management facility.	
12. Remediate and rehabilitate operational areas.	No reasonable stakeholder complaints left unresolved. <u>Contaminated Site Remediation</u> Contaminated sites are remediated in accordance with criteria developed with the principles of the National Environment Protection Measure for contaminated sites, and in consultation with the EPA. <u>Note</u>: Well abandonment and well site restoration issues are addressed under Objectives 6 and 12 in the Drilling and Well Operations SEO (Santos 2009).	Temporary ponds re-profiled following completion of operations and restored in accordance with well lease restoration criteria in the Drilling and Well Operations SEO. Flare pit cleaned up and remediated following completion of operations. Well leases ultimately restored in accordance with the Drilling and Well Operations SEO. <u>Contaminated Site Remediation</u> Areas of potential contamination (e.g. from spills or leaks, including serious or reportable incidents as outlined in Section 3) assessed to determine level of contamination and appropriate remediation measures developed in consultation with DMITRE and EPA.	

3 Reporting

It is a requirement under Section 85 of the Petroleum and Geothermal Energy Act that 'serious' and 'reportable' incidents must be reported to the Minister.

3.1 Definitions

Serious Incidents

Section 85(1) of the Act defines a 'serious incident' as an incident in which:

(a) a person is seriously injured or killed

(b) an imminent risk to public health or safety arises

(c) serious environmental damage occurs or an imminent risk of serious environmental damage arises

(d) security of natural gas supply is prejudiced or an imminent risk of prejudice to security of natural gas supply arises

(e) some other event or circumstance occurs or arises that results in the incident falling within a classification of serious incidents under the regulations or a relevant statement of environmental objectives.

Reportable Incidents

Section 85(1) of the Act defines reportable incidents as incidents (other than a serious incident) arising from activities conducted under a licence that are classified under the Regulations as a reportable incident.

Regulation 32(1) classifies the following as reportable incidents:

(a) an escape of petroleum[1], a processed substance, a chemical or a fuel that affects an area that has not been specifically designed to contain such an escape

(b) an incident identified as a reportable incident under the relevant statement of environmental objectives.

Regulation 12(2) requires an SEO to identify events which could arise that could, if not properly managed or avoided, cause a serious incident or a reportable incident within the meaning of Section 85 of the Act.

Table 2 identifies the potential serious and reportable incidents relevant to fracture stimulation activities, pursuant to Regulation 12(2) and Regulation 32(1)(b). These definitions are based on the standard incident definitions for facilities and pipelines that have been developed by DMITRE.

[1] In gaseous, liquid or solid state, as per Petroleum and Geothermal Energy Act definition

Table 2: Potential Serious and Reportable Incidents

Serious Incidents	Reportable Incidents
1. A person is seriously injured[2] or killed. 2. An imminent risk to public health or safety arises. 3. Serious environmental damage occurs or an imminent risk of serious environmental damage arises. For example: ▪ Disturbance to sites of cultural and / or heritage significance without appropriate permits and approvals[3]. ▪ A spill or release of fuel, oil, chemicals or fracturing fluid that could contaminate soils, shallow groundwater or surface waters. ▪ Identification of cross flows in aquifers, or uncontrolled flows to the surface. ▪ Any well incident or failure that threatens or poses an imminent risk to safety or a risk of serious damage to environmental values whether or not those values are referred to in State or Commonwealth legislation. ▪ Detection of a declared weed, animal / plant pathogen or plant pest species that has been introduced or spread as a direct result of activities. ▪ Any removal of rare, vulnerable or endangered flora and fauna without appropriate permits and approvals[4]. 4. An event that compromises the physical integrity of an asset or facility. For example: ▪ Pipeline rupture or facility failure. 5. An uncontrolled release resulting in the activation of emergency response and / or evacuation procedures of an area in or adjacent to the release, and / or fire or explosion.	1. An escape of fuel, oil, chemicals or fracturing fluid that affects an area that has not been specifically designed to contain such an escape (other than a serious incident). 2. An event that has the potential to compromise the physical integrity of an asset or facility. For example: ▪ An unapproved excursion outside of critical design or operating conditions / parameters. ▪ Failure of a critical procedural control in place to reduce a credible threat to low or as low as reasonably practicable (ALARP)[5]. 3. Malfunction or failure of critical plant or equipment that had (or still has) potential to cause a serious incident. 4. Unresolved reasonable complaints from stakeholders regarding operations.

3.2 Reporting Requirements

Serious Incidents must be reported to the Minister as soon as practicable after the occurrence, as per Section 85 of the Act and Regulation 32.

Reportable Incidents must be reported to DMITRE on a quarterly basis within 1 month of the end of the quarter, as per Regulation 32.

[2] Includes an immediately notifiable work-related injury pursuant to Division 6.6 of the *Occupational Health, Safety and Welfare Regulations 1995* that results in the issuing of a Prohibition Notice by SafeWork SA.

[3] Pursuant to *Aboriginal Heritage Act 1988* and *Heritage Places Act 1993.*

[4] Pursuant to *Native Vegetation Act 1991* (flora) and *National Parks and Wildlife Act 1972* (fauna).

[5] As per the Safety Management System process articulated in AS 2885.1-2007, or similar risk assessment process.

3.3 Reporting to EPA

Where applicable, incidents causing or threatening serious or material environmental harm under the *Environment Protection Act 1993* must be reported to the EPA in accordance with section 83 of the *Environment Protection Act 1993.*

The reporting obligation under the Environment Protection Act does not apply to:

- petroleum exploration activity undertaken under the Petroleum and Geothermal Energy Act; or
- wastes produced in the course of an activity authorised by a licence under the Petroleum and Geothermal Energy Act when disposed of to land within the area of the licence.

4 List of Abbreviations

APPEA	Australian Petroleum Production & Exploration Association
AS 1940	Australian Standard *AS 1940 Storage and Handling of Flammable and Combustible Liquids*
DFW	Department for Water (South Australia) (part of DEWNR as of 1 July 2012)
DEWNR	Department of Environment, Water and Natural Resources
DMITRE	Department for Manufacturing, Innovation, Trade, Resources and Energy
EIR	Environmental Impact Report prepared in accordance with Section 97 of the *Petroleum and Geothermal Energy Act 2000* and Regulation 10.
EPA	Environment Protection Authority
ERP	Emergency response plan
MSDS	Material Safety Data Sheet
NGER	National Greenhouse and Energy Reporting (Act)
PPE	Personal protective equipment
SEO	Statement of Environmental Objectives prepared in accordance with Section 99 and 100 of the *Petroleum and Geothermal Energy Act 2000* and Regulations 12 and 13.

5 References

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