Buru Energy Submission to the Scientific Inquiry into Hydraulic Fracture Stimulation in Western Australia

16 March 2018

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Introduction

On 5 September 2017, the Western Australian Government announced an independent scientific panel inquiry (Inquiry) to assess and report on the potential impacts arising from the implementation of hydraulic fracture stimulation (fraccing) on the onshore environment of Western Australia. The Inquiry was established under section 25 of the *Environmental Protection Act 1986* (EP Act). The scope, terms of reference and other relevant information is provided on the Inquiry website: https://frackinginquiry.wa.gov.au/.

The panel has asked for input from stakeholders to ensure it has:

(a) a full and appropriate understanding of the environmental values potentially at risk from unconventional oil and gas developments involving fraccing;

(b) data or other evidence that might inform a scientific risk analysis of those impacts, with an emphasis on local geographies, geologies, and local evidence from Western Australia; and

(c) any reflections or experience on what a regulatory framework should ideally look like.

Buru Energy Limited

Buru Energy Limited (Buru Energy, Buru) is a West Australian oil and gas exploration and production company with a sole focus on exploring and developing the petroleum resources of the Canning Basin, in the Kimberley region of Western Australia.

Buru Energy is one of the few companies who has recently fracced wells in Western Australia: Yulleroo 2 in 2010, Asgard 1 in 2015 and Valhalla North 1 in 2015. Fracs undertaken by Buru Energy have been focussed on exploring and appraising the Laurel Formation, located more than 2.5 km below ground level.

Environmental monitoring programs implemented during the 2015 frac program have provided qualitative, scientific information regarding fraccing in West Australian conditions. The 2015 frac program was undertaken after a thorough consultation program with local communities and delivered significant benefits to the Noonkanbah community. This submission describes the community consultation and benefits derived from the frac program, and provides the results of environmental monitoring. A concept for an unconventional gas field in the Yulleroo area is also presented, along with a review the current regulatory framework for unconventional activities in Western Australia based on Buru Energy's experience. Lastly, recommendations for reform to improve public confidence in the industry and its regulation are provided.

Consultation with Key Stakeholders

Buru Energy focusses consultation on effective engagement with stakeholders directly affected by activities, in particular land holders and local communities. In 2010, Buru Energy fracced three zones of the Yulleroo 2 well, located in Exploration Permit (EP) 391 on the Yawuru Native Title Determination. The Yulleroo 2 frac program was undertaken following consultation with the Yawuru Native Title holders and provision of formal notice under the EP 391 Heritage Protection Agreement. At the time of the Yulleroo 2 frac, the level of public interest in fraccing was extremely low.

In 2012/13, the Buru Energy (with its joint venture partner Mitsubishi Corporation (MC)) started planning to hydraulically fracture petroleum wells in the Asgard/Valhalla and Yulleroo areas. These plans coincided with increasing community concerns regarding fraccing so Buru Energy supported a number of independent specialist reviews of fraccing. Two of these reviews were undertaken for Traditional

Owner groups directly affected by the proposed fraccing, while a third review was undertaken for other Traditional Owners in the basin so that these groups had access to the same independent information. These reviews were undertaken independent of Buru Energy and involved 11 specialists from four different universities and CSIRO. The reviews demonstrated that the fraccing proposed at Yulleroo, Valhalla North and Asgard used best available techniques and would have very low risk to the environment. A further independent retrospective review of the Yulleroo 2 frac in 2010 undertaken for Yawuru demonstrated that the 2010 frac program was low risk and contamination of groundwater was highly unlikely. This was supported by Buru Energy’s groundwater monitoring at Yulleroo 2 and in the wider Yulleroo area, which has found no impacts of petroleum operations on groundwater.

Buru Energy’s 2015 Frac Program

In 2015, Buru Energy (as Operator of the joint venture with MC) fracced the Asgard 1 and Valhalla North 1 exploration wells in EP 371. Over two weeks, 11 zones were fracced before well intervention and flowback occurred. The environmental monitoring programs undertaken during fraccing, including groundwater quality, groundwater quantity (drawdown), air quality, flowback water and microseismic monitoring, demonstrated no adverse environmental effects of fraccing. Environmental monitoring was undertaken with the involvement of the Yungngora and Warlangurru Traditional Owners.

The 2015 frac program delivered considerable benefits to the nearby Noonkanbah community. For example, employment was provided to 33 workers from Noonkanbah community during the program with more than 14,000 hours worked. Due to the current moratorium on fraccing, appraisal and development of the resource is currently on hold, the wells are suspended and employment opportunities for Noonkanbah community are limited.

Yulleroo Conceptual Field Development

To demonstrate what the scale of an unconventional development in the Canning Basin might look like, Buru Energy has designed a conceptual field development at Yulleroo based on current technical and operational knowledge. The Yulleroo conceptual field development considers a production of some 714 PJ of gas with associated liquids over approximately 20 years. The modelled development will require up to eight well pads with ten wells drilled from each, for a total of 80 wells.

This conceptual field would require the clearing of approximately 100 ha of vegetation, which represents ~0.5% of the vegetation in the Yulleroo area. This is approximately half the land clearing required for an average centre pivot irrigation system. Water use for the gas field is also minimal in the context of available groundwater, with the development requiring approximately 1 GL of water over the 20-year life of the field. Numerical groundwater modelling has demonstrated that the extraction would result in minimal groundwater drawdown (~0.1 m within 1 km of the bore) and would not impact on nearby pastoral bores or sensitive areas. The Yulleroo field development would provide substantial direct and indirect benefits to the local Traditional Owners, community and economy.

Regulation of Hydraulic Fracturing in Western Australia

Current Regulatory Framework

Buru Energy considers that Western Australia has a robust petroleum regulatory regime. This has evolved over 60 years alongside a globally significant petroleum industry, has been tailored to local conditions and reflects industry best practice. Since 2011, there has been significant reform of the Western Australian petroleum regulatory framework to ensure it meets leading practice for the regulation of unconventional oil and gas activities. This has culminated in the implementation of a whole-of-

government approach for the regulation of hydraulic fracturing in Western Australia[1]. Following is an overview of the approvals process for Buru Energy's 2015 frac program to illustrate how the whole-of-government approach is applied:

- Well programs were required to be approved by Department of Mines, Industry Regulation and Safety (DMIRS) for approval under the *Schedule of Onshore Petroleum Exploration and Production Requirements 1991* (Onshore Schedule)[2].
- Environment Plan was required to be approved by DMIRS under the *Petroleum and Geothermal Energy Resources (Environment) Regulations 2012* (Environment Regulations).
- Environment Plan Bridging Document was required to be approved by DMIRS under the Environment Regulations to revise some minor operational details.
- Buru Energy referred the frac program to the Environmental Protection Authority (EPA) under Part IV of the *Environmental Protection Act 1986* (EP Act). The EPA decided not to formally assess the proposal on the basis that the proposal was unlikely to have a significant effect on the environment.
- The EPA decision not to assess the frac program was appealed under s100 of the EP Act with 48 valid appeals lodged. The Appeals Convenor considered the appeals with advice provided to the Minister for Environment. The Minister subsequently dismissed all appeals.
- Buru Energy lodged an Application Enquiry to the Department of Water and Environmental Regulation (DWER) to determine if a works approval or licence was required under Part V of the EP Act. DWER advised that a works approval was not required for the frac program as the expected volumes of oil and gas produced were below threshold levels.
- Licences for the take of water for the 2015 frac program were applied for and granted by DWER under section 5C of the *Rights in Water and Irrigation Act 1914*.

The above process for the 2015 program took around eight months (November 2013 to June 2014).

Proposed Regulatory Reform

Buru Energy supports the application of an objective, risk-based regulatory approach for petroleum activities as legislated in Western Australia. Application of the regulatory framework for petroleum activities should be evidence-based and commensurate with the potential risk and scale of the activity.

Buru Energy notes the levels of community concern regarding hydraulic fracturing and has identified opportunities for regulatory reform that should ultimately improve the public's perception of the industry and its regulation. Regulatory reform to increase community confidence in the regulatory framework is suggested in the following areas:

- use of a risk-based classification method to classify activities as low, medium or high risk with greater scrutiny applied to high risk activities;
- development of standard approaches (i.e. reference cases) for petroleum operations, particularly for low risk activities. This will reduce the burden on regulators and provide consistent information to the general public;
- compulsory groundwater monitoring associated with hydraulic fracturing activities;
- review of the guidelines for making appeals under the EP Act to ensure appeals are legitimate;
- improvement of the definition of stakeholders under the Environment Regulations to ensure that consultation is primarily focussed on stakeholders with a direct interest in a proposal; and
- target transparency reforms towards landholders and key stakeholders.

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[1] Guideline to the Regulatory Framework for Shale and Tight Gas in Western Australia – A Whole of Government Approach 2015.

[2] Note the Onshore Schedule has since been superseded by the *Petroleum and Geothermal Energy Resources (Resource Management and Administration) Regulations 2015.*

Buru Energy acknowledges that it, as well as the wider industry and the government, has a responsibility to further engage with the broader community; to address concerns and increase understanding of the onshore oil and gas industry.

Conclusion

Buru Energy has fracced three wells in the Canning Basin. The environmental monitoring data collected during the frac programs demonstrates that fraccing can be undertaken safely with negligible impacts to the environment and local communities. The impact to the environment is significantly less than impacts associated with many other mining, industrial and agricultural activities carried out in Western Australia. In fact, in the remote areas where Buru Energy operates, the positive impacts (benefits) associated with fraccing projects are considerable.

Buru Energy considers that the development of the Canning Basin unconventional resources is key for the responsible regional development of the West Kimberley. These projects are particularly important as unconventional resources occur away from regional centres, in areas where meaningful employment opportunities are central to addressing economic disadvantage amongst remote Aboriginal communities. Projects will provide significant benefits to these local Aboriginal communities and Western Australia generally with minimal impact to the environment.

1. BACKGROUND

1.1. Buru Energy

Buru Energy Ltd (Buru Energy, Buru) is a Western Australia (WA) based ASX listed oil and gas exploration and production company with a sole focus on the Canning Basin in the West Kimberley. The Canning Basin holds a very large potential gas resource. The Australian Energy Market Operator reports WA's resources of tight and shale gas are in the range of 187,699 PJ to 295,864 PJ, a large proportion of which are located in the Canning Basin[3]. These estimates are based on Department of Mines, Industry Regulation and Safety (DMIRS) current, best estimates of risked recoverable resources and are comparable to (and in fact slightly larger than) gas resources and reserves located in offshore WA[3]. Under a whole of government approach (discussed in Section 8), Buru Energy's operations are primarily regulated by the *Petroleum and Geothermal Energy Resources Act 1967* (PGER Act).

Since its establishment in 2008, Buru Energy has been actively exploring and appraising the gas resources of the Laurel Formation in the Canning Basin. Buru Energy was joined in this appraisal by Mitsubishi Corporation in 2010, but remained the Operator of the Joint Venture. The Laurel Formation is the primary focus of the gas appraisal program, although it is not the only geological formation holding unconventional oil and gas resources. The Laurel Formation is a more than 2,000 m thick tight gas resource at depths between ~2.5 km and ~4.5 km. To date, the exploration and appraisal process has included drilling of eight vertical wells, with three wells (Yulleroo 2, Asgard 1 and Valhalla North 1) having been hydraulically fracture stimulated (fracced). The drilling and fraccing of these wells has been successful in defining large contingent gas resources in the Yulleroo area on the western side of the basin, and in the Asgard/Valhalla area on the eastern side of the basin (Figure 1). Following an asset-swap with Mitsubishi Corporation in May 2017, Buru Energy now holds 100% of the Yulleroo tight gas field, located in Exploration Permit (EP) 391 and EP 436, while Mitsubishi Corporation has 100% of the Asgard/Valhalla tight gas pool located in EP 371.

This submission focusses on Buru Energy's experience as Operator of the exploration and appraisal of the tight gas resources of the Laurel Formation in both the Yulleroo and Asgard/Valhalla areas. The Asgard 1 and Valhalla North 1 pilot frac program in 2015 is used throughout this submission as the primary case study. During this program, seven zones in Asgard 1 and four zones in Valhalla North 1 were fracced over a period of around two weeks. Following the fraccing operations, well intervention and flowback operations were undertaken to test the response of the wells to the fraccing. This response was very favourable with strong gas and hydrocarbon liquid recoveries from the fracced zones. Further evaluation of the resource will require the drilling and multi zone fraccing of horizontal (or deviated) wells.

To provide an indication of the scope and scale of a commercial development and to put this in perspective, an indicative commercial field development scenario at Yulleroo is included as Chapter 2 in this document.

[3] AEMO (2017). Gas Statement of Opportunities for Western Australia. Australian Energy Market Operator. December 2017.

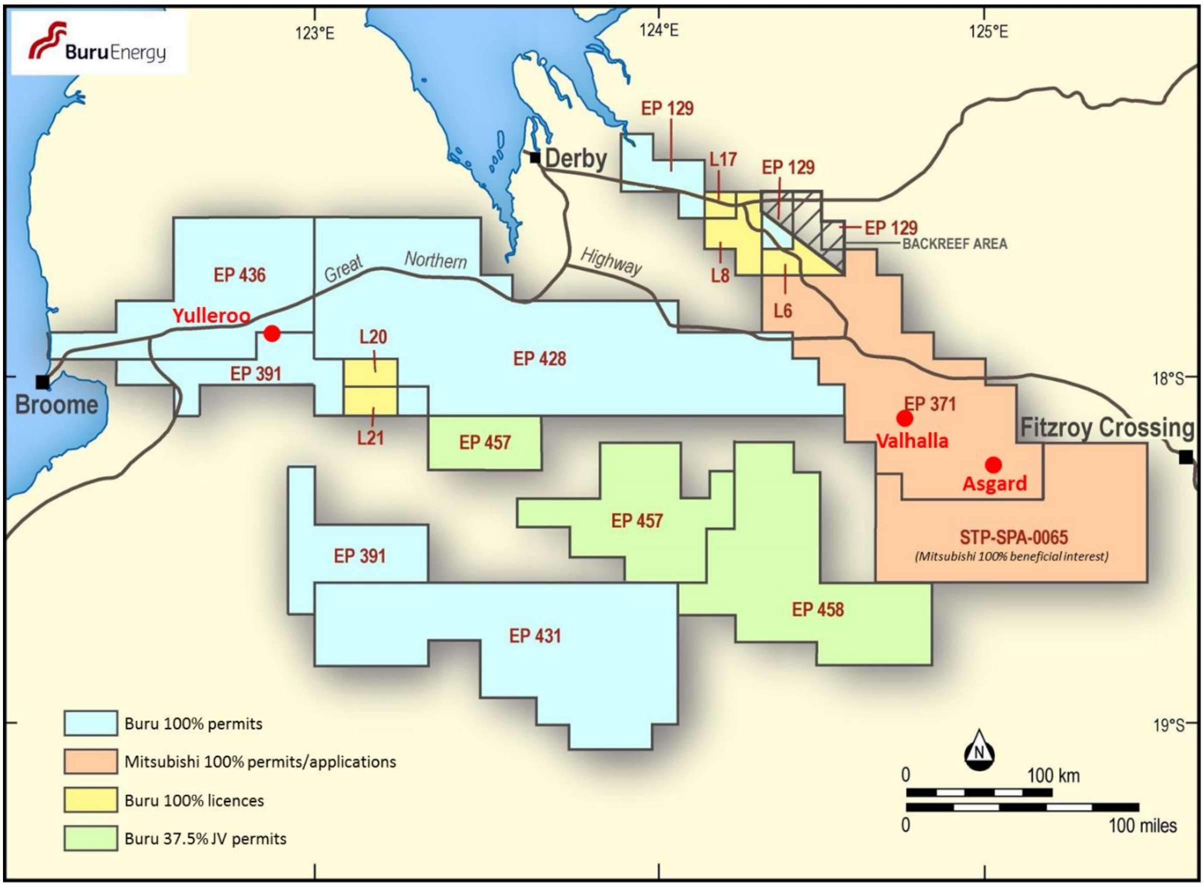

Figure 1: Location of Yulleroo and Asgard/Valhalla gasfields and relevant acreage.

1.2. Canning Basin Environment

The onshore Canning Basin is an early Ordovician to early Cretaceous aged geological basin that covers approximately 430,000 sq. km in the West Kimberley region of WA. Buru Energy is the largest acreage holder in the basin, with petroleum exploration and production permits over approximately 22,109 sq. km of the most prospective parts of the basin.

The climate of the Canning Basin is semi-arid to arid with mean annual rainfall of between 600 mm and 900 mm, and annual evaporation rates of approximately 2,400 mm. Most rainfall (>90%) occurs during the wet season between November and March.

The Canning Basin is covered by rangeland ecosystems, with cattle grazing the dominant land use. The average size of cattle stations in the Kimberley is 230,406 ha (2,304 sq. km)[4] with a present carrying capacity of 584,160 cattle units (cu)[5]. Cattle typically graze on native and introduced vegetation that is rarely cleared for pasture or cropping. The landscapes in these areas are dominated by sand sheets and sandy rises, occasionally dissected by alluvial or lacustrine features associated with surface water. Vegetation is relatively uniform and characterised by the pindan assemblage that occurs on sand plains: generally grassland with a sparse overstorey of *Eucalyptus* spp., boabs and bauhinia with a mid-storey of *Acacia* spp.

[4] PLB (2014) cited in: DPIRD (2017). The Western Australian Beef Industry. Last Accessed: 14 February 2018. Available at: https://www.agric.wa.gov.au/industry-development/western-australian-beef-industry?page=0%2C2

[5] A cattle unit is equivalent to a 400 kg steer maintenance grazing.

Threats to rangelands include inappropriate fire regimes[6], invasive species (feral animals and weeds) and erosion[7]. A survey of rangelands in the West Kimberley undertaken across 89,600 sq. km determined that nearly 30% (26,700 sq. km) of rangeland was in poor condition, with pastures degraded to poor or very poor condition and moderate to severe erosion. The most degraded areas were on the most valuable pasture lands, suggesting overgrazing[7].

In the northern rangelands, livestock productivity and ecological health is driven primarily by the cover and composition of desirable perennial grasses in the pasture. Grasslands in the Kimberley are comprised of perennial hummock (mainly spinifex) or tussock grasses with a variable woody overstorey[8]. Due to the reliable summer wet season, the West Kimberley supports productive pasture communities that display good stability and resilience compared to the Pilbara and southern rangelands. Due to the productivity of pasture communities, pastoral rangelands in the West Kimberley support cattle stocking rates of between ~3 and ~5 cattle units (cu) per square kilometre[8].

1.3. Activity Planning

1.3.1. Site Selection

Site selection is a key factor when minimising the environmental, social and heritage impacts associated with a proposal. Site selection is often overlooked in environmental impact assessments, with the location of a project frequently pre-determined by the location of a resource (e.g. ore body or hydrocarbon accumulation). However, site selection can often be optimised at a local scale to minimise or prevent impacts on particular areas or receptors.

Effective site selection relies on having accurate baseline information regarding the environmental and cultural importance of an area. When planning activities, Buru Energy reviews the available spatial information on environmental, social and heritage factors and incorporates this information in the siting of the activities. Environmental and heritage specialists are then sent into the field to collect baseline flora, fauna and heritage information. The location and layout of the activities is then modified as necessary to avoid areas of environmental and heritage importance. Traditional Owner heritage monitors are present during all activities that involve ground disturbance and liaise with the operational teams on the ground. Using this approach, recent seismic surveys undertaken by Buru Energy have effectively avoided areas of environmental and cultural importance by diverting seismic lines around important areas. For example, bilby populations and surface water bodies were avoided during the Kurrajong 3D survey for oil resources. Areas that are culturally important, such as the Blue Hills area near Ungani, have also been avoided during seismic surveys. Most recently, seismic data has been acquired with nodes which do not require line delineation and clearing, further minimising ground disturbance.

Tight and shale gas resources are 'continuous gas resources' that are commonly semi-regional in extent[9]. The Laurel Formation in the Canning Basin has been demonstrated to be a large-scale Basin Centred Gas System (BCGS) covering an area of approximately 38,000 sq. km [10]. These continuous gas resources are typically exploited from well pads with up to 12 deviated (horizontal) wells, which

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[6] DEE (no date). Rangelands biodiversity. Last Accessed: 14 February 2018. Available at: http://www.environment.gov.au/node/20683

[7] DPIRD (2017). Erosion and rangeland condition in the West Kimberley. Last Accessed: 14 February 2018. Available at: https://www.agric.wa.gov.au/rangelands/erosion-and-rangeland-condition-west-kimberley

[8] Warburton, D.P. and Thomas, P.W.E. (2015). Report to the Commissioner of Soil and Land Conservation on the trend of the Western Australian pastoral resource base. Department of Agriculture and Food, Perth.

[9] United Sates Geological Survey Energy Resources Program (2014). Energy Glossary & Acronym List. Last Accessed: 20 December 2017. Available at: https://energy.usgs.gov/generalinfo/helpfulresources/energyglossary.aspx

[10] Kingsley, D. and Streitberg, E. (2013). The exploration history of the Laurel Basin-Centred Gas System Canning Basin, Western Australia. West Australian Basins Symposium. Perth 18-21 August, 2013.

minimises the surface footprint of the project. Further, as a continuous resource is being targeted, there is considerable flexibility in the location of the well pads at the surface which allows sites of environmental and cultural importance to be avoided.

Pad (platform) drilling and long reach deviated or horizontal wells have been routinely used for many decades in offshore developments, where many wells are drilled from a central platform. This method is proposed for any future development in the Canning Basin by Buru Energy.

1.3.1.1. Relinquishment of Exploration Rights over Roebuck Bay

Sometimes the environmental values of an area are not compatible with certain activities. In the Kimberley, the Roebuck Bay area is recognised as having outstanding ecological value. The intertidal wetlands in Roebuck Bay are a key stopover area for bird species migrating between East Asia and Australia and support internationally significant species of wader birds. The Roebuck Bay intertidal area is also culturally important to the Yawuru people, with links to the area dating back tens of thousands of years. For example, raised shellfish middens have been found many kilometres inland[11], coinciding with past higher sea level shorelines.

In May 2011, Buru Energy and Mitsubishi Corporation voluntarily gave up rights to explore for oil and gas in Roebuck Bay by excluding a significant portion of the EP 473 exploration permit as a conservation area. This was done recognising the ecological and cultural values of the Roebuck Bay area, and to allow the Yawuru People to exercise their role as custodians of Roebuck Bay without intrusion from oil and gas exploration. To achieve this, Buru Energy excised the portion of EP 473 that covered Roebuck Bay and the surrounding wetlands. This excise applied for the duration of the permit. Buru Energy’s recommendation was that the area is excluded from any future permits, and the recent proposal for a marine park over the area will provide at least some partial protection.

Buru engaged with Yawuru throughout the process to ensure the rights and interests of the Yawuru people were preserved. The protection of Roebuck Bay demonstrates Buru’s commitment to working with local communities in the Kimberley in an environmentally and socially acceptable way. The Chairman of the Yawuru Native Title Holders PBC described Buru’s protection of this area “*as a demonstration of industry leadership in Aboriginal and resource development co-operation and partnership in the Kimberley region*”.

1.3.2. Risk Management

To ensure operations are undertaken in a responsible manner, and in accordance with the various pieces of legislation Buru Energy operates under (see Section 8), Buru Energy implements a rigorous risk assessment and management process.

For each Activity, Buru Energy undertakes a series of risk assessments in accordance with the procedures outlined in the *Australian and New Zealand Standard AS/NZS ISO 31000:2009* (Risk Management). The assessments cover environmental, cultural, safety and operational risks, and are used to inform the execution of the activity. Personnel from multiple disciplines participate in the assessments, while literature reviews and specialist advice from independent experts and regulatory agencies can also be included. The outcomes of the assessments are included in relevant project documentation (e.g. Environment Plans).

During assessment of environmental risks associated with hydraulic fracturing, Buru Energy also considers the scientific certainty based on a scoring system developed by the UK Department for

[11] Sullivan, P. (1998). Salt water, fresh water and Yawuru social organisation. Chapter 6 in: Customary Marine Tenure in Australia. Peterson, N and Rigsby B (Eds). Sydney University Press.

Environment, Food and Rural Affairs[12]. This measure of scientific certainty takes into account conclusions from peer reviewed studies, availability of on-ground studies and monitoring data, and expert conclusions to rank scientific certainty as Low, Medium or High. The risk assessment process for Buru Energy's 2015 pilot frac program found the scientific certainty for the majority of risks were High, followed by Medium, with few Low rankings.

For each risk, mitigation and management measures to reduce the severity or likelihood of potential impact are identified. During this process, the measures that would result in a worthwhile benefit are included (i.e. the cost or effort in implementing the control is not grossly disproportionate to the reduction in risk gained). The inclusion or exclusion of these is used to determine whether each risk is as low as reasonably practicable (ALARP). Each risk is assessed while taking into account the planned control measures to determine the 'residual risk', which must be of an acceptable level for the operations to go ahead (i.e. Buru will not undertake operations with a high likelihood of serious consequences).

To ensure risks remain ALARP and acceptable, Buru Energy regularly re-assesses the risks of ongoing operations. This is done to capture any learnings from incidents or general operations, and any additional controls that could be reasonably implemented.

Buru Energy also undertakes a program of compliance monitoring, to ensure identified controls are being implemented as planned, and risks are therefore being managed as intended.

ALARP and Acceptability

Opponents of the industry often criticise the ALARP process, stating that industry can just use cost as an excuse for not implementing suitable controls. This is a simplistic interpretation of the ALARP process and also ignores the equal requirement for risks to be of an acceptable level. It is possible for risks to ALARP, but not acceptable; in this situation, the activity would not go ahead without further risk reduction.

The requirement to demonstrate ALARP and acceptable risk levels is recognised as best practice in the oil and gas and other industries.

[12] UK Department for Environment, Food and Rural Affairs (2011). Guidelines for Environmental Risks Assessment and Management. Green Leaves III. November 2011.

2. YULLEROO GASFIELD CONCEPTUAL FIELD DEVELOPMENT

2.1. Introduction

The Canning Basin hosts a very large unconventional (tight) wet gas accumulation. Appraisal of the resource has been undertaken in a staged and strategic manner with the results of each activity carefully assessed before the next one is carried out. This has involved the acquisition of seismic surveys, the drilling of exploration and appraisal wells and the hydraulic fracture stimulation of numerous zones in vertical wells to confirm rock and hydrocarbon properties and potential deliverability. These stages have been completed for the Yulleroo area, and the next stage of the appraisal program will involve preliminary development planning and the drilling and multi-zone fraccing of horizontal sections in the well bore.

The exploration and appraisal activity has been focused on two areas of the basin: the eastern side in the Asgard/Valhalla area (within EP 371 now held 100% by Mitsubishi Corporation) and the Yulleroo area near Broome (within EP 391/EP 436 now held 100% by Buru Energy).

This Section sets out a conceptual staged development of the Yulleroo gas field based on current technical and operational knowledge. Once further technical and operational data is obtained the conceptual plan will be refined, but the overall concept of a staged development and the use of pad drilling with numerous wells per pad will remain.

The conceptual field development is specific to the Yulleroo area and considers a full-scale development of some 714 PJ of sales gas together with associated liquids at a nominal production rate of 130 TJ per day over an approximately 20 year period. This rate is sufficient to support an export pipeline to the Pilbara and is considered to be a realistic first stage development scenario. As an intermediate step, a pilot project producing some 20 TJ per day would be undertaken to provide gas to local markets including power generation and mineral processing. This would provide increased energy security to local communities, and be an economic multiplier for local service providers and Traditional Owners.

To ensure quality baseline information is available when planning appraisal and development activities at Yulleroo, Buru Energy has been collecting environmental information across the region since 2006 (pre-2010 as ARC Energy). Environmental surveys have included the collection of a large amount of flora and fauna information, which has provided a comprehensive understanding of the region's biodiversity. In addition, a separate study has focussed on understanding the distribution and ecology of the greater bilby (*Macrotis lagotis*), which is listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* and the *Biodiversity Conservation Act 2016*. Surveys of bilby populations were undertaken in participation with the Yawuru Native Title Holders who also collected cultural information. Buru has supported a PhD project at Murdoch University to examine the disturbance ecology of the greater bilby in the Canning Basin. This project includes identification of preferred habitat and distribution of bilbies across the Yulleroo area. All collected information will be used to plan and mitigate impacts to the environment during planning for a development project.

2.2. Yulleroo Resources

An independent review of gas resources in the Yulleroo area was undertaken by RISC Advisory (RISC), dated at 1 December 2017. This review estimated that there is in excess of 700 PJ of contingent resources in the immediate Yulleroo area[13], where there is good control provided by four wells and supported by the wet gas flowed to surface following the fraccing of the Yulleroo 2 well. These resources

[13] Buru Energy (2018). ASX Release: Increase in Contingent Resources and Identification of Prospective Resources at Yulleroo. Available at: https://www.asx.com.au/asxpdf/20180118/pdf/43qwtwqm3d5kz6.pdf

are more than sufficient for a domestic gas supply project, and could in time supply markets in the Pilbara.

Analysis of gas produced from the Yulleroo 2 well during the flowback phase determined the gas had a low level of associated inert gases; meaning the gas is suitable for pipeline sale with little processing required. The gas also contains significant amounts of condensate (light oil) and LPGs, which would provide a valuable additional product stream that could supply local markets or be exported.

2.3. Conceptual Field Development Design

2.3.1. Stages of Development

It is envisaged that the development of the gas resources at Yulleroo would be undertaken in two stages: Local Gas and Domestic Gas (Domgas).

2.3.1.1. Local Gas

The first stage (Local Gas) would be a small-scale development on existing well pads to supply gas to the local market, including power generation and mineral processing. This project would involve the drilling of up to eight wells from one or two of the existing well pads with the establishment of a scalable central processing facility.

The central facility would remove the condensate and LPG from the gas and the gas would then be processed either to LNG or compressed to CNG in a small-scale facility for transport to local customers. This local gas project would provide jobs in the drilling, construction and operating phases and would also serve as a training ground for local employees for the next phase of the project.

There is a local market that is currently being serviced by LNG trucked from Karratha of some 6 TJ per day[14]. In addition, current and future markets currently serviced by diesel could add up to a total of some 20 TJ per day.

The local gas project would provide verification of the geological and operational parameters required to proceed to full scale development and would provide an immediate and substantive benefit both economically and in reduction of CO_2 emissions through reduction of transport and diesel usage. This project is scalable and with incremental development will be able to provide gas at these levels for decades.

2.3.1.2. Domgas

The second stage (Domgas) would involve construction of a pipeline to the Pilbara to supply local markets in the Pilbara, where there is a very strong incentive to transition to gas from diesel for power generation, transport and mining usage given the cost and emission reduction benefits. From the Pilbara there is also the potential to provide gas into the southwest WA domestic market.

The majority of initial construction activity at the well sites will involve drilling the required production wells. There will be a focus on the use of local people for drilling (minimal FIFO), which will provide significant job opportunities for Traditional Owners.

The conceptual Domgas stage has been based on the contingent (2C) volume of sales gas at the Yulleroo field estimated by the independent resources review completed in late 2017[15] of 714 PJ of gas.

[14] Directhaul and Energy Developments Ltd (2016). Case Study: Productive Safety - Safely Transporting Essential LNG. Transafe WA Forum. Karratha WA, November 2016.

[15] Buru Energy (2018). ASX Release: Increase in Contingent Resources and Identification of Prospective Resources at Yulleroo. Available at: https://www.asx.com.au/asxpdf/20180118/pdf/43qwtwqm3d5kz6.pdf

The project as modelled would produce at a nominal 130 TJ per day of gas sales over a 17-year period, with a three year "tail" period making the model project 20 years.

The modelled Domgas development will require up to eight well pads with ten wells drilled from each, for a total of 80 wells. It is estimated that between two and ten wells will be drilled and fracced each year under this scenario. The gas will be processed at the expanded central facility established for the Local Gas pilot project, with the associated condensate and LPG transported separately for local consumption and/or export by tanker.

2.3.2. Development Approach

The development of a gas project at Yulleroo represents a unique opportunity to apply the most modern and efficient techniques in an area that is not constrained by the small leasehold areas typical in North America. The North American tenure system makes it difficult to fully exploit the proposed "super pad" technology, except on government lands or in areas of large freehold title such as West Texas. Developments in the Canning Basin can therefore be undertaken by drilling long reach horizontal wells from multi-well "octopus" or "super" pads (Figure 2), resulting in very significantly reduced surface disturbance and highly efficient operations, with fewer pipelines and processing facilities.

Current technology allows up to 40 wells to be drilled from "superpads"[16]. For the purposes of the Yulleroo conceptual development, a less intensive development of up to 10 horizontal wells will be drilled from a single pad. This does not reduce the number of well bores and hence gas recovery when compared to single well pads, but it reduces the surface disturbance from both the well pads and the associated infrastructure by a factor of approximately six. As noted in the 2015 WA Parliamentary Inquiry Report, the use of multi-well pad technology reduces the surface footprint of gas-fields and thereby minimises the environmental impact of tight gas development projects[17].

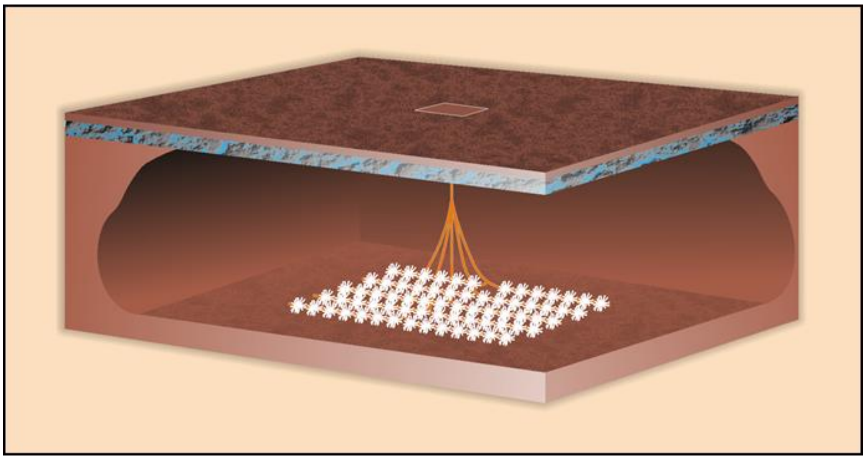


Figure 2: Indicative schematic of horizontal drilling from a single well pad.

2.3.2.1. Construction Phase

For the construction phase, each well site will be cleared to around 250 m x 250 m (approximately 6.25 ha). This will accommodate the drilling rig, the ten development wells, the frac spread and associated services.

Each well is drilled to the required vertical depth (approximately 2,500 to 3,000 m) and then deviated to drill horizontally along the geological formation for the required distance, which may be between one

[16] Pittsburgh Post-Gazette (2018). These days, oil and gas companies are super-sizing their well pads. 15 January 2018. Available at: http://www.post-gazette.com/powersource/companies/2018/01/15/These-days-oil-and-gas-companies-are-super-sizing-their-well-pads/stories/201801140023

[17] Finding 1 of: Standing Committee on Environment and Public Affairs (2015). Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas. Report 42. November 2015.

and four kilometres. Yulleroo development wells will likely include a nominal two-kilometre horizontal section. After each well or section of well is completed, the rig is moved a short distance along the well pad to the next well. On average, each well would take between 35 and 45 days to drill, noting that the North American experience is that these drilling times will be very substantially reduced as the project proceeds. Drilling times may be reduced by utilising a 'batching' process, whereby one section is drilled at a time on a number of wells, with the rig moving between the wells.

Once a number of wells are drilled, the wells would be hydraulically fracture stimulated in batches. Fraccing of each well is estimated to take four to five days (see Section 0).

2.3.2.2. Production Phase

Once the ten wells on each well pad are completed and producing gas, the size of the well pad can be reduced to a much smaller area around the well head (approximately 3 ha). Reducing the well pad size involves ripping to remove compaction, respreading of stockpiled topsoil and vegetation, and allowing the natural vegetation to recolonise the area. An example of a completed well pad during the production phase is provided in Figure 3.

Source: MEG Energy[18]

Figure 3: Example well site during the production phase.

2.3.3. Well Pad Layout

The surface layout of the conceptual Yulleroo field is shown in Figure 4.

The location of the central processing facility and water handling facility will be optimised as the field is designed. This infrastructure will either be located centrally in the field or to the northwest side of the field which is closest to Great Northern Highway.

A total of ~100 hectares would be required to be cleared for the Yulleroo field development. This represents ~0.02% of the vegetation association in the region (refer Section 3.2.2) and ~0.5% of the vegetation in the Yulleroo area, defined as the Yulleroo 3D seismic survey area, which covers around 60 sq. km. As described in Section 1.3.1, as the resource is continuous, the surface location of the well sites can be adjusted to avoid sites of environmental and cultural importance.

[18] MEG Energy (2018). Corporate Responsibility – Environment – Land. Accessed 12 March 2018. Available at: http://megenergy.com/corporate-responsibility/environment/land

2.3.4. Surface Facilities on Each Well Pad

The following surface facilities will be located on each well site:

i) Each well head will have appropriate pressure control systems and instrumentation to allow the well to be monitored remotely.
ii) A separator will be located on each well site to separate the produced hydrocarbon liquids (condensate or light oil) and the minor amounts of water produced from the gas. The LPGs entrained in the gas stream will be removed at the central processing facility.
iii) Piping will be required to transfer the liquids back to the central facility and water handling facility.

All infield flowlines to convey hydrocarbons will be buried. These will run in pipeline corridors mainly coincident with vehicle access ways to minimise ground disturbance.

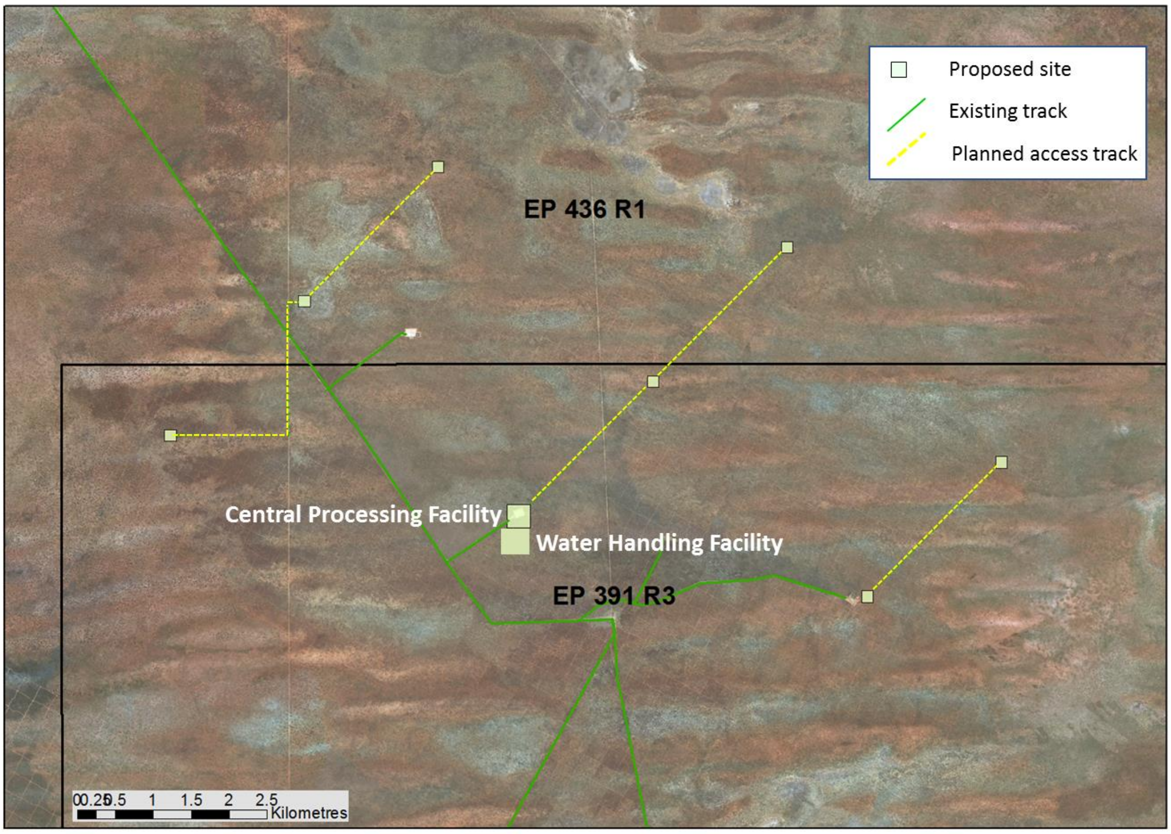


Figure 4: Conceptual layout for Yulleroo development.

2.3.5. Central Processing and Water Handling Facilities

Production of gas and liquids from each well site will be processed at a central processing facility (Figure 5). The central processing facility would be around 300 m x 300 m (9 ha).

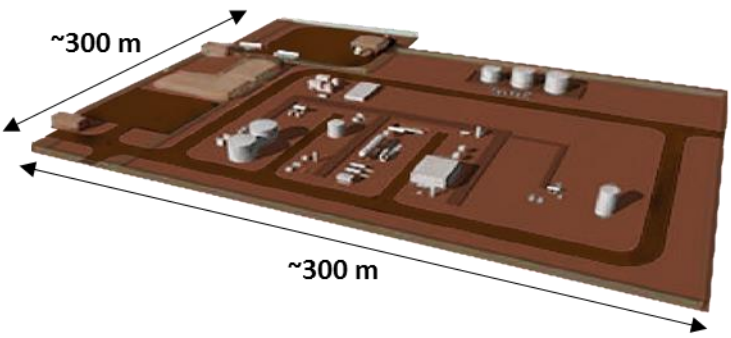


Figure 5: Indicative central processing facility design.

At the central processing facility, the remaining liquids would be extracted from the gas along with the LPG fraction. The liquid fractions and LPG would be either trucked or transferred via pipeline to a storage facility for local use and shipment.

For the Local Gas stage of the project, a processing facility to produce small quantities of transportable gas (Compressed Natural Gas (CNG) or Liquified Natural Gas (LNG)) would initially be located on the central processing facility site.

The water handling facility would be located adjacent to the central processing facility and would be of a similar size (approximately 9 ha), consisting of three above-ground surface water ponds (source water, frac water, flowback water). Flowback water received at the water handling facility would be transferred to the frac water pond for reuse in subsequent fracs, or re-injected into the Laurel Formation, as required.

2.3.6. Petroleum Wells

As outlined in Section 2.3.2, horizontal wells will be used to develop the gas field, allowing as much subsurface formation to be accessed as possible from the smallest area on the surface (Figure 6). Horizontal wells are drilled vertically or on a specific trajectory to a “kick off” point where they are deviated to track horizontally along the desired geological formation. This technology is well developed and wells can now be steered with sub-metre accuracy to well lengths of many kilometres.

Horizontal wells in the Yulleroo field will be drilled to between 2,500 m and 3,000 m depth and then deviated and drilled for up to a further 2,000 m. The 2,000 m horizontal section is located in the target Laurel Formation and is the section where the individual fracs will be placed. Wells are constructed using standard industry practices with up to four strings of casing and continuous pressure monitoring. The fracs along this section are modelled to extend ~50 m vertically and ~250 m horizontally from both experience at the recent Valhalla North and Asgard fracs and rock properties from the Yulleroo wells. Consequently, the horizontal sections of the wells will be placed around 500 m apart.

Fracs will be nominally spaced 100 m apart along the horizontal section and will consist of 70 m of stimulated interval with 30 m of spacing between stages. The number of fracs along a horizontal section will vary between 15 and 20 (depending on optimal spacing requirements).

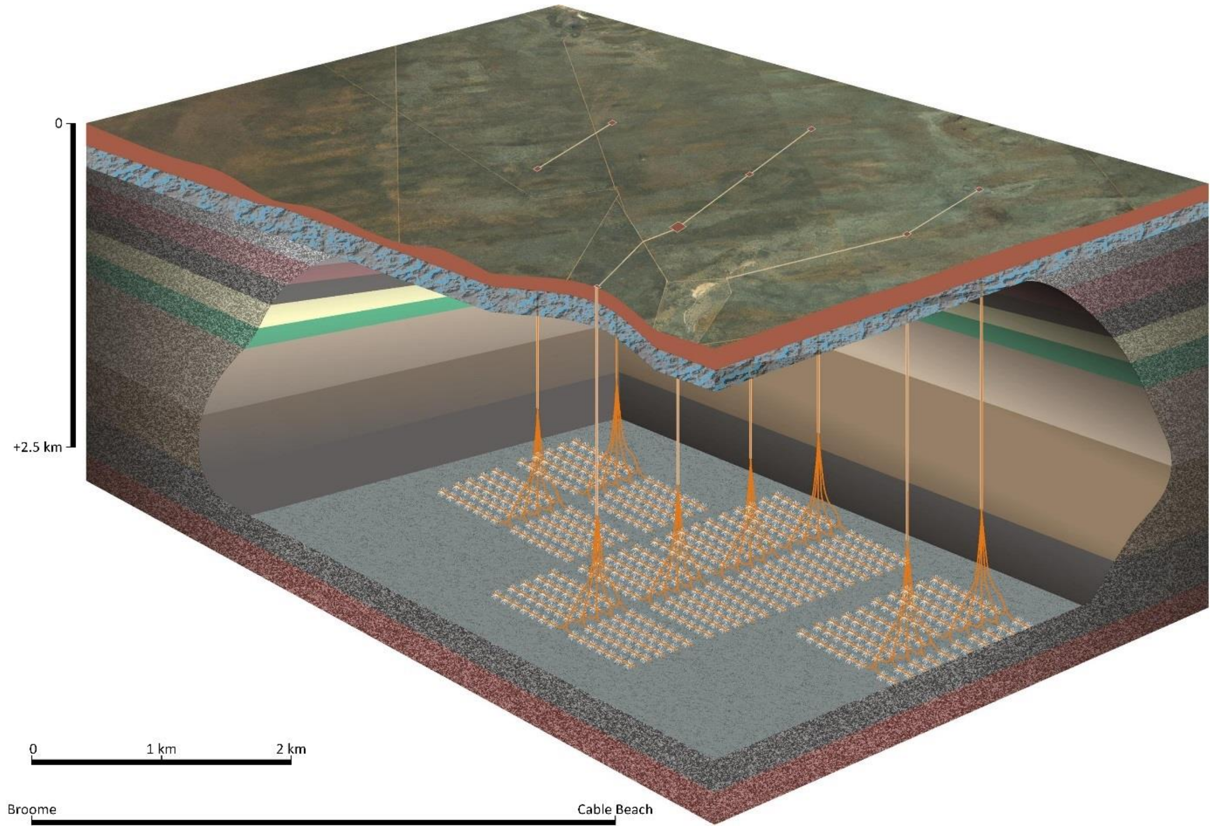


Figure 6: Indicative schematic of a commercial Yulleroo field development.

2.3.7. Overall Field Life

The data collected to date by Buru Energy in drilling and fraccing numerous wells and zones allows an estimate of the potential gas recovery per well. These data have been reviewed by independent technical experts who have estimated that individual horizontal wells as described above (Section 2.3.6) should recover some 8.9 bcf of gas each, with associated liquids. However, these recoveries need to be validated by the performance of horizontal wells and this is part of the data to be acquired during the Local Gas phase of the development.

Fracced wells produce large volumes of hydrocarbons initially, with production rates then declining more quickly than “conventional” wells. Consequently, field development would involve a short ramp up phase and then a consistent well drilling and fraccing program to produce at a steady 130 TJ per day. More wells will be drilled and fracced in the early stages of field development to establish the initial plateau rate. Wells will then be progressively drilled and fracced to maintain the required production rate for the remainder of the field life.

The number of wells required per year is set out in Figure 7, together with the cumulative number of wells in the conceptual Yulleroo field development. In total, 80 wells will be drilled and fracced over the 17-year life of the development. Additional production will be possible by drilling additional wells, but the model assumes that the field development stops after the independently certified 2C resources have been produced. If no more wells are drilled the field rates will gradually decline and a 20-year field life is assumed to take into account this tail production.

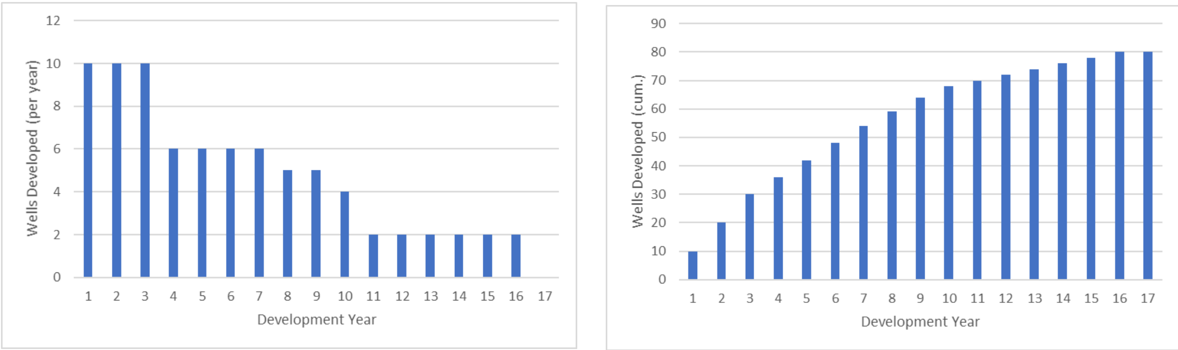


Figure 7: Number of wells developed per year (left) and cumulatively over the life of the field (right).

2.3.8. Fraccing Process

The fraccing process occurs after the well has been drilled and involves the pumping of water, proppant (sand) and chemical additives down the well into the target formation. The water acts as the carrier fluid, the sand enters the micro fissures formed by the water injection and props these open to allow the gas to flow, and the chemicals are added principally to reduce friction in “slick water” fracs. The volume and number of chemicals has reduced dramatically over the last few years as large-scale programs are undertaken in North America.

Typically, the fluid used for fraccing consists of ~94% water, ~5% sand and ~1% chemical additives. For more information on the frac fluid used by Buru Energy, refer to Section 3.4.5 below. The frac phase requires the mobilisation of a specialist crew to the well site. The frac spread consists of an array of large truck mounted pumps together with specialist equipment for handling the proppant and required chemicals. Approximately 30 trucks are mobilised to site for the hydraulic fracturing stage. An aerial image of a frac spread on location at Asgard 1 is shown in Figure 8.

Each frac takes several hours to pump with the anticipated 15 to 20 fracs per well taking a total of four to five days (noting that in North America a frac program of this nature would take some 2 to 3 days due to higher efficiencies). The overall development plan requires the drilling of a maximum 10 wells per year, so fraccing operations will occur for a maximum of around 50 days per year in several phases.

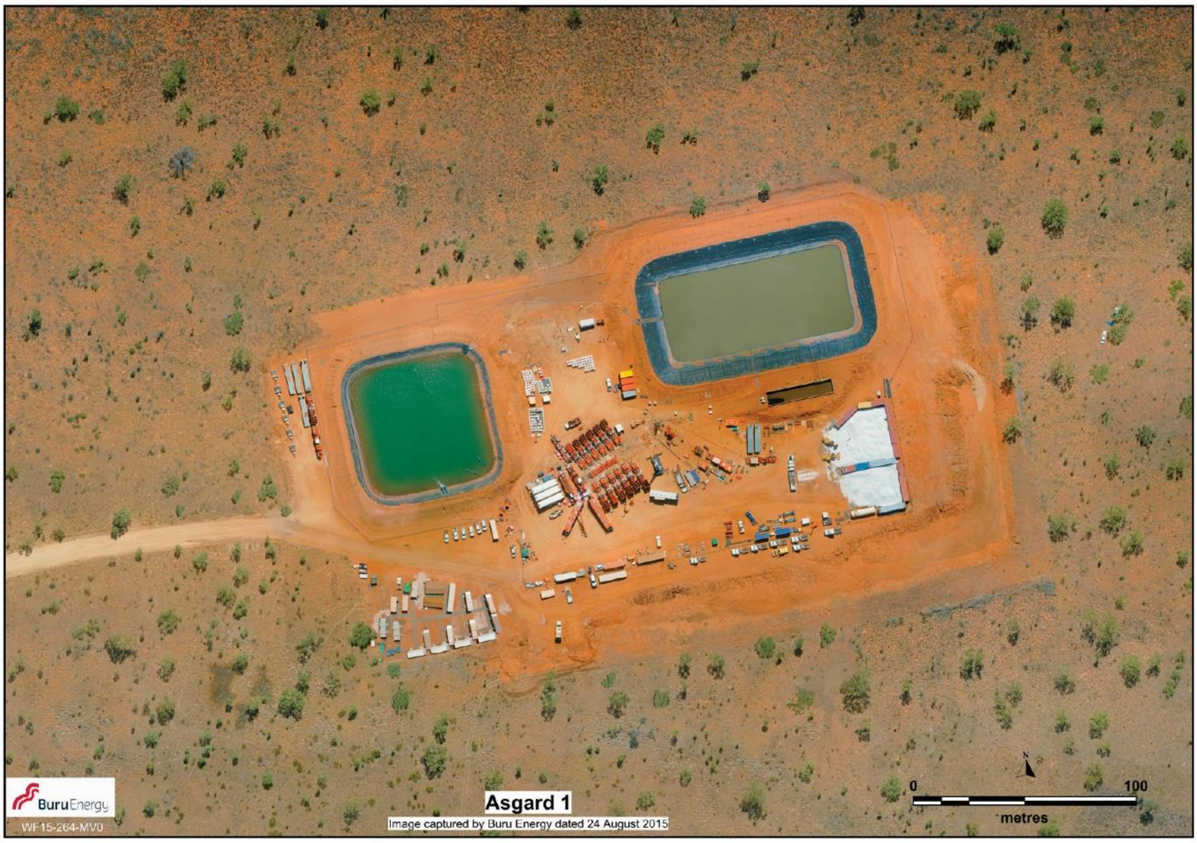


Figure 8: Frac spread on location at Asgard 1 (August 2015).

2.3.8.1. Water Requirements

For the development of a gas field at Yulleroo, water is required for site construction, drilling, camp use and hydraulic fracturing. Adopting a conservative estimate for each of these activities, approximately 21 ML of water is estimated to be used for each well.

Under this development scenario first use water required for the development of the Yulleroo field would be extracted from groundwater and will be licenced under the *Rights in Water and Irrigation Act 1914*. In the Yulleroo area, the surface groundwater resource is the Broome Sandstone Aquifer. The estimated volumes of water that will be used for fraccing of each well are provided in Table 1.

Table 1: Water used for fraccing each petroleum well.

Description	Detail
Number of fracs	15-20 (average 17)
Water use per frac	0.95 ML
Water requirement per well for fraccing	16.15 ML

Based on results of previous fracs in the Canning Basin and analogues from similar fields globally, it is estimated that approximately 50% of the water used for fraccing will flow back to the surface as "flowback water". During the 2015 frac program, Buru Energy undertook a comprehensive water sampling and analysis program to characterise this flowback water (see Section 3.4.6). As well as demonstrating that the flowback water poses low risk to human health and the environment, it was determined that the water is suitable for reuse in fraccing operations. This will allow recycling of flowback water, which will reduce the overall water requirements by around 50% after the initial fracs required for the ramp up phase. Using these parameters an estimate of the water use over the life of the Yulleroo field can be estimated.

The total water use for the field is a function of water extracted from groundwater and recycled flowback water (Figure 9). A total of 1,065 ML (1.065 GL) of water will be extracted from the aquifer over the 20-year life of the field. Of this amount, 0.4 GL will be used for the construction/drilling phase and 0.655 GL will be used for fraccing. Maximum groundwater extraction occurs in the first year (~0.21 GL) when all water is sourced from the aquifer (as there is no significant amount of flowback water yet available for reuse). Over the field life, an average of ~0.055 GL is used per annum (pa).

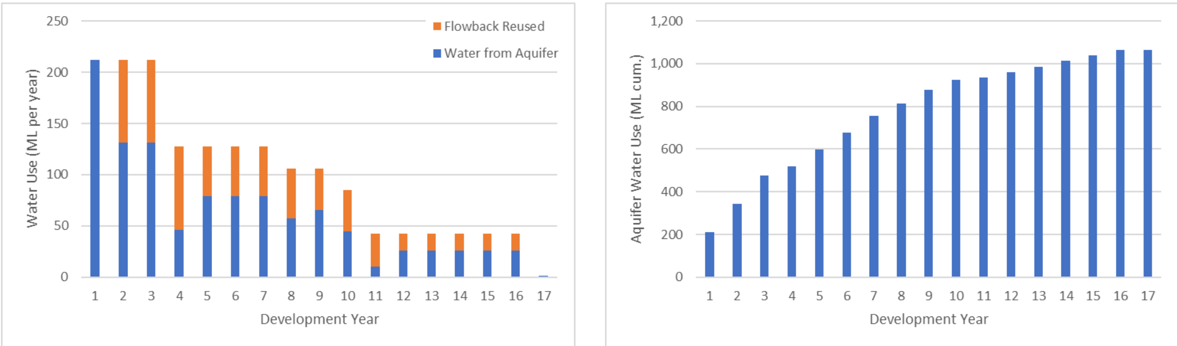
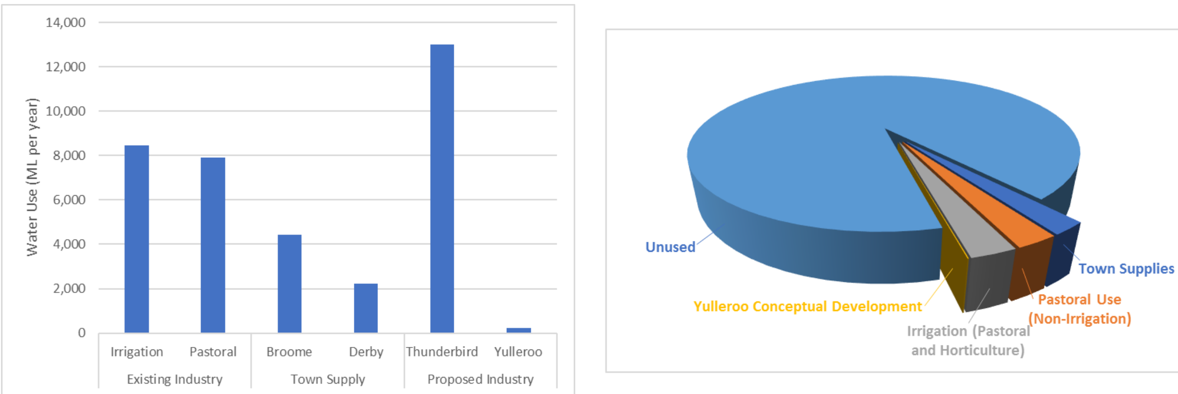


Figure 9: Yulleroo field development water use per year (aquifer and flowback reuse) (left) and cumulative aquifer use (right).

In comparison, water use of the town of Broome (~4.4 GL pa) and water use of Sheffield Resources' Thunderbird mineral sand mining project (up to 13 GL pa) are both significantly larger volumes (Figure 10). The anticipated water extraction is also less than one percent of the 50 GL that the Department of Agriculture estimates can be sustainably extracted from the Broome Sandstone Aquifer[19], and an even smaller proportion of the greater Canning Basin's sustainable yield (Figure 10).



Annual water usage in the Canning Basin   Water usage proportions of the allocation limit

Data Sources: DOW 2010[20], Thomas 2008[21], Sheffield 2017[22]

Figure 10: Comparison of annual water usage in the Canning Basin.

A numerical groundwater model has been constructed to understand the environmental impact associated with extracting this water from the Broome Sandstone in the Yulleroo area. This information is provided in Section 3.7.3 below.

[19] Paul, R.J., George, R.J. and Gardiner, P.S. (2013). A review of the Broome Sandstone aquifer in the La Grange area. Resource management technical report 387, Department of Agriculture and Food, Western Australia, Perth.
[20] Department of Water (2010). Kimberley Regional Water Plan 2010-2030. Department of Water, Western Australia.
[21] Thomas, J.F. (2008). Water Futures for Western Australia 2008-30. Report for the Department of Water, Western Australia.
[22] Sheffield Resources Limited (2017). Thunderbird Mineral Sands Project: Public Environmental Review. EPA Assessment No. 2073. Prepared by MBS Environmental, January 2017.

2.3.8.2. Proppant

The other key material used in the fraccing process is proppant. Proppant used for fraccing is essentially construction sand, and is used to prop the fractures open at the completion of the pumping stage. This allows the gas to flow to the well bore. At present, there is no established source of proppant sand in the Canning Basin and for the fracs that have been undertaken, sand has been trucked from the south-west of the state. For a full development, sand would be required to be sourced locally, which would provide an excellent opportunity for local businesses.

The amount of proppant sand required per frac stage would be subject to continual refinement as the project progresses. An estimated 250,000 lbs (~113 tonnes) of sand would be used for each frac stage, which equates to ~1,920 tonnes per well, or up to 19,200 tonnes per year (Figure 11). Sand would likely be transported to the well site using triple road trains, with some 27 return truck movements required to move the sand from the quarry to the well site for each well.

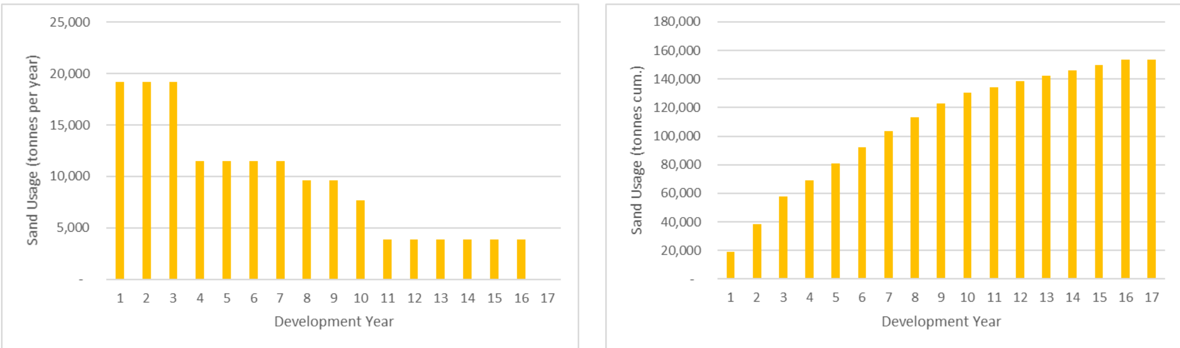


Figure 11: Tonnes of sand used per year (left) and cumulatively over the life of the field (right).

Traffic movements associated with the Yulleroo field and risks on public safety are considered in Section 3.9.2.

2.4. Economic Benefits

Considering the economic benefits of the Yulleroo conceptual field is specifically outside the terms of reference for the scientific inquiry, so no modelling to identify economic benefits to stakeholders is made available. However, production rates from the Yulleroo conceptual field (~130 TJ/day over ~17 years) are comparable to the 'Breeze' scenario modelled by ACIL Allen for the Northern Territory Inquiry (~100 TJ/day over 25 years)[23]. The operating environment in the Northern Territory is not dissimilar to the Canning Basin, which means the Breeze scenario modelled by ACIL Allen provides a useful reference point when considering the magnitude of the economic benefits associated with the field.

The Breeze scenario is estimated to create an additional 2,145 direct and indirect FTE jobs, at an average rate of 82 FTE jobs per annum. It will also support an aggregate population growth of 5,061 persons, or an additional 195 persons per year. Much of this employment is likely to occur in regional areas and in regions with large Aboriginal communities. These regions are typically economically disadvantaged, as outlined in Section 6.1 below.

[23] Chapter 13 in: ACIL Allen (2017). Economic Impacts in Scientific Inquiry into Hydraulic Fracturing in the Northern Territory. Draft Final Report. December 2017.

3. ENVIRONMENTAL IMPACTS

Outcomes of numerous independent reviews of hydraulic fracturing in tight and shale gas formations have shown that the impacts are minor and that risks can be adequately managed through the application of a robust regulatory regime. The key environmental risks associated with hydraulic fracturing are due to chemical storage and handling and spills on surface. These activities are not unique to hydraulic fracturing or even the oil and gas industry, and are adequately managed (and regulated) for a variety of industries across WA. These include the mining industry, which uses and transports long distances a wide variety of chemicals with toxicity many times greater than those used for fraccing (which are generally classed as non-toxic).

Prior to Buru Energy's 2015 frac program at Asgard 1 and Valhalla North 1, robust monitoring programs were designed in consultation with relevant government departments and independent specialists advising Traditional Owners. These monitoring programs covered several environmental values/factors including water quality and quantity, air quality and emissions, impacts associated with seismicity and characterisation of flowback water. The results of these monitoring programs are presented in the following Sections and detected no environmental impacts from the ~3 ha well sites.

3.1. Environmental Benefits and Leading Practice

The Canning Basin is vast, remote, undeveloped and sparsely populated, meaning many aspects of the local environment are poorly understood when compared to more populated or accessible areas of WA. Buru Energy has made significant investments in research projects to increase the understanding of the Canning Basin environment, including: i) supporting a research project at Murdoch University investigating the disturbance ecology of the greater bilby, and ii) characterising the hydrogeology of project areas. Further details on these studies are provided in Sections 3.1.1 and 3.1.2.

Buru Energy's presence in the basin also has associated benefits as the many flora and fauna surveys undertaken. The specialist consultants utilised are required to report results of the flora and fauna surveys to the state government, contributing valuable data and increasing the knowledge of the Canning Basin environments.

Additional examples of Buru Energy's commitment to sustainable development of the Canning Basin include:

- refining seismic survey techniques to minimise ground disturbance;
- drilling slimhole exploration wells to minimise environmental footprints; and
- training of Traditional Owner Environmental Cadets in Conservation and Land Management.

3.1.1. Bilby Ecology

The greater bilby (*Macrotis lagotis*) is listed as Vulnerable under *Environment Protection and Biodiversity Conservation Act 1999* and the *Biodiversity Conservation Act 2016*. In 2012, Buru Energy recognised that little was known about bilbies in the Canning Basin, as most studies were focussed on populations in the Tanami and Gibson deserts, and an isolated population at Currawinya in Queensland. Buru Energy has been collecting information on the presence of bilbies in the Yulleroo area since 2012 when the program commenced.

Given the lack of ecological information available for the bilby in the Canning Basin, to inform risk assessments as well as generally, Buru Energy supported a PhD project at Murdoch University on the disturbance ecology of the greater bilby (*Macrotis lagotis*). The PhD project was undertaken between February 2014 and December 2017 and collected fundamental ecological information for bilbies in the Canning Basin.

The project focussed on the recovery of pindan vegetation that had been disturbed on seismic survey lines, the influence of survey lines on distribution of predator and prey movements. The project used remotely sensed habitat variables to predict occupancy of the greater bilby, dietary preference of the bilby, and the role of bilbies as ecosystem engineers. The effect of fire and seismic lines on bilby ecology was also examined, including any potential interaction between the two. The project also involved collaboration with Traditional Owner ranger groups, to ensure knowledge regarding bilbies is directly passed on to these groups.

Buru Energy placed no restrictions on publication of the results, to ensure that the results of the study are available to all stakeholders and land managers in the West Kimberley, regardless of the findings. The PhD thesis provides important ecological information that will be critical for understanding the response of bilbies to natural and anthropogenic disturbance, and minimising impacts of petroleum activities and those of other landholders. The PhD thesis was submitted for review in December 2017[24] and accepted with minor revisions in March 2018.

3.1.2. Hydrogeology

The Canning Basin is the largest groundwater resource (by volume) in WA and the second largest in Australia after the Great Artesian Basin. Despite the size of the Canning Basin groundwater resource, there have been few studies carried out on the regional hydrogeology. Estimates of sustainable yield from the basin are between 615,000 ML/yr[25] and 827,000 ML/yr[26]. Of this, approximately 33,134 ML (~4%) is being consumed annually.

The potential of the Canning Basin water resource has been recognised by the WA State Government with the implementation of the *Water for Food Project* which seeks to increase agricultural productivity through irrigation. Four *Water for Food Projects* are proposed to exploit the Canning Basin groundwater resource including:

- Fitzroy Valley Groundwater Investigations;
- Knowsley Agricultural Area Water Investigation;
- La Grange-West Canning Basin: Groundwater for Growing Opportunities; and
- Mowanjum Irrigation Trial.

Buru Energy has consulted with the WA Department of Water and Environmental Regulation (DWER) and the Department of Primary Industries and Regional Development (DPIRD) to discuss how hydrogeological assessments and hydrogeological information collected by Buru Energy could supplement the Water for Food Project. A range of information from petroleum wells, water bores and hydrogeological assessments has been provided to these government agencies as well as interested Traditional Owner groups, allowing these groups to build on the scientific investigations undertaken by Buru Energy in the region.

3.1.3. Development of Raised Blade Seismic Techniques

Seismic surveys are undertaken prior to drilling or fraccing operations, to image the rock formations below the ground. This information is then used to select and target areas and rock strata for drilling and potentially fraccing. To allow vehicle access across the seismic survey area, temporary access tracks are cleared. Over the years, Buru Energy has refined its temporary clearing technique to minimise disturbance.

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[24] Dawson, S.J. (2017) Disturbance of ecology of the greater bilby (*Macrotis lagotis*). PhD Thesis, School of Veterinary and Life Sciences, Murdoch University (submitted).
[25] WRC (2001). Caring for Kimberley groundwater. Water and Rivers Commission water advice No. 15.
[26] ANRA (2010). Australian Natural Resources Atlas, based on records from 2000 to 2002.

In recent years, seismic lines have been delineated using “raised blade scraping”, where a bulldozer blade is used to remove vegetation at or above ground level, with little or no disturbance to topsoil and vegetative matter below the surface. Following the scraping of seismic lines, any windrows of soil that develop along the margins of the seismic lines are graded to match the surrounding landscape.

This method results in minimal disturbance of seed and root stock, preventing erosion and allowing the vegetation to rapidly regenerate.

In addition, wireless node geophones have recently been employed, which result in less ground disturbance than traditional wired geophones.

3.2. Land Impacts

3.2.1. Terrestrial Environmental Quality

Buru Energy operates in the Dampierland Bioregion of the Canning Basin, an area dominated by eolian landscapes (landscapes that have been formed by action of the wind). These landscapes are dominated by sand sheets and sandy rises that are occasionally dissected by alluvial or lacustrine features associated with surface waters.

Vegetation within the Dampierland Bioregion is relatively uniform and characterised by the pindan assemblage that occurs on sand plains. Pindan is described by Beard (1979) as a “*grassland wooded by a sparse upper layer of trees and a dense, thicket-forming middle layer of anarmed phyllodal Acacia*”[27]. It consists of shrublands and grasslands characterised by low tree savanna mapped as ribbon grass with boababs, bauhinia and beefwood. The trees are small, reaching only 3 to 6 m except for boababs which can grow to 15 m high.

Rangelands are the dominant ecosystems in the Canning Basin and cover 87% of WA. Rangelands are areas of open country which are used for grazing or hunting animals. In the West Kimberley, rangelands are most commonly used for cattle grazing (pastoral rangelands) but are also home to a large proportion of Australia’s indigenous people and are culturally important for uses such as hunting and the collection of bush foods.

Nationally, rangelands are under increasing threat. This is mostly due to unsuitable fire regimes and the prevalence of feral animals and weeds. These pressures are driven by unsustainable land use practices and affect the productivity of rangelands ecosystems and threaten native species such as the greater bilby (*M. lagotis*) and the spectacled hare wallaby (*Lagorchestes conspicillatus*).

3.2.2. Biodiversity

The conceptual field design outlined in Section 2 indicates approximately 100 ha (1 sq. km) of vegetation would be disturbed for the development of a commercial field at Yulleroo. The vegetation in this area is Vegetation Association 7748, which is described as “*Shrublands, pindan; Acacia tumida shrubland with grey box & cabbage gum medium woodland over ribbon grass & curly spinifex*”[27]. Vegetation association 7748 is well represented in the region of the southern Dampier Peninsular, with the Yulleroo area within a 4,744 sq. km area of this vegetation association. The clearing required for the Yulleroo commercial field represents ~0.02% of the vegetation association in this area.

Following construction of the petroleum wells on the well pads, the well sites will be progressively rehabilitated during the operational phase (as described in Section 2.3.2.2). This will reduce the net clearing required for the field to 70 ha (0.7 sq. km).

[27] Beard, J.S. (1979). Vegetation survey of Australia: Kimberley. 1:1,000,000 Vegetation Series. Map and Explanatory Notes, Perth, Western Australia: University of Western Australia Press.

Fauna of conservational significance that may be present in the Yulleroo area include the greater bilby (*M. lagotis*) and the spectacled hare wallaby (*L. conspicillatus*). Buru Energy has been collecting baseline information on fauna species occurring in the Yulleroo area since 2012, including supporting the research project at Murdoch University described in Section 3.1.1. The availability of extensive baseline datasets will allow Buru Energy to plan the Yulleroo gas field to minimise impacts on bilbies and other species of conservation significance in the area.

An environmental impact assessment for the gas field will be required to be undertaken prior to any development activities occurring. This will include consideration of the impact of clearing on habitat fragmentation and movement of fauna species.

3.2.2.1. Weed Management

There are multiple land uses in the West Kimberley region including Native Title, pastoral activities, petroleum and mining exploration. Many of the weeds occurring in the West Kimberley have been introduced by other land users, in particular by pastoral activities. For example, buffel grass (*Cenchrus ciliaris*) is a weed species that is common across the West Kimberley. This species is highly productive and is recognised as an excellent fodder species. As a result, this species was widely introduced by pastoralists to improve pastoral quality. While this practice has now abated due to increased awareness of the threat that introduced species pose to native biodiversity, buffel grass occurs widely on pastoral stations in the Kimberley.

Buru Energy uses a risk based approach to minimise the spread of weeds associated with petroleum activities. This risk based approach is based on biosecurity checks of equipment for weeds and seeds prior to arrival in the area for ground disturbing activities. During operations, all vehicles and equipment are restricted to operational areas and access tracks.

3.2.2.2. Noise Impacts

The areas that are prospective for oil and gas activities in the Canning Basin are remote, being located at least 20 km from the nearest homestead, 30 km from the nearest community and 70 km from the nearest town. This means that impacts to amenity associated with hydraulic fracturing are mitigated through the absence of nearby receptors.

Impacts of noise associated with fraccing on biodiversity are considered to be low risk based on the following:

- noise impacts are restricted to short periods of ‘loud’ operations – the hydraulic fracturing phase occurs over a period of days with pumping restricted to a few hours for each frac;
- operations that occur over a broader area such as mobilisation and demobilisation are also restricted to short periods (days); and
- vehicles, machinery and equipment are muffled and maintained to relevant standards to ensure efficient operations with no unnecessary noise.

Buru Energy’s contractor used for the 2015 frac program undertook a noise monitoring study during operations at another site in 2016. During this study, a noise logger was located approximately 800 m from a well site where frac operations were being undertaken. Two days of operations were recorded, which on both days included start-up and warm-up of frac equipment, engaging pumps, hydraulic fracturing, and shutdown of engines at the completion of operations. Noise loggers located at operator positions (~1 m from the source) recorded noise levels of between 89 and 106 dB(A) during engine warm-up/idling and between 95 and 108 dB(A) during pumping (fraccing). Noise levels recorded 800 m away from the frac site were typically less than 65 dB(A) and had negligible impact on the ambient noise level.

3.2.2.3. Impacts of Light on Biodiversity

Buru Energy manages light impacts by minimising light generation to that required for safe operations. Further, all lighting on operational sites and camp sites is installed to light the required areas while minimising light spill to the surrounding vegetation (i.e. lighting is installed facing inwards). Use of a gas flare is generally only required during initial exploration well testing phase of operations and would not be used during ongoing gas development and production. There are also techniques to ensure that gas flares are minimised and data is acquired from relatively low levels of testing operations. Once the central facilities are operational all gas, which is valuable commercial commodity, would be captured for sale.

Lighting during night-time operations would have a negligible impact on fauna, potentially attracting or deterring fauna present in the vicinity of the operations. Given the negligible footprint of operations within the surrounding landscape, deterring fauna from the immediate area of operations is unlikely to have any meaningful impact on the species.

In itself, fauna attraction from the immediate vicinity of operations would similarly not have any meaningful impacts on fauna. However, attraction to the operations would increase the potential for other impacts, particularly entrapment or vehicle strike. Buru Energy manages these risks by fencing well sites, fencing open excavations and/or providing fauna egress paths, and by restricting vehicle movements at night (both in the number of movements and vehicle speeds).

3.2.2.4. Rehabilitation and Closure

As outlined in Section 3.2.1, the dominant vegetation in the West Kimberley region of the Canning Basin is pindan. Buru Energy has been collecting information on the recovery of pindan vegetation since 2012. This information has been collected for well sites and seismic lines that were cleared from 2007, providing a 10-year time series of vegetation rehabilitation across operational areas. The following conclusions regarding rehabilitation success are drawn from the bilby PhD study (Section 3.1.1) and monitoring data collected by Buru Energy.

Once decommissioning of petroleum wells is complete, the well pads, access tracks and associated areas are rehabilitated. In the Canning Basin, rehabilitation of these areas is a two-step process comprising on-ground rehabilitation operations, followed by rehabilitation monitoring to measure rehabilitation success. If rehabilitation monitoring indicates that an area is not naturally rehabilitating, active rehabilitation is considered[28].

Rehabilitation operations involve ripping compacted areas, re-contouring the well sites to match the surrounding landscape and re-spreading stockpiled topsoil and vegetation across the disturbed area to encourage regrowth. Rehabilitation monitoring involves the periodic surveying of sites by an environmental consultant to measure rehabilitation success. Buru Energy reports the status of rehabilitated sites to DMIRS annually in January for the previous calendar year.

After one wet season, there is usually significant regrowth of vegetation across the disturbed area. Dawson (2017) found with no discernible difference in vegetation structure and community composition between control (reference) and seismic (impact) plots between 6 and 12 months after disturbance[29]. However, the response of individual vegetation structure characteristics between control and seismic plots did differ. Differences included understorey height and density, likely reflecting the time taken for the vegetation to grow back. Vegetation recovery can also be influenced by fire, which has a significant effect on the structure and species assemblage of control and seismic plots.

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[28] Note: This has not yet been required in Buru Energy's experience.

[29] Dawson, S.J. (2017) Disturbance of ecology of the greater bilby (*Macrotis lagotis*). PhD Thesis, School of Veterinary and Life Sciences, Murdoch University (submitted).

These results are supported by Buru Energy's general rehabilitation monitoring results, which generally show vegetation regrowth across cleared areas following one wet season, with full rehabilitation achieved over a period of years. Further data regarding rehabilitation of pindan vegetation continues to be collected by Buru Energy as the monitoring of rehabilitation continues.

3.2.3. Beneficial Use

The majority of Buru Energy's acreage overlaps with Native Title claims or determinations. The process that Buru Energy follows to consult with the relevant Native Title bodies, avoid impacts on cultural heritage and implement formal agreements is outlined in Section 7. This process ensures that Buru Energy's operations do not impact on potential beneficial uses of the area by the relevant Traditional Owners.

Buru Energy's tenements also overlap with numerous pastoral leases. This is the primary land use in the region, and therefore the most likely to be impacted by Buru Energy's development. Due to the reliable summer wet season, the West Kimberley supports productive pastoral operations with good stability and resilience compared to Pilbara and southern rangelands. Pastoral rangelands in the West Kimberley support cattle stocking rates of between ~3 and ~5 cattle units (cu) per square kilometre[30] (or approximately 1 cu per 25 ha).

A typical well site is around 3 ha, while a commercial gas field development at Yulleroo (Section 2) would involve around 100 ha of clearing. This represents clearing of vegetation of less than one percent in the project area. The potential for impacts on other uses is therefore very limited.

A commercial field development would only displace around 4 cu (i.e. the equivalent of four 400 kg steer). Further, as discussed in Section 5, Buru Energy's operations can provide benefits to pastoral stations such as additional water bores and access tracks to areas that were previously inaccessible.

While unlikely to be required, any exclusion of pastoral operations outside of the cleared project areas could result in a benefit to the vegetation and landforms present, which have been degraded by pastoral grazing[31]. Given the low impact and stable nature of a producing gas field, there is a potential compatibility for these operations to be coupled with conservation areas. This will be explored with the relevant Native Title Determinants and pastoral stations during development of the project.

3.3. Air Impacts

3.3.1. Context

International research has shown that local greenhouse gas (GHG) emissions from shale gas wells are low if adequately managed and should represent only a small proportion of the total carbon footprint of shale gas, which is likely to be dominated by CO_2 emissions associated with its combustion[32]. Typical levels of radon in natural gas have been reviewed and the estimated annual dose from use of natural gas has been found to be extremely small[33].

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30 Warburton, D.P. and Thomas, P.W.E. (2015). Report to the Commissioner of Soil and Land Conservation on the trend of the Western Australian pastoral resource base. Department of Agriculture and Food, Perth.

31 DPIRD (2017). Erosion and rangeland condition in the West Kimberley. Last Accessed: 14 February 2018. Available at: https://www.agric.wa.gov.au/rangelands/erosion-and-rangeland-condition-west-kimberley

32 MacKay, D.J.C. and Stone, T.J. (2013). Potential greenhouse gas emissions associated with shale gas extraction and use. UK Department of Energy and Climate Change. Last Accessed: 15 February 2018. Available at: https://www.gov.uk/government/publications/potential-greenhouse-gas-emissions-associated-with-shale-gas-production-and-use

33 Dixon, D. (2001). Radon exposures from the use of natural gas in buildings. Rad Protect Dosimetry 97(3): 259-264.

During fraccing operations, local air quality could be negatively impacted by i) diesel particulates, ii) increase in methane or CO_2 from flaring, and iii) fugitive emissions from flowlines on site. The Asgard 1 and Valhalla North 1 wells that were stimulated during the 2015 frac program are located 20 km from the nearest homestead, 30 km from the nearest community and 70 km from the nearest town. Similarly, the Yulleroo wells are over 20 km from any homestead, community or town. The remoteness of the region means there is an absence of nearby sensitive receptors.

3.3.2. Air Quality Monitoring

During Buru Energy's 2015 frac program, AECOM were commissioned to undertake an air quality and fugitive emissions study at the Asgard 1 and Valhalla North 1 well sites. This was designed to collect quantitative information on air quality and emissions during the well stimulation and flowback phases.

Air quality monitoring was undertaken using nine static gas samplers (SUMMA canisters) distributed in an arc formation downwind from the well pad infrastructure, with one sampler representing background concentrations upwind of the well pad (Figure 12). Monitoring of air quality was coupled with the release of a known unique tracer gas (acetylene). This tracer gas is unstable in its pure form so does not occur naturally, making it a suitable tracer. Acetylene was released in very low concentrations at a known rate, allowing the tracer ratio emission calculation method to be applied to derive the fugitive gas emission rate.

Collected samples were returned to an accredited laboratory where they were tested to USEPA methods TO-15 and a modified ASTM D-1945 method. The first of these methods was used to detect the gaseous species of interest, such as the hazardous air pollutants including BTEX compounds (Benzene, Toluene, Ethyl Benzene, m,p-Xylene, o-Xylene) and Naphthalene. The second method was used primarily to detect for the gases of interest of methane and the tracer, acetylene, both of which are required to determine the fugitive emission rate.

All results of the study were reported in Buru Energy's *TGS End of Activity Report* (HSE-REP-094) that was submitted to the DMP (now DMIRS) in May 2016 and are summarised below.

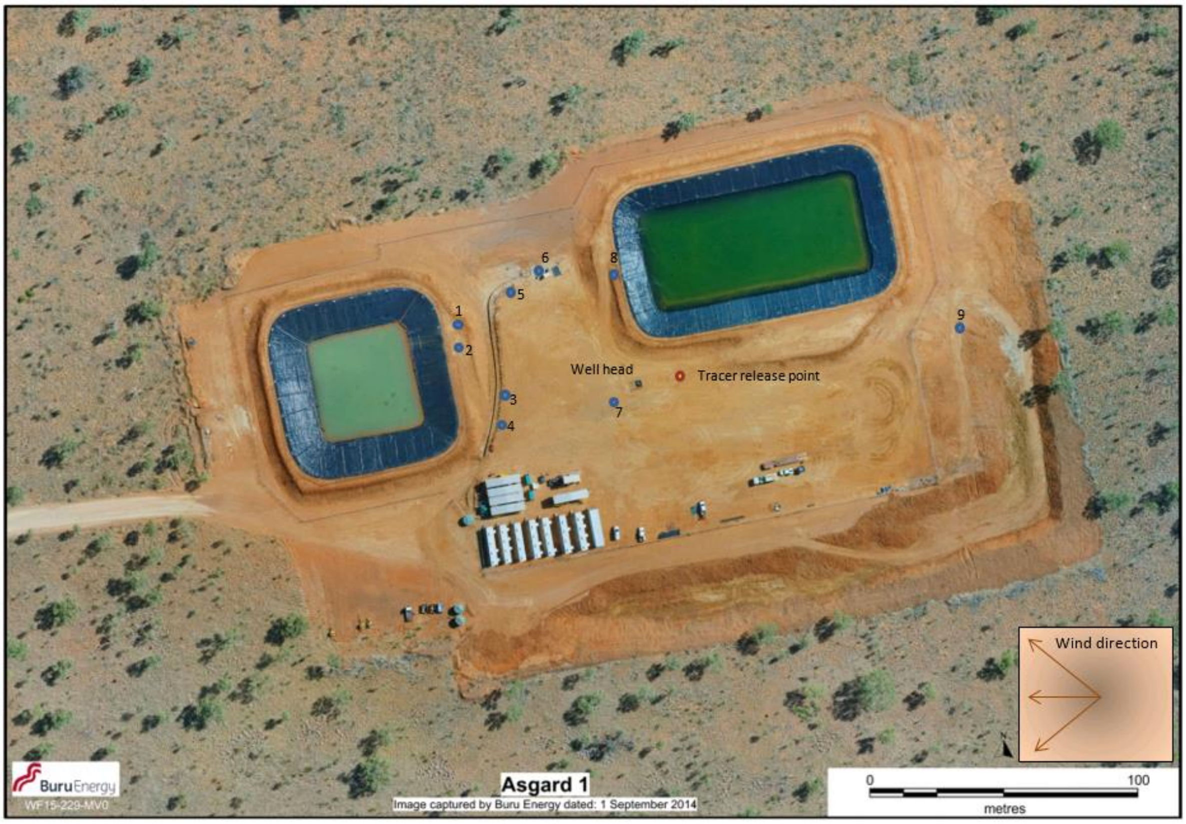

Figure 12: Asgard 1 well site showing the location of sample canisters and the prevailing wind direction.

3.3.3. Methane Concentrations

Methane is a non-toxic, colourless and odourless gas, which is present in the atmosphere at a global average concentration of approximately 1,800 ppbv[34].

The background upwind sample point did not detect methane during the study. Given the global average concentration, presence of cattle in the vicinity of the well sites, and the presence of termite mounds throughout the area, this was considered an erroneous result. In place of the erroneous result, the background concentration published by the World Meteorological Organisation (WMO) was used (1,800 ppbv) in the AECOM study, to allow meaningful comparisons.

The sampling program detected methane at five of the eight downwind sampling locations, with the concentrations marginally above published background concentrations. By way of comparison, the recorded concentrations of methane are similar to levels typically experienced 200 m downwind of a cattle feed lot[35] or within 5 km of a landfill site[36].

3.3.4. Well Pad Emission Rate

Based on the sampling undertaken at Asgard 1, a methane emissions flow rate of 0.3 g/s was determined. This result is based on one sampling location, which successfully detected both the required concentrations of methane and the tracer gas, acetylene. Given the low concentrations of methane detected (as described above) and coupled with the fact that the rate is based on a single data point

[34] WMO (2013). World Meteorological Organisation, Atmospheric Environment Research Division, Geneva, Greenhouse Gas Bulletin No. 9, November 2013.
[35] APAB (2007) cited in AECOM (2016). Fugitive Air Emissions Characterisation – Well Completion Emissions. Report for Buru Energy. March 2016.
[36] Mønster, J., Delre, A., and Scheutz, C. (2015). Quantification of the methane emission from three UK landfills. Kgs.Lyngby: Technical University of Denmark, DTU Environment.

(not statistically reliable), this derived emission rate is not considered to be representative of the operating conditions.

3.4. Risk to Groundwater Quality

Buru Energy has not detected any impacts to surface water or groundwater off the well sites as a result of the 2015 frac program. As such, this section considers the "risk to water resources" associated with hydraulic fracturing in the Canning Basin.

3.4.1. Source-Pathway-Receptor Approach

In assessing the risk to groundwater, Buru Energy has followed the Source-Pathway-Receptor (S-P-R) approach advocated by DWER in *Guidance Statement: Risk Assessments – Part V, Division 3, Environmental Protection Act 1986* (2017). The S-P-R approach states that for contamination of the receptor to occur, there needs to be a source of contamination and a pathway connecting the contamination source with the receptor. Groundwater and surface water (Section 3.5) are the receptors under consideration. The following potential contamination sources and pathways were considered when assessing the risk to groundwater.

3.4.1.1. Receptor

- Groundwater
- Surface Water (see Section 3.5)

3.4.1.2. Potential Source

- Chemicals – concentrated
- Chemicals – dilute
- Flowback fluid

3.4.1.3. Pathway

There are six potential pathways by which groundwater or surface water may be contaminated by chemicals, hydrocarbons or flowback water during the hydraulic fracturing process. These are shown in Figure 13 and are outlined below:

- Pathway 1: Leakage of hydraulic fracturing fluid, flowback or produced water, or methane from operating or abandoned wells.
- Pathway 2: Contamination of shallow groundwater through fractures induced by the hydraulic fracturing process by propagation of the fractures to the surface or connection of the fractures with faults.
- Pathway 3: Surface spills of chemicals, hydraulic fracturing fluid, flowback water or produced water at the well site or other handling facility within the well pad area that infiltrates to groundwater.
- Pathway 4: Surface spills of chemicals during transport that infiltrates to groundwater or is washed off-site into a surface water body.
- Pathway 5: Surface spills of chemicals, hydraulic fracturing fluid, flowback water or produced water within the well pad or during transport that is washed off-site into a surface water body.
- Pathway 6: Overtopping or failure of flowback water storage ponds.

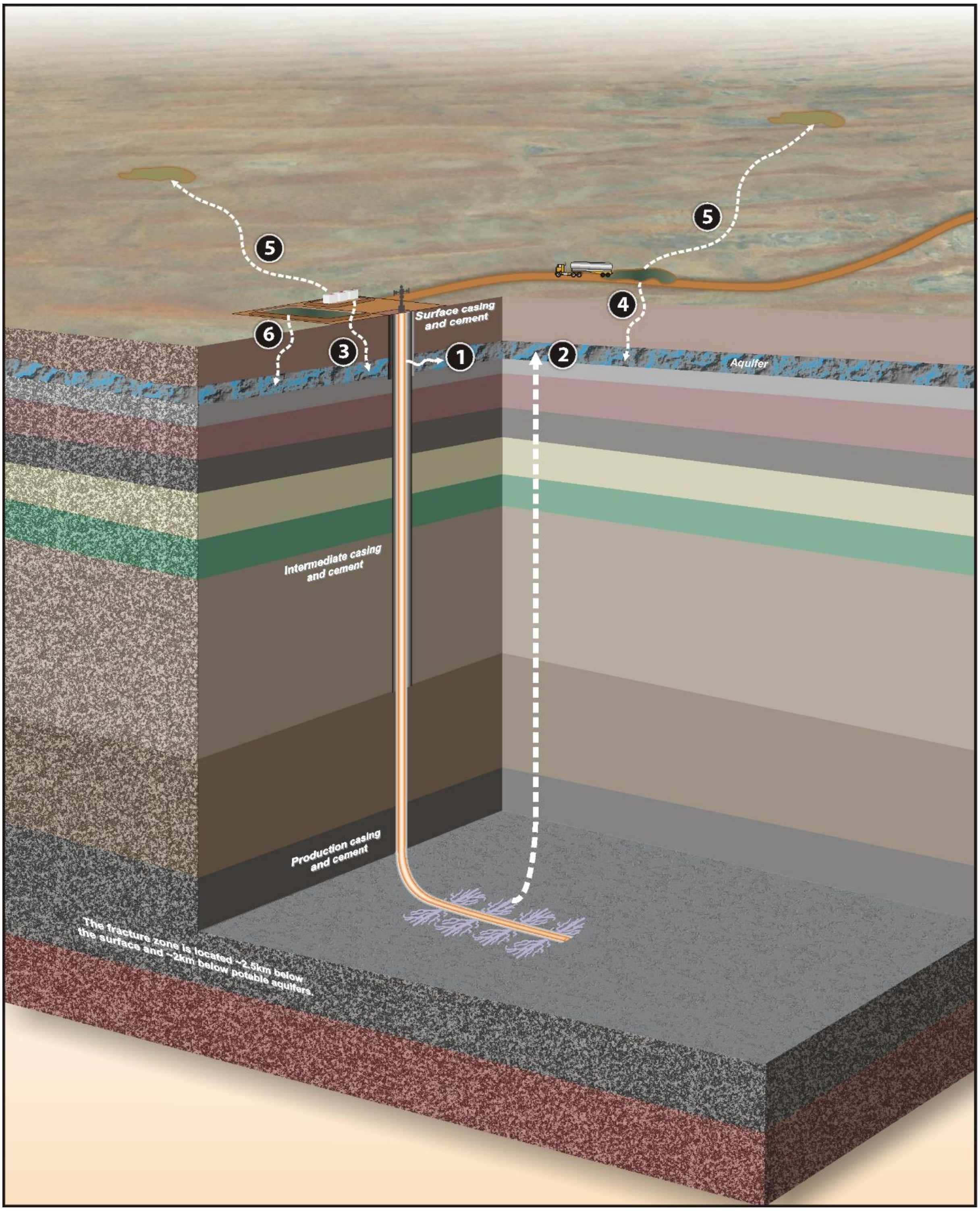

Figure 13: Potential contamination sources and pathways from tight and shale gas activities.

3.4.2. Characterisation of Groundwater (Receptor)

The Environmental Protection Authority's (EPA) Environmental Protection Bulletin (EPB) No. 22 notes that groundwater resources in the Canning Basin are not as well understood as the Perth Basin[37]. To address these gaps in knowledge, Buru Energy engaged with the Department of Water and Environmental Regulation (DWER) (formerly Department of Water) in 2013 to understand DWER's requirements for a hydrogeological model suitable for informing an environmental risk assessment.

Given the relatively small volumes of water proposed to be extracted during the 2015 frac program (<50 ML), DWER advised Buru Energy that a conceptual hydrogeological model should be developed to inform the environmental risk assessment. This guidance is consistent with the advice provided in EPB No. 22.

Accordingly, conceptual hydrogeological models were developed for the Asgard/Valhalla and Yulleroo areas[38]. Contour plots of groundwater levels for each area are provided in Figure 14 and Figure 15, while hydrogeological cross-sections for each area are provided in Figure 16 and Figure 17.

The hydrogeological models demonstrated:

- Groundwater in the Asgard/Valhalla area flows westwards though there are also indications of a southerly component towards the Fitzroy River. Based on groundwater travel times for the Liveringa and Noonkanbah Formations, it would take approximately 16,000 years for groundwater to travel from Valhalla to the Fitzroy River.
- Groundwater in the Yulleroo area flows westwards towards Roebuck Bay. Groundwater travel times are quickest for the Broome Sandstone, with groundwater from the Yulleroo area taking 420 years to reach Lake Eda and 1,700 years to reach Roebuck Bay.
- Infiltration rates in the Asgard/Valhalla area are slow with water likely to take between 70 days and 300 days to travel from the ground surface to the water table.
- Infiltration rates in the Yulleroo area indicate that water is likely to take between 10 and 20 days to travel from the ground surface to the water table.
- The Laurel Formation and the overlying Anderson Formation are both considered to be aquitards with low permeability, or minor aquifers with high salinity (~100,000 mg/L TDS).

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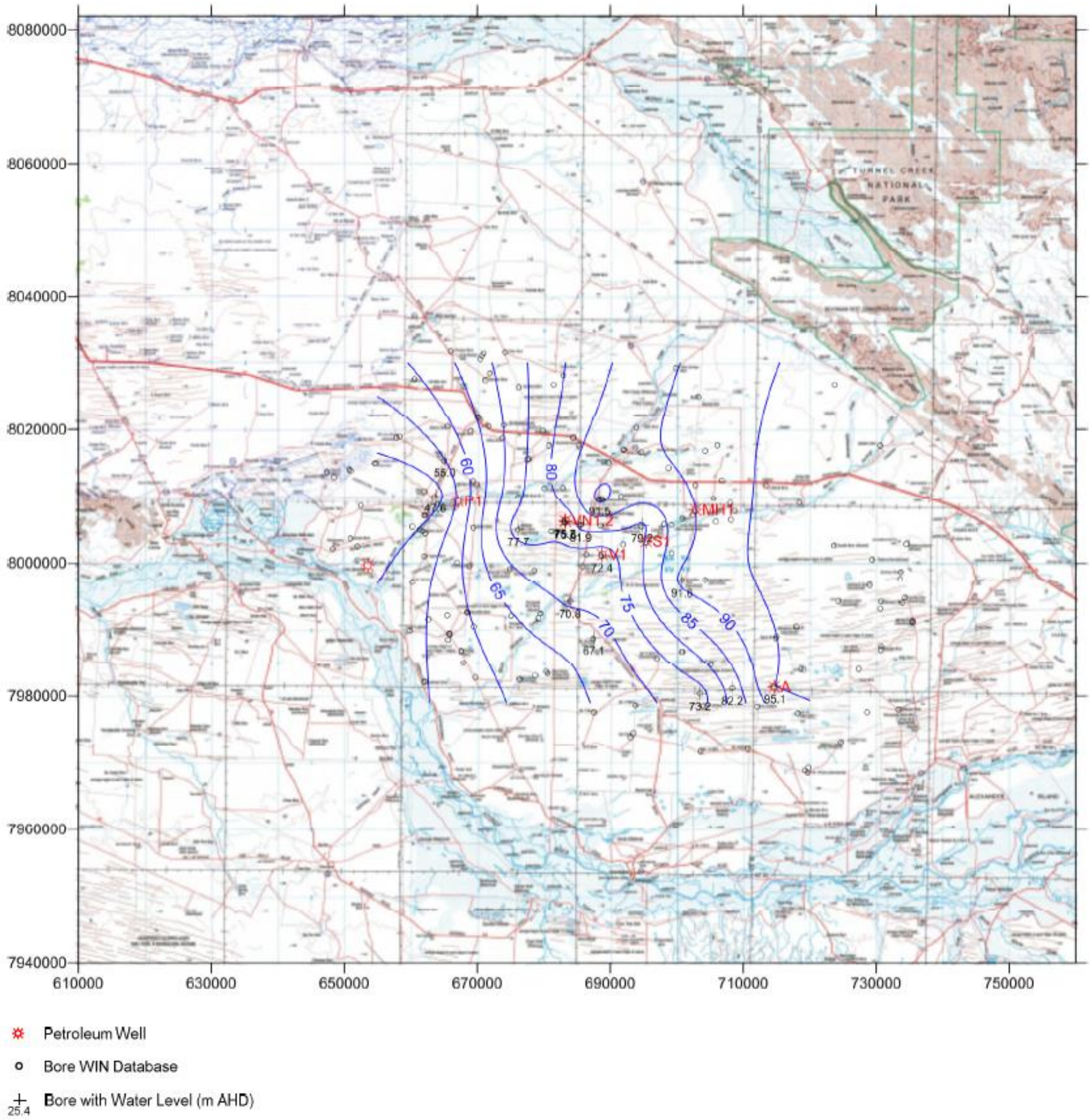
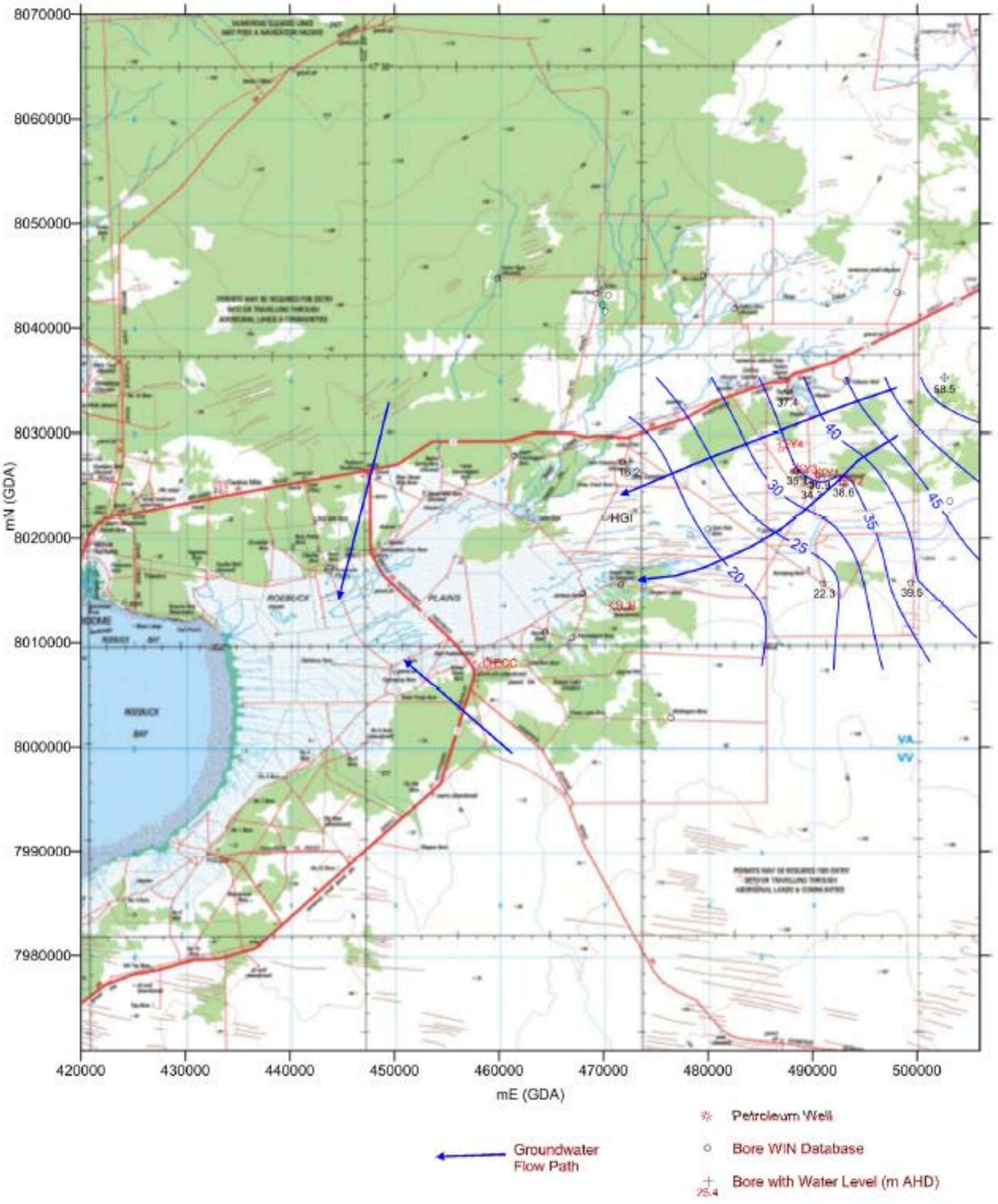
[37] EPA (2014). Environmental Protection Bulletin No. 22. Hydraulic fracturing for onshore natural gas from shale and tight rocks. December 2014.
[38] Rockwater (2015). Hydrogeological Assessment of Project Areas. Report for Buru Energy Ltd. June 2015.



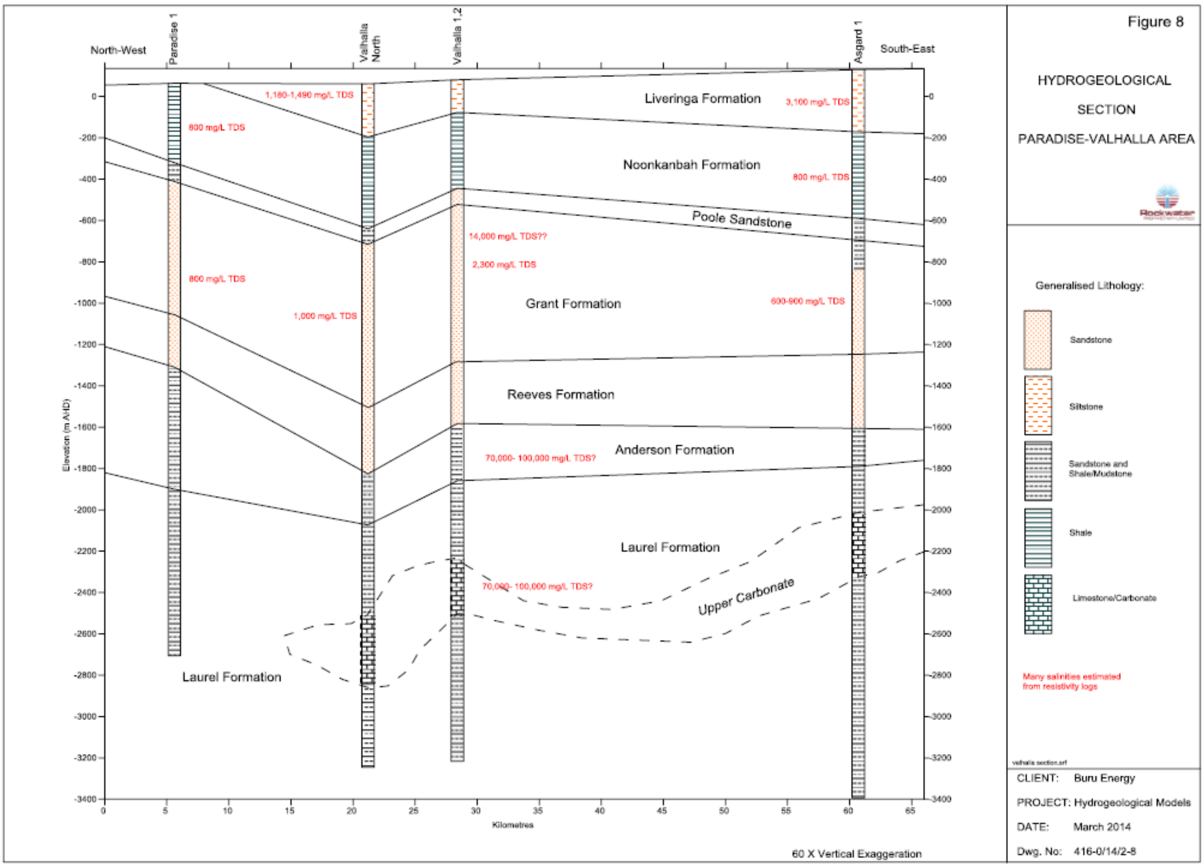
Source: Rockwater 2015

Figure 14: Groundwater levels (m AHD), Valhalla Area.



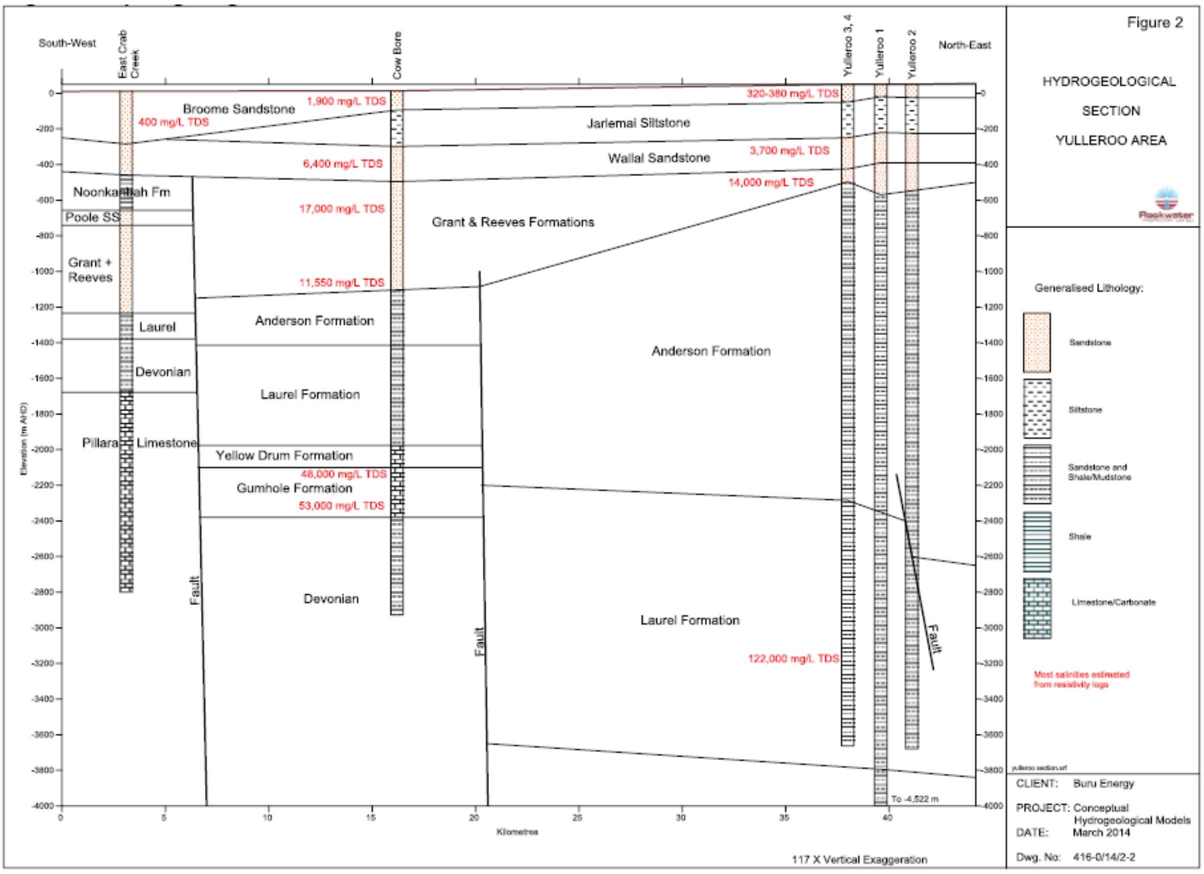
Source: Rockwater 2015

Figure 15: Groundwater levels (m AHD), Broome Sandstone, Yulleroo Area.



Source: Rockwater 2015

Figure 16: Hydrogeological cross section for Asgard/Valhalla area.



Source: Rockwater 2015

Figure 17: Hydrogeological cross section for Yulleroo area.

3.4.3. Monitoring of Groundwater Quality (Receptor)

Buru Energy implemented a comprehensive groundwater monitoring program for the 2015 frac program. The groundwater monitoring program included monitoring of reference (control) and surveillance (impact) bores before, during and after the frac program in a Before-After-Control-Impact (BACI) design. The monitoring program demonstrated that fraccing had were no impact on the quality of groundwater.

3.4.3.1. Initial Baseline Monitoring

Buru Energy commenced baseline monitoring in prospective tight gas project areas at Asgard/Valhalla and Yulleroo in August 2012. Groundwater samples collected from the production water bores on site were initially used to characterise groundwater quality in the project areas. This was supplemented by sampling of nearby pastoral bores to further characterise groundwater quality and assist with the development of the conceptual groundwater models described in Section 3.4.2.

Given that the 2015 frac program was focussed on the Asgard/Valhalla area, the most extensive groundwater monitoring has been undertaken at these sites and is described further below. Monitoring in the Yulleroo area remains in the baseline phase, with over five years of data collected to date.

3.4.3.2. Layout of Monitoring Bores

During planning for the 2015 frac program, a groundwater monitoring program was developed in 2013 and 2014 to allow any impacts associated with fraccing to be detected, and the source of these impacts to be identified. The monitoring program was developed with advice from Buru's specialist consultant Rockwater Pty Ltd, Professor Neil Coles (University of Western Australia, UWA), DWER and independent specialist reviewers advising Traditional Owners.

Groundwater monitoring bores were installed at the Asgard 1 and Valhalla North 1 well sites in November 2014. The layout of monitoring bores on Asgard 1 is shown in Figure 18 while the layout of monitoring bores on Valhalla North 1 are shown in Figure 19. The layout of monitoring bores included upstream reference (control) bores and downstream surveillance (impact) bores. These were sampled before, during and after the frac program to conform to a BACI design for impact assessment (Table 2).

The monitoring program included shallow and deep monitoring bores. Shallow bores were screened in the surface alluvium while deep bores were screened in the water table of the surface aquifer (Liveringa Aquifer). Only shallow bores were installed downstream of the ponds as any impacts associated with a leak from the ponds would be detected in shallow bores.

Table 2: Layout of monitoring bores at each well site.

Bore Location	Purpose	Well Site	Bores
Nested shallow and deep monitoring bores located up-gradient of well site.	Reference bores	Asgard 1	AB1S AB1D
		Valhalla North 1	VNB4S VNB4D
Nested shallow and deep monitoring bores located downstream of well head.	Surveillance bores to detect any impact associated with well activities	Asgard 1	AB2S AB2D
		Valhalla North 1	VNB1S VNB1D
Shallow monitoring bore located down-gradient of source water pond.	Surveillance bore to detect any impact associated with source water pond.	Asgard 1	AB4S
		Valhalla North 1	VNB2S
Shallow monitoring bore located down-gradient of flowback water pond.	Surveillance bores to detect and impact associated with flowback water pond.	Asgard 1	AB3S
		Valhalla North 1	VNB3S

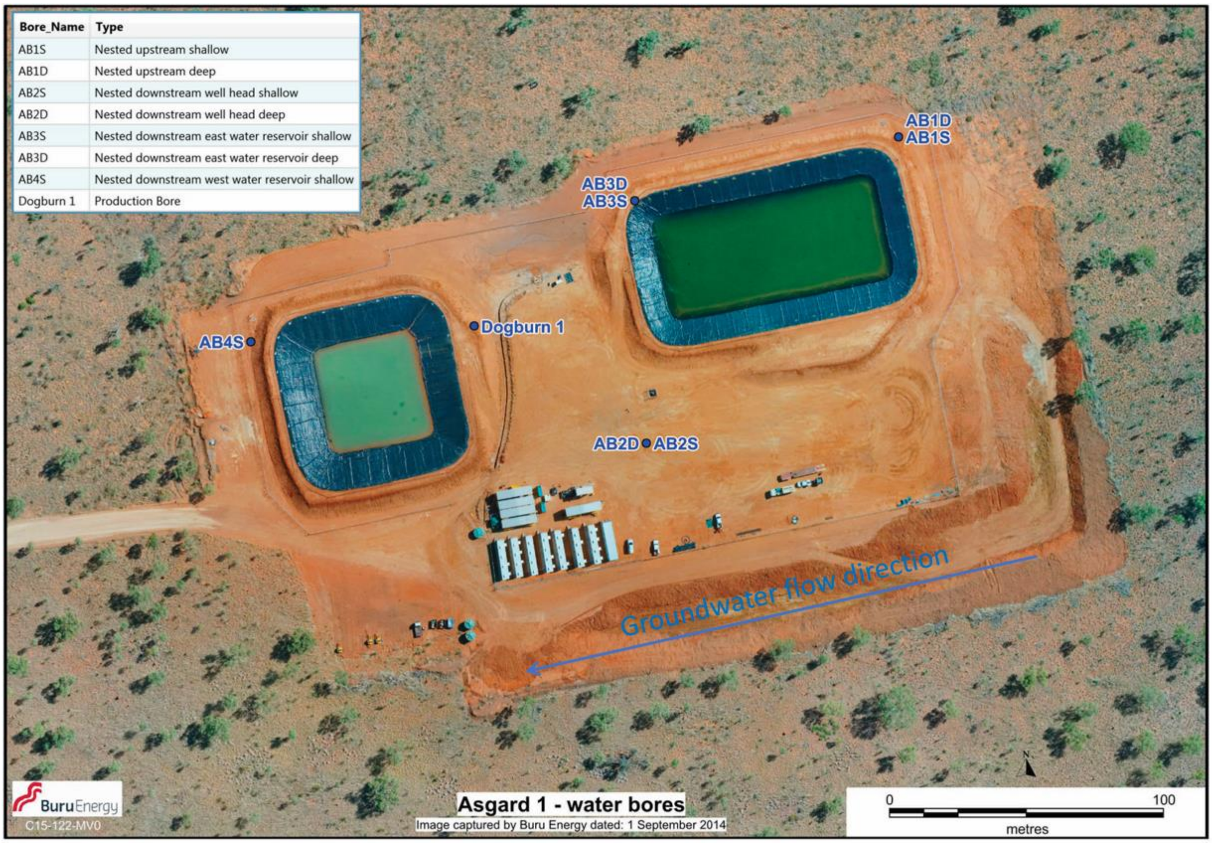


Figure 18: Layout of monitoring bores on Asgard 1 well site.

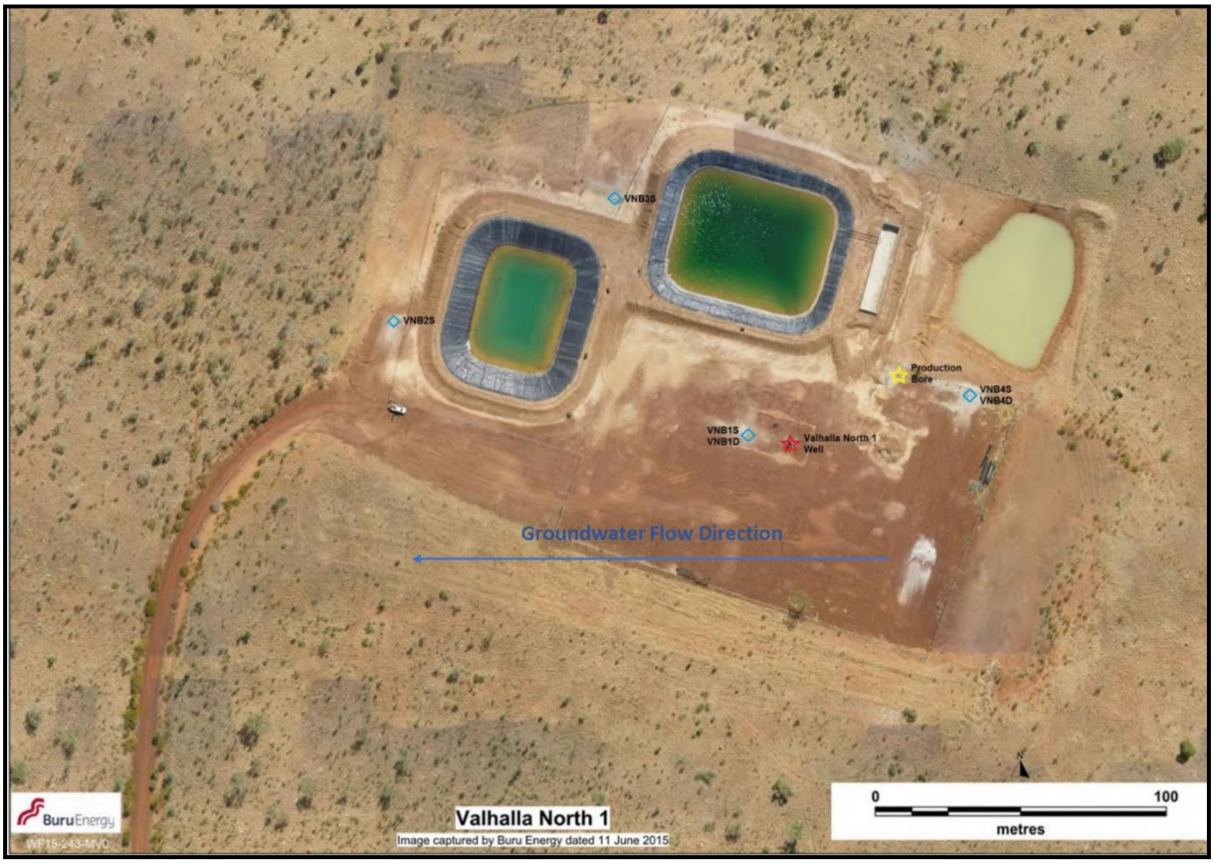


Figure 19: Layout of monitoring bores on Valhalla North 1 well site.

3.4.3.3. Parameters for Monitoring

The following parameters were included in the groundwater monitoring program:

- general parameters (including pH, Conductivity);
- anions (including Chloride, Fluoride);
- cations (including Sodium, Potassium);
- metals (including Arsenic, Barium); and
- hydrocarbons (including total hydrocarbons, dissolved gases).

While some of these parameters can be measured in the field using calibrated instrumentation, all are analysed by sending samples to a laboratory accredited by the National Association of Testing Authorities (NATA).

Of the measured parameters, chloride was selected as the key sentinel indicator for detecting groundwater impacts associated with hydraulic fracturing activities for the following reasons:

- chloride is non-volatile, non-sequestering and non-reactive;
- chloride is present in relatively high concentrations in flowback fluid (50,000 to 200,000 mg/L), which is ten to a hundred times the concentration of most inorganics and more than a million times the levels of most volatile and semi-volatile organic constituents;
- chloride in the form of sodium chloride is the third most prevalent chemical additive in hydraulic fracturing fluid after water and sand;
- chloride is readily measured with field kits that can determine its presence with small samples based on conductivity measurements; and
- baseline sampling determined that chloride levels were relatively stable.

Chloride was therefore identified as an excellent parameter for detecting even the smallest leaks of hydraulic fracturing fluid or flowback fluid to the environment.

3.4.3.4. Monitoring Frequency

The distance that the monitoring bores were located from potential contamination sources on site was based on groundwater flow rates, so that a leak could be detected within three months of it occurring. Correspondingly, this required that groundwater monitoring leading up to, during and immediately following the 2015 frac program occurred at least at this frequency.

During baseline monitoring, bores were sampled on a six-weekly basis, which was increased to four-weekly in the three months leading up to the commencement of frac operations.

As stated above, chloride was selected as the key sentinel indicator for monitoring impacts on groundwater quality. During the frac program (surveillance monitoring period), all bores on site were sampled daily and tested for chloride. This on-site monitoring during the frac program was supplemented by fortnightly sampling with samples sent to a NATA accredited laboratory for analysis of the full suite of parameters.

If significant shifts in chloride were detected from daily monitoring at the well site, this would have provided the trigger for further groundwater samples to be collected and analysed for the full suite of parameters. Note that for contamination to occur, there would have needed to be well failure or significant fluid loss. Either of these scenarios would have been rapidly recognised on site and significantly prior to receipt of any test results.

Following the completion of the hydraulic fracturing and flowback operations, the petroleum wells were suspended. During the post operations phase, groundwater monitoring occurred quarterly until October 2016 (one-year post-fraccing). During this period, no impact on groundwater sampled from the monitoring bores by the hydraulic fracturing and flowback activities has been detected. Given the

proximity of the monitoring bores to the petroleum wells and retention ponds, any impact on groundwater as a result of fraccing or flowback would have been detected by that point. Given the demonstrated lack of impacts, in October 2016 Buru Energy re-scheduled the water sampling to six-monthly in line with other suspended wells, in consultation with DMIRS.

3.4.3.5. Peer Review of Hydrogeology and Monitoring Program

To ensure the technical studies and resulting environmental impact assessment undertaken by Buru Energy for the 2015 frac program were robust, Buru Energy engaged Professor Neil Coles from UWA to peer review these components prior to submission of documents for regulatory approval. At the time of undertaking the peer review, Professor Coles was the Director WA State Centre of Excellence for Ecohydrology at UWA. The review concluded the following[39]:

The evidence and documentation provided by Buru Energy demonstrates that the operations satisfy the Significance Test (DMP, 2013) and comply with internationally recognised operational standards and fall within the criteria defined so as to manage the associated risks to As Low As Reasonably Practical (ALARP). As a result, it is considered that this small scale, "proof of concept", exploration drilling proposal is unlikely to have a significant effect on the environment. The potential impacts associated with the proposal are managed or mitigated relative to DMP Guidelines and conform to water monitoring requirements suggested in the DMP (2013, 2014) and ERA 2011 guidelines.

In addition, the review determined that the groundwater monitoring program "*fits within the needs of the operations, and reflects the precautionary monitoring principles*".

3.4.3.6. Monitoring Results – Chloride

Results of the daily monitoring program are provided in Appendix 1. The monitoring recorded no anomalous chloride levels at either well site. This clearly shows no impact of fraccing on groundwater at the Asgard 1 or Valhalla North 1 well site.

3.4.3.7. Monitoring Results – Full Suite of Analytes

As described in Section 3.4.3, baseline monitoring commenced in 2012 and dedicated environmental monitoring bores were installed at the Asgard 1 and Valhalla North 1 well sites in June 2014. Groundwater monitoring was undertaken from the groundwater monitoring bores from installation, providing two years of baseline data from production water bores on site and a further 12 months of baseline data from dedicated environmental monitoring bores prior to the start of fraccing operations.

Collected samples were analysed for over 65 parameters at a NATA accredited laboratory. Of these parameters, chloride was identified as a key sentinel indicator for monitoring and impact assessment. Results for dissolved gases (methane, ethane and propane) are also of interest from the monitoring program as these are constituents of the targeted hydrocarbon stream.

Results for chloride and dissolved gases are included in Appendix 2. As for the daily monitoring, there was no increase in chloride detected by laboratory samples during the monitoring program. Similarly, there was no increase in dissolved methane, dissolved ethane or dissolved propane associated with hydraulic fracturing activities.

The results demonstrate no impact of fraccing on groundwater quality as a result of Buru Energy's 2015 frac program. Groundwater quality results have been presented to, and discussed with Noonkanbah rangers who participated in the monitoring program with monitoring results made publicly

[39] Coles, N. A. (2014). Water resources and impacts: assessment of Buru Energy TGS14 Activity Final Report prepared for Buru Energy Limited. UWA Perth WA. Report Number CEE 01/2014.

available on Buru Energy's website since November 2014 (http://www.buruenergy.com/2015-tight-gas-pilot-exploration-program/).

3.4.4. Chemicals – Concentrated (Potential Source)

3.4.4.1. Transport

Chemicals for hydraulic fracturing are transported to site in accordance with the *Dangerous Goods Safety Act 2004* and the associated *Dangerous Goods Safety (Road and Rail Transport of Non-Explosives) Regulations 2007* (DG Transport Regulations). Transport of dangerous goods in WA is undertaken by the service company and associated contractors. Under Regulation 180 of the DG Transport Regulations, contractors are required to have an emergency response plan in place for the transport of dangerous goods. This transport emergency response plan is required to be in writing and deal with any dangerous situation that arises from the transport of the goods.

3.4.4.2. Storage and Handling

Chemicals on site are stored and handled in accordance with the *Dangerous Goods Safety Act 2004*, the *Dangerous Goods Safety (Storage and Handling of Non-Explosives) Regulations 2004* and an Environment Plan prepared under the *Petroleum and Geothermal Energy Resources (Environment) Regulations 2012* (Environment Regulations) for the activity. Specific controls implemented for the storage and handling of dangerous goods on site include:

- dangerous goods will be stored within bunded areas in accordance with relevant SDS;
- bunds are designed to be impermeable (e.g. 0.75 mm HDPE) in accordance with DWER *Water Quality Protection Note (WQPN) 65: Toxic and hazardous substances*;
- chemical storage on site is in accordance with DWER *WQPN 65: Toxic and hazardous substances*. This considers stormwater management, location of storage area in relation to conservation areas, sensitive areas and Public Drinking Water Source Areas (PDWSAs), waste disposal and emergency response;
- transport and refuelling of dangerous goods on site is undertaken in accordance with relevant company and contractor procedures; and
- ensuring spill kits are located on site.

A site-specific spill response plan is also prepared under the Environment Regulations, which considers the distance to sensitive receptors, the characteristics and volumes of chemicals stored on site and the spill response equipment available on site and in the wider region.

3.4.5. Chemicals – Dilute (Potential Source)

During the fraccing process, chemicals are mixed with water and proppant (typically sand) in the blender to form the hydraulic fracture fluid, which is then pumped down the well bore and into formation as part of the fraccing process. The composition of frac fluids has evolved greatly in recent years with a concerted move to more benign fluid systems. Typical fluids used for fraccing are made up of ~94% water, ~5% proppant sand and ~1% chemical additives.

3.4.5.1. Chemical Disclosure

Regulation 15(9) of the Environment Regulations requires that an Environment Plan for a petroleum activity: …. *include details of any chemicals or other substances that may be —*

(a) in, or added to, any treatment fluids to be used for the purposes of drilling or hydraulic fracturing undertaken in the course of the activity; or

(b) otherwise introduced into a well, reservoir or subsurface formation in the course of the activity.

The *Chemical Disclosure Guideline*[40] provides additional information regarding chemical disclosure requirements for petroleum activities. Buru Energy disclosed all downhole chemicals used the 2015 frac program in accordance with the Environment Regulations. These are available on the DMIRS website and were also made available on Buru Energy's website.

3.4.5.2. Ecotoxicity of Buru Energy's Frac Fluid

The ecotoxicity of hydraulic fracturing fluid was considered when selecting a contractor for Buru Energy's 2015 frac program. Ecotoxicity assessments of the Halliburton CleanStim and Condor Friction Reduced Water System were commissioned, and were undertaken by Ecotox Services Australia using the eastern rainbowfish *Melanotaenia splendida splendida* under test protocol ESA SOP 117 (ESA, 2011 based on USEPA, 2002).

It should be noted there was no regulatory requirement for Buru Energy to undertake the ecotoxicity testing. Rather, the tests were undertaken for the benefit of Traditional Owners and other stakeholders to confirm that the frac fluid was not "dangerous" or poisonous. The tests were undertaken on a genus of fish found in the river systems in the region; however, it is worth noting that the frac fluid is highly unlikely to come in contact with any organisms (other than bacteria).

Both frac fluids were determined to have extremely low toxicity. For the CleanStim chemical mixture, the fish were unaffected at concentrations of up to 200 mg of the chemicals per litre of water (i.e. the EC_{50} was >200 mg/L, and the NOEC was 200 mg/L). Condor's Friction Reduced Water System was found to have an EC_{50} of 7.1 g/L (7,100 mg/L) and a NOEC of 6.3 g/L (6,300 mg/L).

The Condor Friction Reduced Water System was used for the 2015 frac program. According to Appendix 3 of the NICNAS guidance document[41], any material with an EC_{50} >100 mg/L and a NOEC >1 mg/L is classified as very slightly toxic, which is the lowest toxicity rating in Australia. This indicates that the fluid system used in the program (injected into the Laurel Formation more than 2.5 kilometres below surface) is ten times less toxic than the lowest toxicity rating in Australia and 30 times less toxic than chlorinated swimming pool water.

3.4.5.3. Demonstration that the Frac Fluid is Non-toxic

To further demonstrate that the frac fluid used in the 2015 frac program was non-toxic, Buru Energy's Executive Chairman drank the Condor Friction Reduced Fluid System at Buru Energy's Annual General Meeting (AGM) held on 28 April 2016. The fluid drunk by the Executive Chairman was prepared by the fluid provider under controlled laboratory conditions and then transported to the AGM and opened under a strict chain of custody. Prior to drinking, the fluid was opened by a representative of the freight company who confirmed the integrity of the seal. Key aspects of the preparation and transport process were also filmed. A video is available from: https://www.youtube.com/watch?v=A49rJobH-zU.

The demonstration was repeated on 1 December 2016 at a function in Broome attended by Buru Energy's Kimberley stakeholders and shareholders.

3.4.5.4. Summary

The public disclosure of frac fluid, ecotoxicity tests and drinking of the frac fluid serves to demonstrate that the frac fluid poses extremely low risk to the environment and has a very minor potential as a source of contamination.

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[40] DMP (2013). Chemical Disclosure Guideline Version 2. August 2013. Department of Mines and Petroleum, Western Australia.
[41] Commonwealth of Australia (2013). NICNAS Handbook—a guide for importers and manufacturers of industrial chemicals in Australia.

3.4.6. Flowback Fluid (Potential Source)

Once fraccing of the well is complete, and following a short period of clean-up flow, the flowback phase commences. The primary objective of the flowback phase is to determine the rate and composition of gas and liquid hydrocarbons that flow from the fracced zones. The fluid (termed flowback fluid) that flows back from the well during this phase represents another potential contamination source associated with fraccing.

Flowback fluid is generally comprised of a portion of the hydraulic fracturing fluid that was injected into the well, produced hydrocarbons and formation water. During the 2015 frac program, flowback fluid flowed to an impermeable, concrete reinforced, horizontal flare pit. At the flare pit, gases and small amounts of liquid hydrocarbons associated with the flowback fluid were flared, while flowback water was diverted to a water retention pond (Figure 20).

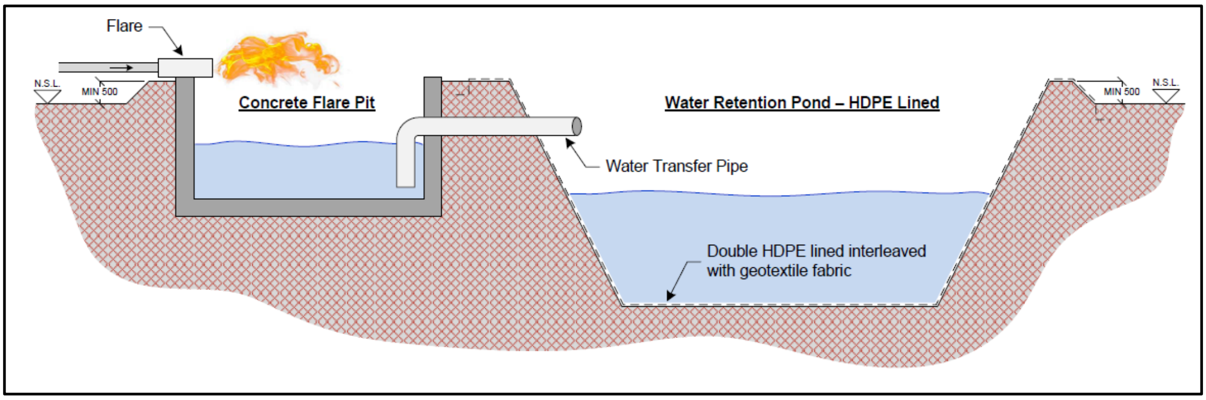

Figure 20: Management of fluids through the flare pit during flowback.

3.4.6.1. Flowback Water Management

Flowback water is the mixture of fraccing fluid and formation water that is received at surface during well flowback. As the composition of flowback water depends to an extent on the targeted formation, Buru Energy took a conservative approach to managing flowback water during the 2015 frac program. This conservative approach was adopted until the composition and volumes of flowback water was understood and included the following:

- Designing water retention ponds based on a conservative estimate for the volumes of flowback fluid likely to be returned. Flowback ponds were constructed based on 70% flowback of injected fluid compared to industry averages of ~50%.
    - Following construction of the flowback ponds and finalisation of the program, a capacity assessment of the flowback ponds was undertaken. This determined the minimum freeboard on the ponds following flowback was 2.4 m at Asgard 1, which greatly exceeded the 1 in 20-year ARI for a 72-hour period specified in DWER WQPN No. 26.
- Flowback water ponds were constructed to be “triple lined” with two layers of HDPE liner separated by geotextile fabric. As each HDPE layer met the requirements of WQPN No. 26 individually, this design exceeded regulatory requirements.

A comprehensive sampling and analysis program was then undertaken to characterise the composition of flowback water. Characterisation of the flowback water was important to determine the environmental risk posed by this water and inform opportunities for beneficial use.

3.4.6.2. Results of Flowback Water Analysis

The flowback water sampling program is described in Appendix 3 along with laboratory analysis for all collected samples. The COPC in the water retention ponds pre- and post-flowback are also compared to ANZECC Stockwater Guidelines[42] and Australian Drinking Water Guidelines[43] in Appendix 3.

With the exception of Barium and Boron, all water quality results for flowback water were below guideline levels. Barium was elevated compared to the health values for the Australian Drinking Water Guidelines, while Boron was elevated compared to the low risk trigger level in the ANZECC Stockwater Guidelines.

Radiological Analysis

Representative samples from the flowback fluid were also analysed for Naturally Occurring Radioactive Materials (NORMs). The results of these analyses are provided in Appendix 3 (Table A3-5). The only samples that exceeded the Australian Drinking Water Guidelines were from Asgard 1 (#122, #160), with a relatively high concentration of Radium-228. The guidelines state that the concentration of radionuclides in drinking water should not result in an annual dose of over 1 mSv for any radionuclide (i.e. if a person consumed that water for a year). The sample with the highest concentration was the Asgard #160 sample, which, using the method described in the guideline, was calculated to result in a potential annual dose of 2.6 mSv. However, the composite sample collected from the flowback pond was well below the guideline level, resulting in a potential annual dose of 0.68 mSv which is below the guideline level.

The concentrations of radionuclides in the flowback ponds are also below the ANZECC Stockwater and irrigation water guidelines. Given the levels of NORMs observed in flowback water, there is no risk to humans or animals associated with exposure to flowback water on site.

3.4.6.3. Beneficial Use of Flowback Water

Opportunities for the beneficial use of flowback water were considered following the 2015 frac program. Characterising flowback water quality to determine if it is suitable for reuse was a key environmental objective of the program.

Despite being unsuitable for drinking, the water is suitable for reuse in subsequent frac programs. Buru Energy provided the analysis results to the frac services and fluid provider and was advised that the flowback water was suitable for reuse in fraccing operations. Reuse of flowback water will reduce the total water use requirements in a commercial field scenario, which is recognised as best practice for minimising water use.

As the dominant land use in the Canning Basin is pastoralism, beneficial reuse of flowback water for beef cattle may also be considered should a gas field be developed. In this case, comparison of flowback water to ANZECC Stockwater guidelines for beef cattle are relevant. Flowback water met ANZECC Stockwater guidelines with the exception of chloride and boron. While specific values are not provided for chloride under the Stockwater guidelines, the value of 17,000 mg/L for chloride exceeds the maximum 4,000 mg/L TDS for beef cattle. Concentration of boron in flowback water (9.4 mg/L at Asgard 1, 14 mg/L at Valhalla North 1) also exceeds concentrations of boron under the Stockwater guidelines for beef cattle (5 mg/L). If deemed worthwhile, these exceedances could be addressed through dilution with bore water prior to providing the water for pastoral use.

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[42] ANZECC and ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. National Water Quality Management Strategy, Paper No. 4. October 2000.

[43] NHMRC and NRMMC (2011). Australian Drinking Water Guidelines. National Water Quality Management Strategy. Updated October 2017.

3.4.7. Well Integrity (Potential Pathway)

The International Standards Organisation (ISO) defines well integrity as:

> *"Well integrity refers to maintaining full control of fluids (or gasses) within a well at all times by employing and maintaining one or more well barriers to prevent unintended fluid movement between formations with different pressure regimes or loss of containment to the environment."*

In accordance with *NORSOK Standard D-010: Well integrity in drilling and well operations*, two independent and verified barriers are required to be maintained in petroleum wells during the well lifecycle to prevent outflow from the well bore to the environment. These barriers are established during drilling (construction) of the petroleum well and maintained throughout the well lifecycle, including suspended or decommissioned wells. For the environment to be subject to potential contamination, both barriers must fail.

3.4.7.1. CSIRO Review of Well Integrity

The *Scientific Inquiry into Hydraulic Fracturing in the Northern Territory* engaged CSIRO to provide independent external analysis of well integrity. This analysis is available from: https://frackinginquiry.nt.gov.au/inquiry-reports?a=465932.

The CSIRO study represents the most contemporary and independent analysis of well integrity in petroleum wells. The study largely used data sets from the United States where there is a large sample of petroleum wells available for analysis. The CSIRO review found that the rate of well integrity failures that have the potential to cause environmental contamination (dual barrier failure) is in the order of 0.1%. Several studies show no well integrity failures[44], while the rate for a single well barrier failure was in the order of 1-10%.

3.4.7.2. Buru Energy Management of Well Integrity

In WA, well integrity is regulated by DMIRS under the *Petroleum and Geothermal Energy Resources (Resource Management and Administration) Regulations 2015* (RMA Regulations), the object of which includes "*ensuring that operations relating to the exploration for petroleum or geothermal energy resources, or the recovery of petroleum or geothermal energy in the State are – …carried out in a way that reduces the risk of aquifer contamination*".

The process that Buru Energy applies for managing well integrity during the well life-cycle in accordance with the RMA Regulations is described in Appendix 4 and includes well design, well construction, verification of well construction, monitoring of well integrity and decommissioning.

Buru Energy has only ever had one material well integrity incident in its Canning Basin operations, being a damaged valve on the Yulleroo 2 well head. Prior to that incident, there was an instance of a minor leak from the Yulleroo 2 well head. Both of these incidents are described below.

Yulleroo 2 Well Head – Minor Leak

On 9 April 2013, Buru Energy was made aware of a hissing sound from the Yulleroo 2 well head. The Company investigated and determined that there was a minor leak of gas from the grease nipple on the non-return valve connected to the annulus pressure gauge. This was leaking as grease had hardened in the seat of the grease nipple, releasing a small amount of gas. Both grease nipples were replaced, which addressed the leak.

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[44] Kell, S. (2011). State oil and gas agency groundwater investigations and their role in advancing regulatory reforms. A two-state review: Ohio and Texas. Available at: https://fracfocus.org/sites/default/files/publications/state_oil__gas_agency_groundwater_investigations_optimized.pdf.

This incident and corrective actions were reported to DMIRS in the recordable incidents report for May 2013, provided under the Environment Regulations.

Yulleroo 2 Well Head – Damaged Valve

In January 2015, Buru Energy were made aware of damage to the Yulleroo 2 well head when the media reported an alleged gas leak at this well site.

The allegation was investigated by DMIRS with the findings set out in a report entitled "*Investigation Factual Report: Leak of gas at Yulleroo-2*", which was tabled in Parliament in November 2016. Some of the key findings of the report are summarised below:

- An unauthorised person or persons entered the fencing enclosure around the Yulleroo 2 well head and Christmas tree prior to 6 January 2015 and took a video recording purporting to show a gas leak. This video recording was sent to the ABC.
- Still photographs extracted from the video by the ABC show the gas recorder being held adjacent to the Yulleroo 2 Christmas tree. The extract "image.jpg" also shows that the valve stem on the C-section annulus valve was bent.
- Examination of a reflection off the gas detector of an individual making a video recording indicates that the person was not wearing appropriate PPE.
- A gas leak was found to have occurred past the packing around the valve stem of the C-section annulus valve when the valve was manipulated on 7 January. The valve itself was found not to be leaking.
- Examination of the valve stem on site on 7 January and later at TKM premises on 5 February showed that the valve stem was bent. The examination at TKM premises revealed scarring to the valve gate and seat that provided a leak path past the valve stem. The scarring was caused by a significant blow being struck to the valve stem while the valve was in a partially open position.
- The still image "image.jpg" sent to the DMP on 6 January shows that the valve stem was bent (at the time the video was recorded). It is unknown if the valve stem was bent on the same occasion as the video recording or if the valve stem was bent at some time before. The last authorised inspection of the Christmas tree valves by Buru subcontractors did not indicate any damage.
- It is known to be common for the packing to reform a seal around the valve stem after a period of hours following deformation to the seal. For gas to be recorded leaking from the valve stem, either the valve damage occurred shortly before the recording was made and the recording was done before the packing reformed a seal around the valve stem or the valve damage occurred at some earlier time, the packing reformed a seal around the valve stem then the valve was re-manipulated to allow gas to leak shortly before the recording was made. In either case, the implication is that the individual who made the recording was in close proximity when the unauthorised manipulation of the valve occurred.

The report also noted:

- at the time of the incident, protesters against hydraulic fracturing had set up a camp at the turn-off to Great Northern Highway and the Yulleroo field;
- when going to inspect the alleged gas leak at Yulleroo on 7 January 2015, representatives from Buru Energy, the DMP and TKM Wellhead Services were blocked from gaining access to the site by a protestor at the protest camp for over an hour and police had to be called.

Subsequently, an anti-fracking activist was charged and found guilty of trespass to the Yulleroo 2 site.

3.4.8. Fracture Trajectory (Potential Pathway)

Risks to groundwater associated with the uncontrolled upward propagation of fractures has been suggested by industry opponents as a possible pathway for contamination of aquifers. In a WA setting, this pathway is implausible as noted by Finding 29 of the 2015 WA Parliamentary Inquiry Report into hydraulic fracturing:

> *Finding 29: The Committee finds that the likelihood of hydraulic fractures intersecting underground aquifers in negligible*.

This finding was based on the distance tight and shale gas deposits are found below the surface and potable aquifers and that the furthest a hydraulic fracture has been observed to propagate upwards is 588 m [45]. The research regarding fracture propagation was undertaken by the ReFINE Project in the United Kingdom and was based on data from several thousand-shale gas fraccing operations in the United States. There are also physical factors that impose a constraint on fracture growth such as the volume of fluid used in a fracture, which imposes a bulk limit on fracture height, meaning that unbounded fracture growth to shallow depths is not physically plausible.

3.4.8.1. Fracture Trajectory during 2015 Frac Program

In the context of international research regarding fracture trajectory, the Laurel Formation in the Canning Basin is over 1,000 m below the deepest recognised aquifer and over 2,000 m below aquifers used for potable water. During Buru Energy's 2015 frac program, the height of fractures was monitored using a microseismic array deployed around the well site.

Observed frac heights were calculated from the microseismic results and GOHFER model (Grid Oriented Hydraulic Fracture Extension Replicator) model developed by Baree and Associates. Average fracture heights during the program were 63 m at Asgard 1 and 151.5 m at Valhalla North 1. All fractures were restricted to the target Laurel Formation and were at least 1,200 m below the deepest recognised aquifer in the region, being the Betty Unit of the Grant Group.

The data from Buru Energy's 2015 frac program confirm the finding of the 2015 WA Parliamentary Inquiry Report, that the risk to aquifers associated with this pathway is negligible.

3.4.9. Loss of Fluid Containment on Site (Potential Pathway)

Loss of fluid containment may also occur through a spill of concentrated chemicals on site, failure of flowback water ponds, failure of source water ponds or from diesel storage on site.

Storage and handling of chemicals on site is described in in Section 3.4.4.2 above. Chemicals are stored and handled in accordance with the *Dangerous Goods Safety Act 2004*, the *Dangerous Goods Safety (Storage and Handling of Non-Explosives) Regulations 2004* and an Environment Plan prepared under the Environment Regulations. Bunds on site are designed in accordance with *WQPN 65: Toxic and hazardous substances*.

The conservative design of ponds used contain flowback water on site are described in Section 3.4.6.1. These ponds greatly exceeded the requirements of DWER's *WQPN No. 26: Liners for containing pollutants, using synthetic membranes*. Results of flowback water analysis from the 2015 frac program have demonstrated that flowback water poses a low risk as a contamination source to the environment (Section 3.4.6). Based on these results, all flowback water ponds for future stages of development will be designed to meet the requirements of *WQPN No. 26*.

[45] Davies, R.J., Mathias, S.A., Moss, J., Hustoft, S. and Newport, L. (2012). Hydraulic fractures: how far can they go? Marine and Petroleum Geology 37: 1-6.

Groundwater is used as source water for hydraulic fracturing and is stored in a source water pond on site. Ponds used for hydraulic fracturing source water during the 2015 frac program were the same design as the flowback water ponds described in Section 3.4.6.1. All source water ponds for future stages of development will be designed to meet the requirements of *WQPN No. 26*.

Tanks used for diesel storage and produced hydrocarbons on site are either double skinned or located in bunded areas, meeting the requirements of *WQPN No. 65: Toxic and hazardous substances.*

3.4.10. Overtopping of Fluid from Flowback Ponds (Potential Pathway)

Overtopping of fluid from flowback ponds was considered as a potential contamination pathway. As described in Section 3.4.6.1 and prior to the frac program, the minimum freeboard on the ponds following flowback was estimated to be 2.4 m at Asgard 1.

Following the completion of the flowback program and following the 2015/16 wet season, the Valhalla North 1 flowback pond had ~8 metres of freeboard while the Asgard 1 flowback pond had ~6 metres of freeboard.

The estimated and actual freeboard on flowback water ponds greatly exceeded the recommended freeboards specified in *WQPN No 26* of 0.5 m freeboard plus capacity to store rainfall resulting from a 90-percentile wet season.

3.4.11. Loss of Fluid Containment during Transport (Potential Pathway)

All transport of chemicals to site is undertaken in accordance with the *Dangerous Goods Safety Act 2004* and the associated *Dangerous Goods Safety (Road and Rail Transport of Non-Explosives) Regulations 2007* (DG Transport Regulations) as described in Section 3.4.4.1. Any other fluids requiring transport such as wastewater transported for offsite disposal or produced hydrocarbons will be transported in accordance with the DG Transport Regulations.

3.4.12. Overall Risk to Groundwater

The risk to groundwater associated with fraccing in the Canning Basin is considered low. The frac fluid used by Buru Energy in the Canning Basin is ten times less toxic than the lowest toxicity rating in Australia, and 30 times less toxic than swimming pool water. It can be, and has been, safely drunk by Buru Energy's Chairman, shareholders and key stakeholders. Flowback fluid from the 2015 frac program was fully characterised and found to meet relevant guideline levels with the exception of barium and boron, which were elevated compared to the Australian Drinking Water Guidelines and ANZECC Stockwater Guidelines, respectively.

Buru Energy has a good understanding of the potential contamination pathways. Risks associated with well integrity have been informed by a recent CSIRO review for the Northern Territory Inquiry which determined that well failure that has the potential to cause groundwater contamination is in the order of 0.1%. Similarly, international literature and Buru's experience has demonstrated that risks to groundwater associated with fracture trajectory are negligible.

Other pathways relate to the risk of surface spills and leaks. Outcomes of the environmental risk assessment for the 2015 frac program determined that spills and leaks of chemicals and flowback water at the surface were the risks with the highest potential to impact on groundwater. This finding is consistent with the findings of the 2015 WA Parliamentary Inquiry into fraccing, reports from the UK Royal Society and Royal Academy of Engineering[46] and reports from specialist reviewers advising Traditional Owners (refer to Section 6.2.2). When planning infrastructure associated with the 2015 frac

[46] Royal Society and Royal Academy of Engineering (2012). Shale gas extraction in the UK: a review of hydraulic fracturing, June 2012, p 19.

program, Buru Energy therefore took a conservative approach and 'overengineered' infrastructure such as flowback water ponds, until the flowback water could be fully characterised.

In WA, there is an effective regulatory framework for managing risks associated with surface spills and leaks. Regulation includes the *Dangerous Goods Safety Act 2004* and associated regulations for transport, storage and handling of dangerous goods administered by DMIRS, *WQPN 26: Liners for containing pollutants, using synthetic membranes* and WQPN 65: *Toxic and hazardous substances*. These regulatory instruments and standards not only apply to hydraulic fracturing but to a range of other industries (e.g. mining, aquaculture). This is because these risks are not unique to hydraulic fracturing but are effectively managed (and regulated) across these industries in WA.

During the 2015 frac program, a robust and comprehensive groundwater monitoring program was undertaken to ensure any impacts to groundwater as a result of fraccing were detected. Results before, during and after fraccing were made available on Buru Energy's website with no impacts detected.

3.5. Risk to Surface Water

Buru Energy has not detected any impacts to surface water associated with hydraulic fracturing activities, with both the Asgard/Valhalla and Yulleroo areas located away from surface water sources. As such, this section considers the "risk to surface water resources" associated with hydraulic fracturing in the wider Canning Basin.

3.5.1. Extraction of Surface Water

The Canning Basin is the second largest groundwater resource in Australia with less than 10% of the sustainable yield of groundwater allocated to various users. Groundwater in the region provides a ready source of water for petroleum activities and means there is little requirement to extract water from surface water bodies to support petroleum activities.

As groundwater bores can be drilled on well sites within the potential areas of gas development, this limits the requirement to import source water for hydraulic fracturing in the Canning Basin. This also eliminates traffic movements associated with transport of source water for hydraulic fracturing, and means that the transfer of water will be limited to in-field transfers of water for reuse/recycling or disposal.

3.5.2. Spills Running off site to Surface Water Body (Potential Pathway)

The nearest surface water bodies to prospective gas developments in the Canning Basin are located many kilometres away as outlined below:

- The nearest surface water body to the Yulleroo region is Taylors Lagoon, located ~5 km to the northeast of the Yulleroo 4 petroleum well. Taylors Lagoon is considered an Environmentally Sensitive Area (ESA) which is an area of high conservation value.
- The nearest surface water body to the Valhalla North 1 well is Mt Hardman creek, which is located ~2 km southeast of the well site. Mt Wynne Creek is located ~4 km northwest of the well site.
- Mt Hardman Creek is also the nearest surface water body to Asgard 1, being located 25 km northwest of the well site.

3.5.2.1. 2015 Frac Program

Spill trajectory analysis associated with the 2015 frac program determined that the largest feasible spill from chemicals and fluid on site would be restricted to the gravel hardstand area of the well site and could be readily cleaned up.

During the program, there were three small spills on the well site, each of which were <60 L. These spills were all immediately cleaned up with no impacts on surface water.

3.5.2.2. Commercial Field

The risk to surface water sources associated with a commercial field development in the Yulleroo area will also be considered in planning that activity. The key risk source from a commercial development will be the water handling facility that will be located centrally in the field. Water retention ponds will be designed in accordance with *WQPN No 26: Liners for containing pollutants, using synthetic membranes* to mitigate overtopping of ponds and loss of fluid containment on site.

A spill response plan will also be in place as required under the Environment Regulations. This spill response plan will consider various spill scenarios along with the distance to sensitive receptors, including surface water bodies.

3.5.3. Overall Risk to Surface Water

The risk to surface water associated with fraccing in the Canning Basin is considered low. Surface water is not proposed to be extracted for fraccing activities and the prospective gas fields are located many kilometres from prospective unconventional well sites. Given the volumes of fluid used on site and the containment measures in place, fraccing activities (and the associated gas field) will pose a negligible risk to surface water in the region.

3.6. Risk to Soil Quality

Soil could be impacted by hydraulic fracturing activities due to the spillage of chemicals during fraccing or the spillage of flowback water following fracturing. Measures in place to mitigate spills of concentrated chemicals to the environment during transport, storage and handling are outlined in Sections 3.4.4.1 and 3.4.4.2 above. Measures in place to mitigate spills during fraccing and following flowback are outlined between Sections 3.4.9 and 3.5.2 above. These controls apply equally to the mitigation of impacts on soil quality as to the mitigation of impacts on groundwater quality or surface water quality.

During operations, Buru Energy undertakes routine inspections of operational sites to check for spills to the environment. While formal checks occur weekly, any spills are typically detected within a few hours of occurring on operational sites due to the number of people on site. In the event that a spill is detected, the affected area of soil is scraped up and removed for disposal at a licenced disposal facility. Sampling of soil may then be undertaken to ensure no contamination has occurred.

Buru Energy also undertakes soil sampling from the lease area before and after operations on site to allow detection of any impacts associated with the activities.

3.7. Impacts on Groundwater Quantity

This Section considers the impacts of Buru Energy's 2015 frac program on groundwater resources at Asgard 1 and Valhalla North 1. Numerical groundwater modelling has also been undertaken for the Asgard/Valhalla and Yulleroo areas, to consider the potential impact of groundwater extraction associated with the commercial development of gas.

3.7.1. 2015 Frac Program

All water used during the 2015 frac program was licenced in accordance with the *Rights in Water and Irrigation Act 1914* as administered by DWER. DWER allocates water use via licences within the sustainable volume available for a groundwater resource. DWER have determined that the Canning-Kimberley groundwater area, which includes the Liveringa Aquifer, has an allocated limit of over 300,000 ML/year[47], of which <10% is currently allocated to various users.

Licences GWL179166 and GWL179134 cover the abstraction of water from the Liveringa Aquifer for fraccing operations at Asgard 1 and Valhalla North 1, respectively. Extraction limits set were based on the maximum expected volumes required for the frac program, including associated activities such as use by the camp and dust suppression, plus contingencies. A maximum of 39.4 ML per year was permitted to be extracted from the production water bore at Asgard 1, and a maximum of 33.4 ML per year permitted to be extracted from the production water bore at Valhalla North 1.

Water use during the 2015 frac program was well below allocation limits, with around 12 ML used at Asgard 1 and around 9 ML at Valhalla North 1. Less water was used as the initial estimates were highly conservative, fewer zones were fracced than initially proposed, the volume of water used for each frac was less than anticipated, and the program was undertaken close to the wet season and so less dust suppression was required. Buru Energy's water use during the 2015 frac program represented a negligible portion of the Canning Basin allocation limit (<0.01%) and is far less than water used by other sectors in the region including communities, pastoralists and other industrial users.

3.7.2. Groundwater Drawdown

3.7.2.1. Context

As the surface Liveringa Aquifer in the Asgard/Valhalla area is an unconfined aquifer, drawdown of groundwater would be detected as a cone of depression forming around the production bore; an example of this is illustrated in Figure 21. The occurrence and extent of any cone of depression is dependent upon the volumes of water extracted from the production bore relative to the volumes available in the aquifer. Smaller cones of depression are associated with extraction of relatively small volumes of water from productive aquifers.

[47] DoW (2014). Water resources inventory 2014: Water availability, quality and trends. Department of Water, Western Australia.

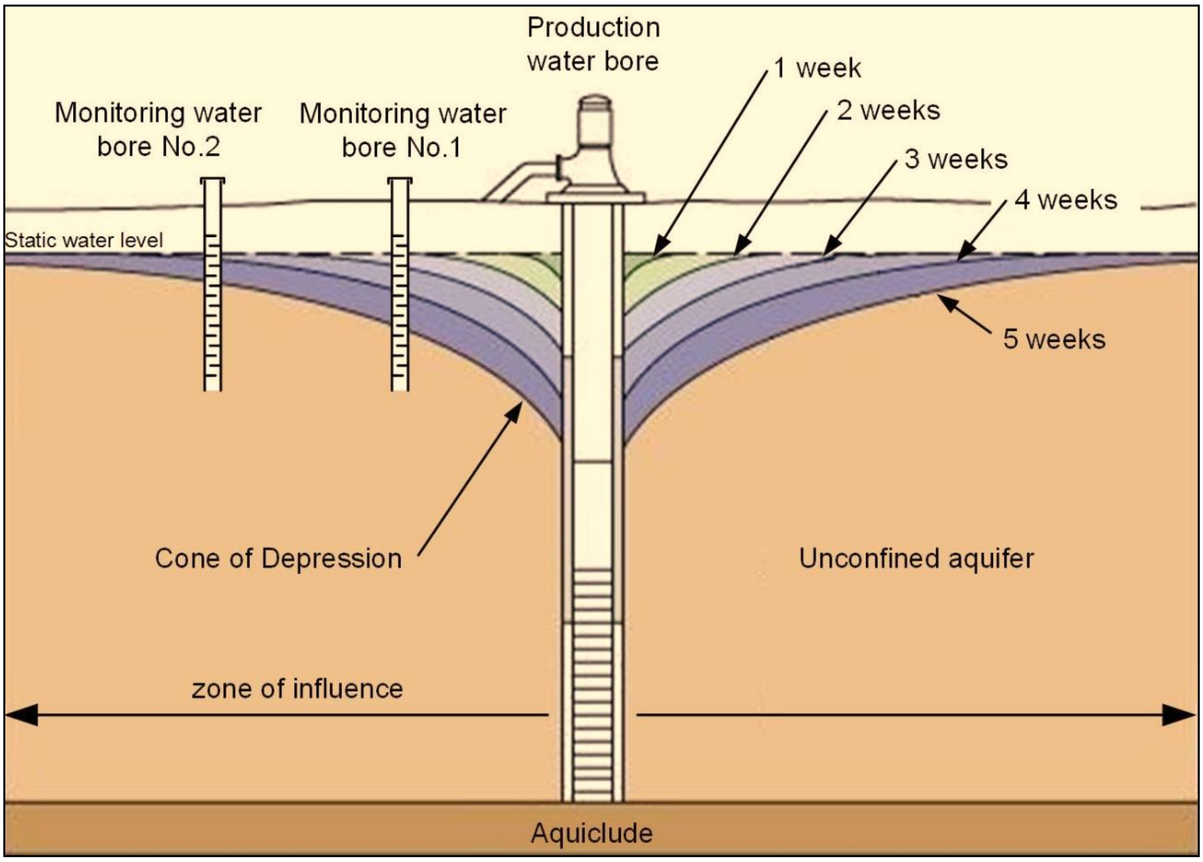

Figure 21: Example of a cone of depression around a production water bore with constant pumping.

3.7.2.2. Monitoring Drawdown

To examine the impact of groundwater extraction on drawdown of the Liveringa Aquifer, continuous depth loggers (Winsitu Rugged Troll 100) were installed in two deep environmental monitoring bores at both the Asgard 1 and Valhalla North 1 well sites during the 2015 frac program. As well as providing a time-series of groundwater depth, any cone of depression formed during groundwater extraction could be detected as these loggers were installed in environmental monitoring bores located at different distances from the production water bore (i.e. the bore that water was sourced from for the operations).

The results of groundwater depth monitoring at the Asgard 1 and Valhalla North 1 well sites are shown in Figure 22 and Figure 23, respectively.

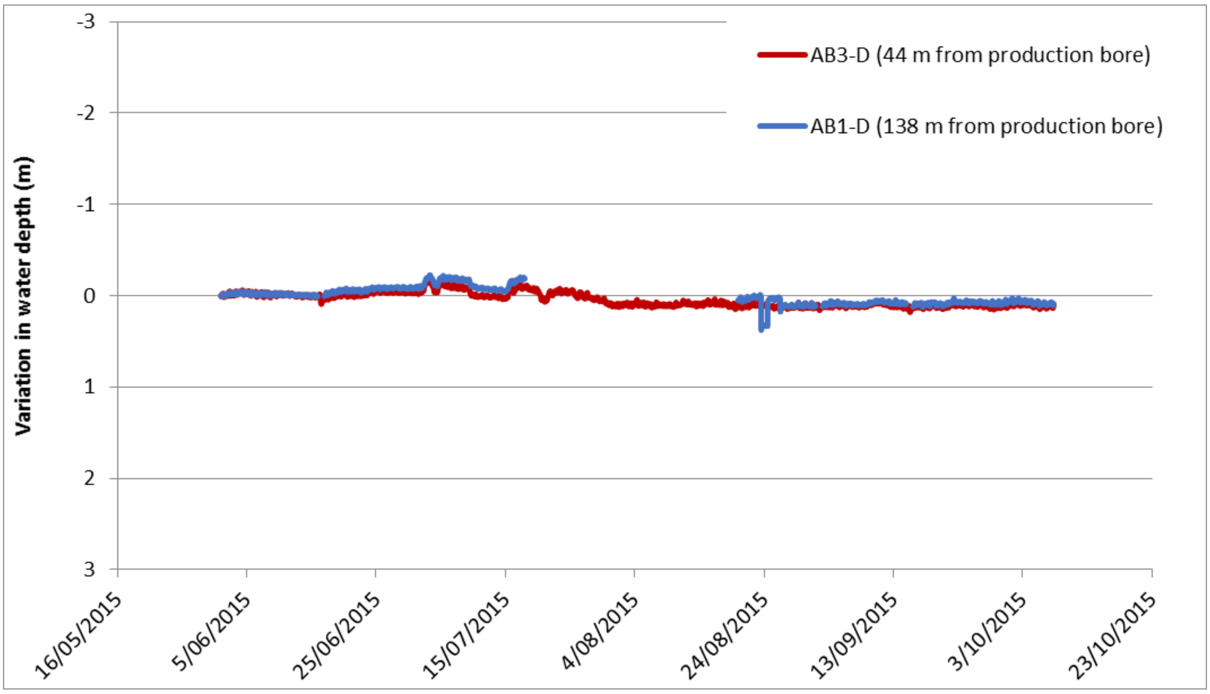

Figure 22: Variation in groundwater levels recorded at the Asgard 1 well site during the 2015 program.

The gap in data from AB1D between mid-July and mid-August 2015 was due to the cable holding the depth logger tangling following sampling of the bore, suspending the logger above the groundwater level in the bore. This was rectified during the following sampling event, in mid-August 2015.

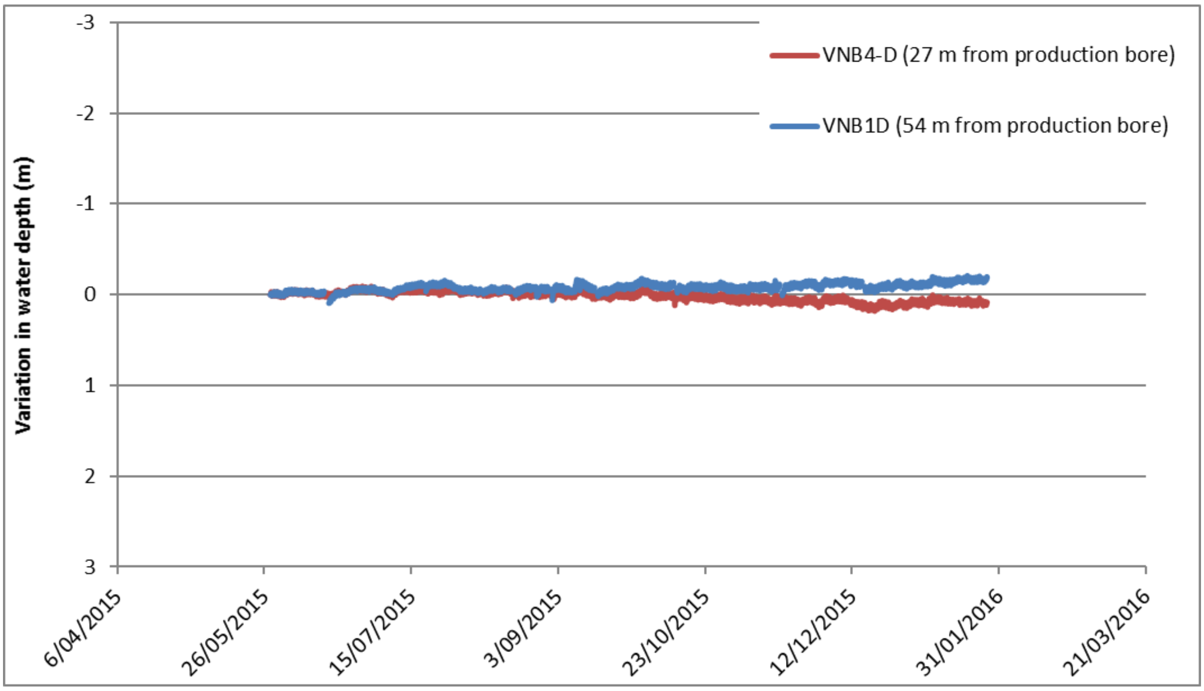

Figure 23: Variation in groundwater levels at the Valhalla North 1 well site during the 2015 program.

During the sampling period, water level in each of the bores varied within about 30 cm with little seasonal variation. There was no evidence of groundwater drawdown or a cone of depression forming at either the Asgard 1 or Valhalla North 1 well sites during the 2015 frac program; water levels at both well sites were consistent throughout the program and within the range of natural variability. There was therefore no evidence of the water extraction having an impact on groundwater resources of the Liveringa Aquifer.

3.7.3. Numerical Modelling

Buru Energy commissioned a specialist groundwater consultant (Rockwater) to undertake numerical modelling of groundwater in both the Asgard/Valhalla, and Yulleroo areas. The results of the modelling are summarised below, with further description of the modelling parameters and calibration provided in Appendix 5.

3.7.3.1. Asgard and Valhalla

Following the completion of 2015 frac program at Asgard 1 and Valhalla North 1, the conceptual hydrogeological model for this region was upgraded to a numerical model utilising the data collected during the program[48].

The numerical model was used to predict groundwater drawdowns from pumping a bore for six months and producing the total licence allocation for Valhalla North (33,400 kL, 183 kL/day). Drawdowns at two layers were modelled: deep (at the depth of the production bore screening), and shallow (in the water table).

The modelling indicates drawdowns of 1 m or more may extend up to 410 m from the production bore in the deep layer. Drawdowns in the shallow depths would be much smaller, around 1.2 m in the vicinity of the bore, decreasing to 1 m around 56 m from the bore, and 0.1 m at 690 m. The calculated drawdowns are consistent with groundwater monitoring results at Valhalla North and Asgard (Section 3.7.2) where drawdowns at shallow depths (albeit with lower pumping rates) are small and difficult to distinguish from normal seasonal fluctuations of about 0.2 m to 1 m.

The numerical model was then used to determine groundwater drawdown for pumping over six months to produce a volume of 10,000 kL corresponding to the volume used in the 2015 frac program, and to produce 100,000 kL, a nominal high-use scenario.

Outcomes from modelling show that even with extracting the maximum volume from a bore on site, groundwater levels would be expected to recover to within 0.2 m of the static water level without hours of pumping ceasing and to fully recover within weeks.

3.7.3.2. Yulleroo

During engagement with the Yawuru Traditional Owners in 2014, a numerical groundwater model was constructed for the Broome Sandstone Aquifer in the Yulleroo area[49]. This model considered the impact of groundwater extraction associated with exploration activities on the Broome Sandstone aquifer. The model has recently been re-run to consider the impact of water extraction associated with the Yulleroo conceptual field described in Chapter 2 on the Broome Sandstone aquifer and subterranean fauna[50]. The results of the numerical modelling are summarised below, with further description of the modelling parameters and calibration provided in Appendix 5.

Aquifer water use during a commercial field development is anticipated to range from approximately 72 kL/day to 581 kL/day. As described in Section 2.3.8.1 above, aquifer water use will be greatest during the first year of development, and will gradually decline over the life of the development as the number of wells constructed is reduced and more water is recycled. The modelling assumed all groundwater will be sourced from a single bore.

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[48] Rockwater (2016). Hydrogeological Assessment of Paradise-Valhalla-Asgard Project Areas. Report for Buru Energy. September 2016.
[49] Rockwater (2014). Numerical flow and solute transport modelling, for Yulleroo project. Report for Buru Energy Ltd. March 2014.
[50] Rockwater (2018). Results of Groundwater Modelling, and Subterranean Fauna Risk Assessment. March 2018.

The modelling determined that the maximum drawdown would occur at the end of Year 3, with the extent of a 0.01 m drawdown being 4.8 km from the bore, and an average drawdown of 0.1 m within 1 km of the bore. The modelling showed that drawdown would not affect the pumping capacity of the nearby Bohemia Bore, and will have no impact on Taylors Lagoon to the north of the proposed field. Buru Energy will continue to refine the numerical model over time as more information on the aquifer is collected (e.g. through installation of additional bores and undertaking pumping tests).

3.7.4. Risks to Associated Fauna

3.7.4.1. Asgard and Valhalla Area

Based on the hydrogeological assessment undertaken and the monitoring results from the 2015 frac program, a desktop assessment was undertaken to assess the potential risk to stygofauna and troglofauna associated with the Liveringa Aquifer in the Asgard/Valhalla area[51]. This risk assessment considered the following issues:

- likelihood of occurrence in the region,
- aquifer properties such as permeability, groundwater salinity etc,
- potential habitat loss associated with groundwater drawdown.

The risk assessment also considered indirect impacts such as groundwater contamination, changes to hydrology and nutrient balances.

The risk assessment determined that the absence of caves or significant voids in the fine-grained sediments in the Asgard/Valhalla area indicates there is unlikely to be habitat suitable for troglofauna. Further, given the level of drawdown, there is unlikely to be a direct impact to any troglofaunal habitat (if present).

The outcomes of the desktop risk assessment in relation to stygofauna are included below:

> *"Based on results of previous sampling, it appears that sandstone aquifers of the Kimberley contain moderately diverse stygofauna communities with very few stygofauna species restricted at small (project level) scales. The range of groundwater salinities recorded at Valhalla are within the tolerance levels recorded for stygofauna, and the shale and siltstone of the Liveringa Formation could potentially provide habitats for stygofauna. However, the reported low yields from bores screened in this formation suggest that suitable voids within sediments may be limited. The absence of more permeable sandstone lithologies previously reported to support stygofauna communities in the Kimberley may indicate that the potential for stygofauna is moderate to low. The regional extent of aquifers in the project area and absence of any geological barriers that may prevent dispersal suggest that any stygofauna community at Valhalla is unlikely have a restricted distribution. Given the relatively small impact areas (drawdowns of at least one metre over a 400 m radius) surrounding production bores, it is unlikely that the project will have a significant impact on the stygofauna values of the area or that the disturbance of potential habitat at Valhalla would result in a level of impact that would result in unacceptable risks to the conservation status of any stygofauna community."*

3.7.4.2. Yulleroo Area

The numerical modelling of groundwater extraction at Yulleroo also included an assessment of the risk of groundwater drawdown on stygofauna and troglofauna[52]. This assessment determined that the minimal drawdown of groundwater in the Yulleroo region would not significantly impact on stygofauna

[51] Rockwater (2016). Hydrogeological Assessment of Paradise-Valhalla-Asgard Project Areas. Report for Buru Energy. September 2016.
[52] Rockwater (2018). Results of Groundwater Modelling, and Subterranean Fauna Risk Assessment. March 2018.

species. Furthermore, any stygofauna that may be present would not be restricted to the project area. The assessment also concluded that impacts on troglofaunal, if present, would be negligible.

A summary of the findings is included below:

> *"The Broome Sandstone aquifer is a highly productive unconfined aquifer that is regionally widespread and is also known to provide suitable habitat for stygofauna. There are no geological barriers to stygofauna dispersal in the vicinity of the Yulleroo project and similar connected habitat exists outside the impact area of the project. Based on local groundwater conditions and results of previous stygofauna sampling in the region, it is unlikely that any stygofauna species would be restricted to the impact area (defined by the localised cone of depression in groundwater levels). Any loss of stygofauna habitat as a result of drawdown from the Yulleroo borefield over the 16 year project life is unlikely to impact the distribution of individual stygofauna species. Therefore, from an impact assessment perspective, development of the Yulleroo water supply is unlikely to affect the stygofauna values of the area. Troglofauna should not be considered a relevant environmental factor for the project."*

3.8. Beneficial Use of Water

Hydraulic fracturing and its associated activities could impact other beneficial users of water due to competition for water or loss of utility of due to contamination. The following considerations are relevant to this aspect of water in the Canning Basin:

- As outlined in Section 3.1.2 above, the annual sustainable yield of groundwater in the Canning Basin is between 615,00 ML/yr and 827,000 ML/yr, of which 33,134 ML (~4%) is consumed annually. As outlined in Section 2 above, a maximum of ~212 ML of groundwater is proposed to be extracted for a commercial field at Yulleroo, which represents ~0.035% of the annual sustainable yield of the resource.
    - Numerical modelling of this level of groundwater extraction from the Broome Sandstone determined that it would have a negligible effect on groundwater with drawdown restricted to 4.8 km the from production bore on site (if a single bore was used). At the nearest water bore (Bohemia Bore, 1.7 km away), drawdown would be around 0.04 m and would not reduce affect the yield of the bore.
- The Asgard 1 and Valhalla North 1 wells are located more than 55 km from the nearest PDWSA at Fitzroy Crossing, and 35 km from the nearest community water supply at Yungngora Community.
- The Yulleroo area is located more than 38 km from the nearest PDWSA at Broome.
- The risk to groundwater resources due to contamination is considered low as outlined in Section 3.4 above.

3.9. Social Surrounds

3.9.1. Amenity and Aesthetic Enjoyment

A number of factors are known to affect the amenity and aesthetic enjoyment of a landscape, including the presence of anthropogenic structures and areas of outstanding natural features and landscapes. In Australia there are no established or measurable thresholds for significance of change to landscapes or visual impacts. However, visual amenity may be considered as a factor of the magnitude of the change expected due to the development, taking into account the impact of development on factors including geology, topography, ecology and dynamic landscape processes that may be affected.

The Asgard/Valhalla and Yulleroo areas are part of the "Sandland Province", so named because the landscape was literally drowned in sand during a period between 14,000 years ago and 25,000 years

ago[53]. This resulted in the already relatively flat landscapes being covered by dust and sand resulting in the very flat pindan plains and parallel sand dunes that can be observed today. The vegetation on the sandplains is similarly uniform and is characterised by the pindan vegetation assemblage, which is present in an area of approximately 4,744 sq. km (refer to Section 3.2.2). As an example, the landscape in the vicinity of Yulleroo 2 is shown in Figure 24.

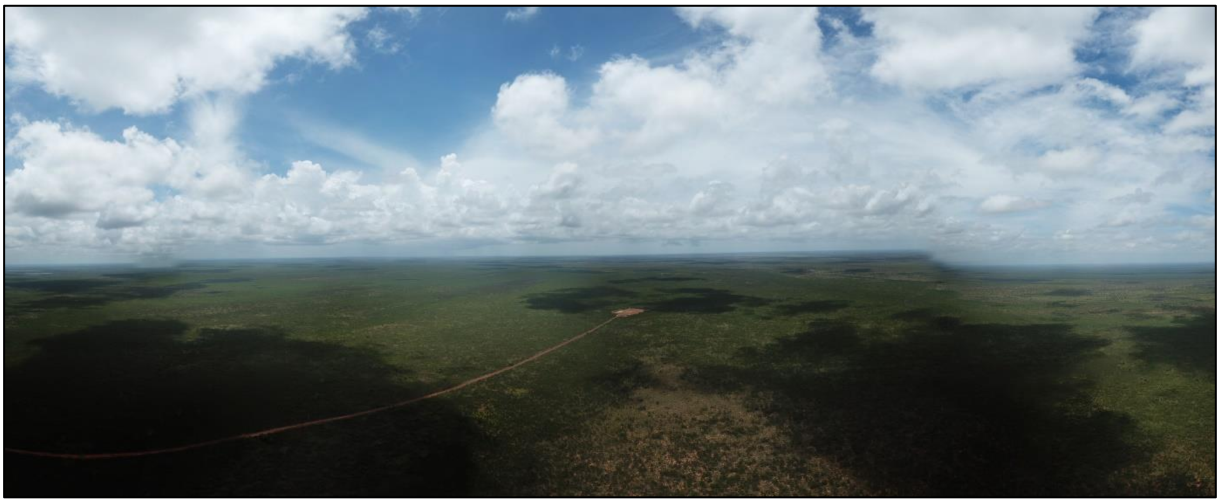

Figure 24: Landscape in the vicinity of Yulleroo 2 (February 2018).

The predominant land use in the Asgard/Valhalla and Yulleroo areas is pastoral rangeland. The areas are infrequently used for recreation and is not used for tourism. Recreational uses for the area are restricted to hunting by Traditional Owners, an activity that is rarely undertaken in the region and would not be impacted given the negligible footprint of a potential field development (Section 2).

Key areas of aesthetic enjoyment in the West Kimberley are generally associated with rocky outcrops and gorges, water bodies, and the coastline, which the Asgard/Valhalla and Yulleroo areas are remote from. Such areas include:

- Windjana Gorge and Tunnel Creek (approximately 60 km from Asgard/Valhalla);
- Geikie Gorge (approximately 70 km from Asgard/Valhalla);
- Fitzroy River (approximately 30 km from Asgard/Valhalla);
- Cape Leveque (approximately 150 km from Yulleroo); and
- Roebuck Bay (approximately 60 km from Yulleroo).

Based on the landscape values of the activity areas, the small footprint of a potential commercial development and the current land uses, it is not considered that development would impact on the amenity or aesthetic enjoyment of the region.

3.9.2. Public Safety

The areas that are most advanced for the development of unconventional gas in the Kimberley are Asgard/Valhalla and Yulleroo. These areas are remote, being located at least 20 km from the nearest homestead, 30 km from the nearest community and 70 km from the nearest town. The remoteness of these locations mitigates many of the potential risks to human health associated with construction and operation activities. The risks to public health associated with construction or operation of the gas fields are considered in Section 4.3 below.

The other means by which public safety may be impacted is associated with an increase in vehicle traffic. Up to 190 return truck trips will be associated with each frac campaign (fraccing 3-4 wells). These

[53] Jennings, J.N. and Mabbutt, J.A. (1977). Physiographic outlines and regions. In: 'Australia – A geography' (ed. D.N. Jeans). Sydney University Press.

traffic movements comprise approximately 30 truck movements associated with the frac spread, ~110 traffic movements associated with proppant sand, and a further ~50 movements associated with incidental traffic movements to site.

Based on these movements and the requirement for up to three frac campaigns per year, the number of heavy vehicle movements to and from the Yulleroo field is estimated as ~80 and ~510 return trips per annum (Figure 25). Between ~4 and ~20 of these return heavy vehicle trips per year will be associated with the transport of concentrated chemicals as described in Section 3.4.4. The highest number of heavy vehicle movements would occur in the early years of development when fraccing activity peaks (Figure 25).

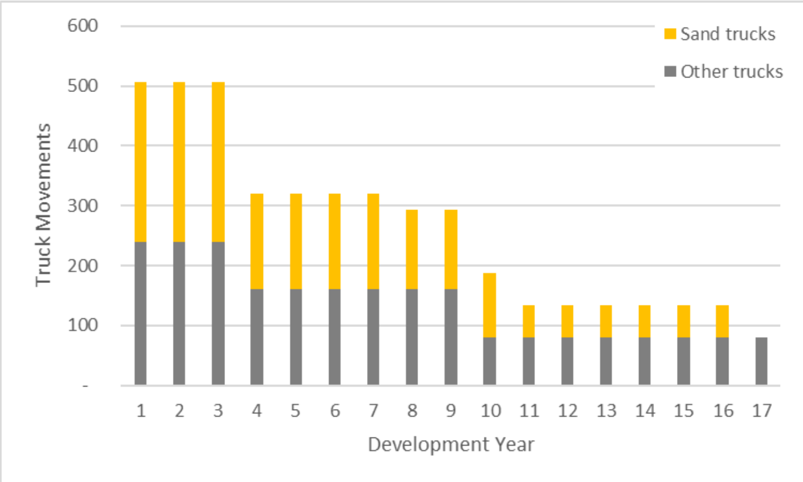

Figure 25: Number of heavy vehicle movements associated with fraccing at a commercial Yulleroo field.

Traffic volumes in the Kimberley are reported in the Kimberley Traffic Digest[54] as the average number of vehicles and heavy vehicles at certain locations within the Kimberley on a typical day. Between 2009 and 2014, the daily average of vehicles using the Great Northern Highway in the vicinity of Yulleroo was between 360 and 790. Of these movements, between 20.5% and 32.2% of traffic is related to heavy vehicles movements. Heavy vehicle traffic for fraccing will be mobilised to site via Great Northern Highway and would occur over a few days under a campaign-specific *Traffic Management Plan*. This increase in traffic is very minor relative to background levels and is unlikely to impact on public safety. Under ordinary circumstances, there will be no requirement for heavy vehicles to go into Broome or other towns in the region.

The incremental increase in public safety risk due to heavy vehicle traffic associated with the Yulleroo field would be offset by a reduction in LNG road tankers between Karratha and the Kimberley, as the local supply of gas would be available. Road tankers currently truck LNG from Karratha to power stations in Broome, Derby, Looma, Fitzroy Crossing and Halls Creek, with around 500 trips undertaken each year[55]. These trips are more than 800 km along a route that is shared with other heavy vehicles and tourist traffic.

[54] MRWA (no date). Kimberley Traffic Digest 2009/10 – 2014/15. Last Accessed 16 March 2018. Available from: http://reportingcentreresources.mainroads.wa.gov.au/public/data/xrc4111/AADT/traffic_digest.206.pdf
[55] Directhaul and Energy Developments Ltd (2016). Case Study: Productive Safety - Safely Transporting Essential LNG. Transafe WA Forum. Karratha WA, November 2016.

3.9.3. Seismicity

There has been increased occurrence of seismic events associated with oil and gas activities (induced seismicity) in the United States, and in particular Oklahoma[56]. In Oklahoma, these events are related to the reinjection of wastewater into disposal wells with less than 10% of the injected volumes being hydraulic fracturing fluid[57] . Injection rates into water disposal wells vary widely but may be up to 1 million barrels per month[58] (~1,900 ML per annum). Larger volumes of water disposal into wells are more likely to induce seismic events, along with proximity of the injection well to large faults, amount of the formation affected by injection, larger fluid pressure changes and duration of injection[58]. Thus, wastewater injection into formations is more likely to induce seismic events than hydraulic fracturing which is associated with smaller volumes of fluid injection and of much shorter duration.

From the conceptual field model and based on 50% flowback of frac fluid, an estimated 650 ML of water will be flowed back from the wells during the life of the field at an average of ~40 ML per annum. If all of this water is reinjected to formation (which is highly unlikely given the water will be reused in subsequent fracs), the volume of water reinjected is one to two orders of magnitude lower than the volumes typically reinjected in the United States. The field is also remote, being located tens of kilometres from the nearest homestead, community or town. Prior to injecting wastewater from the Yulleroo field into rock formations, a geological risk assessment would be undertaken to consider the properties of the receiving formation, the presence of faults and the volume, rate and duration of the proposed injection.

3.9.3.1. Background Microseismic Activity in the Canning Basin

To understand background microseismic activity in the Canning Basin, a microseismic monitoring program was implemented at the Asgard/Valhalla and Yulleroo sites by *Hasting Micro-Seismic Consulting* leading up to the 2015 frac program. The Canning Basin was determined to be "seismically quiet" with 19 regional and 7 local events detected by the two arrays, none of which were related to petroleum activities[59]. The main seismic events detected were associated with blasting activities at the Ellendale diamond mine (this mine subsequently closed in July 2015).

3.9.3.2. Microseismic Monitoring During Fraccing

A microseismic array was also deployed in the weeks leading up to Buru Energy's 2015 frac program at Asgard 1 and Valhalla North 1. This array was set up to monitor the extent and direction of the induced fractures and respond to potential induced seismicity.

During fraccing operations, 15 acoustic receivers were located in an array around each well and were connected to microseismic recording equipment on the well site using radio telemetry, monitored in real-time in an on-site office. The sensors around each well site were located along fence lines, existing tracks and seismic lines, with access coordinated by the Noonkanbah rangers. During operations, all microseismic information was recorded with events greater than a certain magnitude (as determined from collected baseline data), attributable to fraccing operations. As the acoustic receivers were located in an array, the x, y, z location of microseismic events and therefore the propagation of fractures could be determined.

[56] United States Geological Survey webpage 'Induced Earthquakes'. Last Accessed 15 February 2018. Available at: https://earthquake.usgs.gov/research/induced/myths.php.
[57] Murray, K. E. (2013). State-scale perspective on water use and production associated with oil and gas operations, Oklahoma, U.S. Environmental Science and Technology Vol 47(9): 4918–4925, doi: 10.1021/es4000593.
[58] Rubinstein, J.L. and Mahani, A.B. (2015). Myths and Facts on Wastewater Injection, Hydraulic Fracturing, Enhanced Oil Recovery, and Induced Seismicity. Seismological Research Letters 86(4).
[59] Hasting Micro-Seismic Consulting (2013). *Yulleroo and Valhalla Passive Seismic Monitoring Report, Days 166 to 329*. Report to Buru Energy. February 2013.

Buru Energy developed the *Microseismic Monitoring Procedure* (HSE-PRO-020) for the operations, which included a traffic-light based assessment for responding to potential induced seismicity events during fraccing. The traffic light assessment tool is shown in Table 3.

Table 3: Traffic based assessment for responding to potential induced seismicity.

Light	Description
	Green All Events PPV < 3.5 mm/s Threshold: • (PGA <~5 cm/s^2 below 10 Hz, ML < ~3.5) Actions: • Continue pumping as schedule

	Orange
	Recorded event PPV > 3.5 mm/s and < 16 mm/s
	Threshold:
	• (~5 cm/s^2 < PGA < ~20 cm/s^2 below 10 Hz, ~ 3.5 < ML < ~4.5)
	Actions:
	• Continue pumping at current rate. Cross check PPV, PGA and event magnitude. Adjust ML 3.5 and ML 4.5 categories accordingly.
	• If PPV < 3.5 mm/s revert to Green
	• If 3.5 mm/s < PPV < 16 mm/s maintain rate for 3 hours. Observe microseismic and accelerometer readings.
	  ○ No new events PPV > 3.5 mm/s. Revert to Green.
	  ○ Additional events 3.5 mm/s <PPV<16 mm/s (~3.5 < ML < ~4.5) and not increasing in size. Remain at Orange.
	  ○ Do not increase rate until no new events PPV > 3.5 mm/s (or ML > ~3.5) for 3 hours. Revert to Green.
	  ○ Additional events 3.5 mm/s < PPV < 16 mm/s (~3.5 < ML < ~4.5) and increasing in magnitude. Proceed to Red.
	• If PPV > 16 mm/s. Proceed to Red.

	Red
	Shut down. Recorded event PPV > 16 mm/s
	Threshold:
	• (PGA > ~20cm/s^2 below 10Hz, ML > ~4.5)
	Actions:
	• Do not bleed off. Observe microseismic for 3 hours.
	  ○ New Events PPV < 3.5mm/s (or < ML ~3.5) Leave Well shut in.
	  ○ New Events PPV > 3.5mm/s (or > ML ~3.5) Slowly bleed off well to pit (attempting to keep near well fractures open).
	  ○ Buru Energy engineering management to conduct risk assessment and advise when and if pumping should recommence.

During the 2015 frac program, between 0 and 860 microseismic events were detected from each stimulated zone with detections of microseismic activity much greater at the Valhalla North 1 well than the Asgard 1 well. Fracture stimulation was not associated with any microseismic events above the safe operating thresholds specified in Table 3, with all events in the "green traffic light" category. The recorded microseismic events were of insufficient magnitude to be felt at surface and did not exceed the threshold that might cause any hazard to the well or at the surface.

4. HUMAN HEALTH

The health of Aboriginal people in the Kimberley, particularly in remote Aboriginal communities, is significantly worse than the general population[60]. Factors contributing to poor health include overcrowding of housing, inadequate service provision (such as waste removal) and lack of access to healthy food[61]. Development in the region can benefit health and wellbeing of these communities, by providing employment opportunities, financial benefits, provision/ upgrade of infrastructure, and supporting community programs.

Opponents of hydraulic fracturing and development in general of the Kimberley often state that hydraulic fracturing causes significant health impacts. As noted in the 2015 WA Parliamentary Enquiry, public concerns regarding health risks are largely based on the use of chemicals in hydraulic fracturing fluid. Previous sections of this submission have addressed these concerns, with the use of chemicals and the ecotoxicity of Buru Energy's 2015 fracturing fluid considered in Sections 3.4.4 and 3.4.5.

Further, the WA Department of Health (DOH) assessed the risk to human health through chemical contamination of drinking water, the results of which are summarised in Section 4.1. Risks to human health are considered for workers and the general public are considered in Sections 4.2 and 4.3, respectively.

4.1. WA Department of Health Review

A Human Health Risk Assessment (HHRA) was undertaken for hydraulic fracturing in WA[62]. The HHRA considered the risk to human health via potential impacts to drinking water supplies. DOH's key findings were:

> *"The HRA has found that, under the right conditions, hydraulic fracturing of shale gas reserves in WA can be successfully undertaken without compromising drinking water sources.*
>
> - *Firstly, in WA, shale and tight gas reserves have been identified at depths of between two and four kilometres below ground level which are a considerable distance below potable ground water sources.*
> - *Secondly, the risks to drinking water sources associated with hydraulic fracturing can be well managed through agreed industry and engineering standards, best practice regulation, appropriate site selection (including consideration of Public Drinking Water Source Areas) and monitoring of the drinking water source."*

The DOH also made the following key recommendations to prevent impacts on human health:

- applying the Australian Drinking Water Guidelines for chemicals found in drinking water;
- a process for notification of incidents that have the potential to impact human health or drinking water; and
- ongoing consultation and collaboration between relevant government agencies.

Buru Energy implemented a thorough groundwater monitoring program during the 2015 frac program around the frac well sites with results compared to baseline levels. No increases in chemical parameters found in groundwater were detected. Buru Energy also compares water quality monitoring results to relevant guideline levels, including the Australian Drinking Water Guidelines.

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[60] Rural Health West (2013). Kimberley – population and health status. WA Country Health Service.

[61] Kimberley Aboriginal Health Planning Forum (2014). Health in the Kimberley – An Aboriginal Perspective. Prepared for the Kimberley Development Commission.

[62] Department of Health (2015). Hydraulic fracturing for shale and tight gas in Western Australian drinking water supply areas: Human Health Risk Assessment. June 2015.

The Administration Agreement between DMIRS and DWER[63] states that DMIRS will advise DWER of any reportable incident within a Public Drinking Water Source Area (PDWSA). Buru Energy's acreage has minimal overlap with PDWSAs, and Buru Energy has not undertaken any well operations (drilling or fraccing) within 40 km of a PDWSA.

4.2. Health of Workers

The other potential sources and pathways for impacts on human health are via a reduction in air quality and contamination of groundwater with flowback water. Risks associated with air quality and groundwater quality are considered in Sections 3.3 and 3.4 respectively.

Buru Energy considers the health and safety of its workers to be the number one priority in all operations. Potential risks to workers are managed to as low as reasonably practicable (ALARP), in accordance with the *Petroleum and Geothermal Energy Resources (Occupational Health and Safety) Regulations 2010* and *Petrol and Geothermal Energy Resources (Management of Safety) Regulations 2010*. In terms of the risk to workers' health during hydraulic fracturing operations, Buru Energy implements numerous measures including:

- proper storage and handling of chemicals (refer to Section 3.4.4);
- proper storage and handling of flowback water (refer to Section 3.4.6);
- ensuring integrity of wells (refer to Section 3.4.7) and all equipment;
- located camp sites away from operational areas;
- gas detection to identify any leaks;
- monitoring of groundwater quality and treatment if necessary to ensure potability; and
- ensuring workers wear appropriate PPE, including dust masks when handling proppant.

These ensure that risks to the health of workers are ALARP.

In addition, Buru Energy undertook an air quality monitoring program during its 2015 frac program (refer to Section 3.3). The program found that methane concentrations were only marginally above background levels. While this was a preliminary study, a comprehensive study by Monash University[64] found that petroleum industry workers have better health than the general public, and are less likely to die from diseases such as cancer and respiratory conditions.

4.3. Health of Public

Given the low risk to workers as described in Section 4.2, risks to the general public (who are ordinarily located tens of kilometres from potential development areas) are negligible. Any processes with the potential to have impact such as a localised reduction in air quality would rapidly diminish with increasing distance from the operational area.

Groundwater in the Yulleroo area flows westwards, and would take 1,700 years to travel from the Yulleroo wells to Roebuck Bay (approximately 60 km away) near Broome[65]. Similarly, groundwater in the Asgard/Valhalla area flows westwards towards the Fitzroy River (approximately 30 km away), and would take around 16,000 years to do so. There are no communities between the Asgard/Valhalla area and the Fitzroy River. The nearest community to the west of the area is Looma, approximately 60 km away. While contamination of groundwater is highly unlikely (see Section 3.4), any contamination would significantly dissipate/dilute/degrade before reaching the nearest downstream community receptor.

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[63] DMP and DOW (2015). Administrative Agreement Between the Department of Mines and Petroleum and Department of Water for Onshore Petroleum and Geothermal Activities in Western Australia.
[64] Monash University (2013). Health Watch: The Australian Institute of Petroleum Health Surveillance Program. Fourteenth Report. November 2013
[65] Rockwater (2015). Hydrogeological Assessment of Project Areas. Report for Buru Energy Ltd. June 2015.

Public Health England[66] concluded that publicised health problems in the United States appear to be attributable to operational failures and inadequacies in the regulatory environment (rather than any unavoidable risk of fraccing operations). Numerous independent reviews and enquiries, including the 2015 WA Parliamentary Enquiry, have come to the same conclusion: that if undertaken properly under robust regulation, hydraulic fracturing poses minimal risk to public health.

[66] Public Health England (2014). Review of the Potential Public Health Impacts of Exposures to Chemical and Radioactive Pollutants as a Result of the Shale Gas Extraction Process.

5. IMPACTS ON AGRICULTURE (PASTORALISM)

5.1. Pastoral Stations in the West Kimberley

Pastoral rangelands in the West Kimberley where Buru Energy operates have been described in Section 1.2. Due to reliable wet season rainfall supporting productive pastoral communities, West Kimberley pastoral stations are more productive than pastoral stations in the Pilbara and southern rangelands with West Kimberley pastoral stations supporting an average of ~3 to ~5 cattle units (cu) per square kilometre[67]. Cattle in the region have been selected to suit the environmental and climatic conditions with the majority of cattle being Brahman with some degree of *Bos indicus* genetics[68]. Cattle graze over large areas that are often unfenced, and are mustered annually during the dry season with saleable cattle turned-off and breeding cattle released back onto the pastoral station.

Outside of the towns and off Great Northern Highway, there is very little infrastructure in the West Kimberley with isolated homesteads, station tracks, fencelines, cattle yards and water bores often the only 'infrastructure' present across large areas of the basin.

5.2. Impact of Potential Gas Field

Section 2 outlines the impact of a potential gas field in the West Kimberley on pastoral operations. Key metrics associated with a gas field are:

- approximately 100 ha area required to produce 714 PJ; and
- approximately 1.06 GL of water extracted over the ~20-year field life.

Given the extent of the West Kimberley rangelands and the sustainable yield of groundwater resources, the potential gas field is highly unlikely to impact on pastoral activities (land or water) in the region, as discussed in previous Sections.

5.3. Impacts of Oil and Gas Industry

The oil and gas industry has had a presence in the Kimberley since the 1920s, when the first oil well (Mt Wynne 1) was drilled just north of Christmas Creek. Since that time, more than 250 wells have been drilled in the region with most pastoral stations having at least one petroleum well drilled on them. Due to this shared history of petroleum and pastoral activities in the basin, most pastoralists have a good understanding of petroleum operations, based on first-hand experience.

Petroleum operations occupy a small footprint relative to pastoral stations. The average size of a well site is ~2 hectares which is ~0.001% of the average size of pastoral stations in the region (~230,000 hectares), while a 'large' development (such as a commercial gas field) would occupy only around 0.03%.

Buru Energy typically enjoys good relationships with pastoralists in the West Kimberley, with these relationships maintained through Buru's Broome office. Given the low potential for land use conflicts between onshore petroleum and pastoral activities, relationships are premised on 'good neighbour' principles, where Buru Energy consults with pastoralists before activities occur to minimise or avoid disruption to pastoral activities. Buru Energy provides additional information to pastoralists when requested, such as water bore or water monitoring data.

[67] Warburton, D.P. and Thomas, P.W.E. (2015). Report to the Commissioner of Soil and Land Conservation on the trend of the Western Australian pastoral resource base. Department of Agriculture and Food, Western Australia.
[68] Department of Primary Industries and Regional Development (2017). The Western Australian beef industry. Last Accessed 16 March 2018. Available at: https://www.agric.wa.gov.au/industry-development/western-australian-beef-industry?page=0%2C2

Further, the petroleum industry often provides benefits to the pastoral industry. As the region has low levels of infrastructure, the installation or upgrade of access tracks and drilling of water bores provide valuable benefits to pastoralists. Numerous cattle yards in the West Kimberley are constructed from drill pipe (casing and tubing), provided by the oil and gas industry.

Buru Energy also routinely contracts local pastoralists to supply contract services to support petroleum operations. Most frequently, these contracting opportunities are for civil works which are high value opportunities on the shared petroleum permit/pastoral lease. This provides an additional income stream for pastoralists and benefits Buru Energy, as people with local equipment and knowledge of the landscapes are working on the ground. Buru Energy has been informed by one pastoralist in the region that the only reason they financially survived the live cattle export ban to Indonesia in 2011, and subsequent cuts to Indonesian import quotas, was because of contracting opportunities associated with Buru Energy's operations.

6. COMMUNITY

Buru Energy's exploration and production activities are solely focussed on the Canning Basin, making relationships with the Kimberley community central to conducting operations. Buru Energy's approach to building relationships with the Kimberley community is premised on the following:

- employing local people and using local contractors as much as possible;
- closely consulting with landholders that may be affected by activities and supporting independent advice being provided to landholders, where requested;
- a regional office in Broome staffed by local Kimberley people who have good links to Kimberley Traditional Owners and the community in general; and
- providing sponsorship to various local community groups and events.

6.1. Kimberley Community

The resident population of the Kimberley was estimated to be 39,900 people in 2013 with ~17,200 (43%) people residing in the Shire of Broome, ~10,050 (25%) living in Shire of Derby-West Kimberley, ~4,000 (10%) people living in the Shire of Halls Creek and the remaining ~8,650 (22%) living in the Shire of Wyndham-East Kimberley[69]. Approximately 17,000 (43%) of Kimberley residents are Aboriginal.

Compared to other parts of WA, the Kimberley region is economically disadvantaged. The unemployment rate is 12.2%, which is approximately double the rate in the rest of the state[70]. The level of disadvantage varies regionally across the Kimberley and is most apparent in remote Aboriginal communities[71]. Economic disadvantage closely correlates to increased risk of poor health with people living in remote Aboriginal communities having shorter life expectancies and suffering from a range of preventative diseases. Research demonstrates that increasing Aboriginal employment rates would result in extensive economic, health and social gains to Aboriginal people and communities.

To keep pace with population growth, it is estimated that an additional 34,000 jobs will be required over the next 20 years to match employment rates in the rest of the state, of which 4,000 jobs will need to come from the resources sector[69]. To have the greatest chance to address the economic disparity, many of these jobs will need to be created in remote Aboriginal communities – areas where community members typically rely on the Community Development Program (CDP) for employment. The challenge faced by government is to devise a strategy to improve employment outcomes for people living in remote Aboriginal communities[72].

Employment opportunities for remote Aboriginal communities are centred on the pastoral industry and resource projects. Expanded job opportunities in the pastoral industry provided by the State Government's *Water for Food* initiative will be important for remote indigenous communities, as will those created by resource projects such as Pantoro's gold project, Northern Mineral's heavy rare earths project, and those proposed by Buru Energy, Mitsubishi Corporation and Sheffield Resources (mineral sands). These jobs break will the cycle of welfare dependency and provide stable employment for community members.

[69] Department of Regional Development (no date). Kimberley: A region in profile 2014. Government of Western Australia.
[70] KDC (2015). 2036 and Beyond: A Regional Investment Blueprint for the Kimberley. Kimberley Development Commission. V 2.0. July 2015.
[71] WA Country Health Service (no date). Kimberley – population and health status. Government of Western Australia.
[72] Gray, M., Hunter, B. and Biddle, N. (2014). The economic and social benefits of increasing Indigenous employment. Centre for Aboriginal Economic Policy Research, Topical Issue No. 1/2014.

6.2. Engagement with Traditional Owners

Buru Energy's approach for engagement with Native Title groups in relation to projects is based on the following principles:

- identifying the economic, social, cultural and environmental objectives of the Native Title group in relation to the project and plotting these against the Company's objectives;
- identifying any social, cultural or environmental concerns raised by the Native Title group and supporting independent advice to be provided to Traditional Owners in a range of formats to address these concerns; and
- partnering with the community during operations to ensure the economic, social cultural and environmental objectives are met during the project phase.

Consultation with Native Title groups has occurred at its own pace, allowing Traditional Owners time to digest provided information, discuss the provided information with their family and community and make informed decisions. This approach has been guided by the principles of "Free, Prior and Informed Consent" promoted by the Declaration on the Rights of Indigenous Peoples.

Hydraulic Fracture of the Yulleroo 2 Well

Background

In November 2010, Buru Energy hydraulically fractured three zones in the Yulleroo 2 well, between 2,853 m and 3,119 m below ground level. The Yulleroo 2 well is located within EP 391, which is within the Yawuru Native Title Determination. It should be noted that the frac of the Yulleroo 2 well occurred when the level of public interest regarding fraccing was extremely low. Nonetheless, Buru Energy complied with all regulatory and heritage requirements in regard to the Yulleroo 2 frac test.

Regulatory Approvals

The frac operations were undertaken in accordance with the *Yulleroo-2 Fracture Stimulation & Coiled Tubing Clean-up/ Hang Off & Initial Well Test Program* (W-YUL2-010). Environmental aspects of the program were managed in accordance with the approved *Yulleroo-2 Well Hydraulic Fraccing Operations EMP* (W-YUL2-012).

Heritage Approvals

On 13 August 2010, a notification of on-ground activity for the Yulleroo 2 frac test was provided to Nyamba Buru Yawuru in accordance with the Heritage Protection Agreement (HPA) for EP 391. This notification provided all relevant information regarding the frac test including (but not limited to): i) details of the Yulleroo 2 frac test, ii) techniques, infrastructure and equipment to be used in operations, and iii) the likely effect on the environment and how environmental risks will be managed. The notification of on-ground activity was accompanied by an invitation to Yawuru representatives for a site visit during operations. The Company were in regular communication with the Yawuru leading up to the frac of the Yulleroo 2 well test to ensure the Yawuru were fully informed regarding Buru Energy's activities. No Yawuru Native Title holders took up the opportunity to attend the frac test.

Operations

Hydraulic fracturing operations were undertaken in November 2010. Following completion of frac operations, numerical modelling showed that the fractures extended up to 253 m away from the well bore and a maximum of 51 m high.

Post Operations Review

In early 2012, concerns were raised by members of the Yawuru community regarding the effect of the fracs at Yulleroo 2 on the environment. Buru Energy continued to engage with the Yawuru

community to demonstrate that the frac program did not impact on the environment; however, the concerns persisted. To further address these concerns, Buru Energy commissioned a number of retrospective studies in 2014 by industry experts covering the geological environment, operational approach, downhole chemicals, and hydrogeological environment.

Key findings of the studies were:

- A geomechanical assessment undertaken for the Yulleroo region by Prof. Peter Styles (University of Keel, UK & Editor in Chief of Geoscience) confirmed that while faults are present in the Yulleroo region and near Yulleroo 2 in particular, these faults are closed and pose low geological risk with respect to aquifer impacts.
- A chemical risk assessment was undertaken for the chemicals used in the Yulleroo 2 fracs. This risk assessment found that all chemicals that may be considered toxic in their pure form were also readily biodegradable. This means they could not persist in the environment for more than a few weeks and would have broken down in the target Laurel formation.
- The deepest recognised aquifer in the Yulleroo region was confirmed to be the Grant Group, which is located over 2.2 km above the highest stimulation zone at Yulleroo 2. Given the fracs were determined to extend around 50 m in height, it is inconceivable that the hydraulic fracturing operations could impact on groundwater systems.

All relevant reports relating to the Yulleroo 2 stimulation were provided to the Yawuru specialist reviewers. This review has been completed to the satisfaction of the Yawuru Native Title Group.

Specific initiatives adopted by Buru Energy in relation to the 2015 tight gas (fraccing) project are outlined below.

6.2.1. Identification of Objectives (Gas Roadmap)

Buru Energy started engaging with the Yawuru and Noonkanbah communities in 2012 and 2013 regarding potential tight gas projects at Yulleroo and Asgard/Valhalla, respectively. The first step in the engagement process was the development of a 'Gas Roadmap' document with each group. This document sought to set environmental, cultural/ social and economic objectives for Buru Energy and the respective Native Title group. The Gas Roadmap process was tied to key milestones in the appraisal and development of the tight gas resource. For example, this process identified opportunities to collect ecological and cultural information in the early stages of exploration and appraisal which could be used during later planning for a field development. The process also considered employment and contracting opportunities in the early stages of exploration and appraisal that would lead to full-time roles as field development progressed.

Buru Energy uses the Gas Roadmap to guide community engagement in relation to the tight gas activities, and in particular with the Noonkanbah community where tight gas activities are more advanced. An example of the Gas Roadmap as it relates to economic development (training, employment and contracting) with the Yungngora community is provided in Figure 26 below.

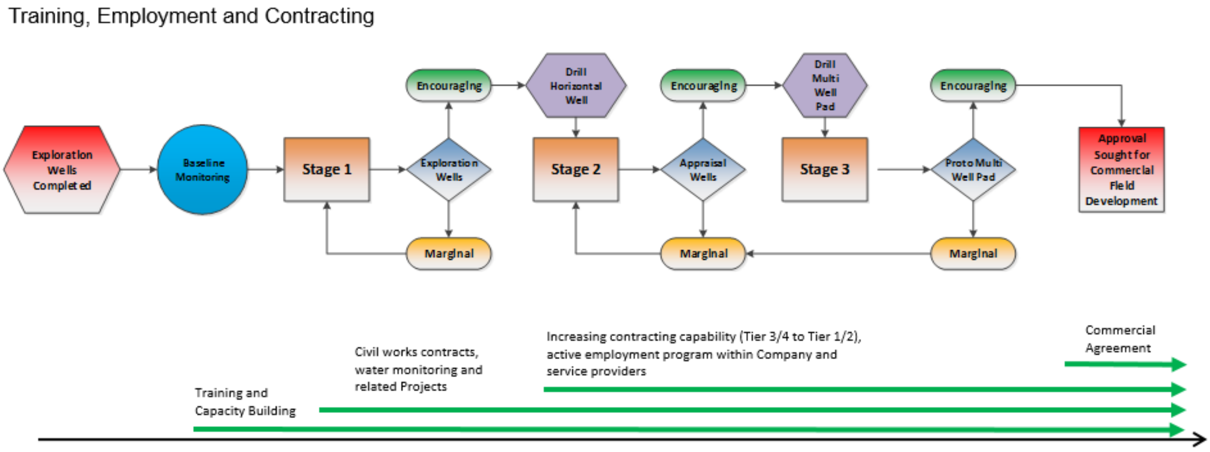

Figure 26: Example of Gas Roadmap developed with Yungngora Community relating to economic development opportunities.

6.2.2. Addressing any concerns raised (Independent Specialist Advice)

When engaging with Native Title groups, a number of environmental concerns regarding fraccing were raised, particularly by members of the Yawuru community. To be in a position to make an informed decision on fraccing, it was recognised that Native Title groups needed access to advice on fraccing from independent experts.

To support Traditional Owners to make informed decisions on fraccing, the Buru Energy/ Mitsubishi Corporation JV supported three independent specialist reviews on fraccing for the Noonkanbah community (Yungngora and Warlangurru people), Yawuru people and KRED Enterprises Pty Ltd (representing the Nyikina Mangala people, Karajarri people and Ngurrara people). The Noonkanbah and Yawuru communities had current proposals for fraccing on their land at Yulleroo and Asgard/ Valhalla, respectively. KRED were included as despite there being no current plans for hydraulic fracturing on the lands of Traditional Owners represented by KRED, a review process was undertaken for this group to ensure Traditional Owners from across Buru's acreage had access to the same independent information.

For each review process, each Traditional Owner group selected their own independent specialists to advise them on Buru Energy's hydraulic fracturing activities. The final panels included 11 specialists from four different universities and the CSIRO, as well as various consultants. Buru Energy provided funding for the independent experts to review proposed activities and hydraulic fracturing in general, and also made available all relevant approvals documentation during the process. The reviews were undertaken independent of Buru Energy, although Buru Energy attended collaborative risk workshops, community meetings and information sessions upon request.

The processes ran for between seven months (Noonkanbah) and 12 months (KRED process). A summary of each review process, including outcomes is provided in Appendix 6.

6.2.2.1. Summary

In summary, all three specialist review processes came to consistent conclusions: that the fraccing activities proposed at Yulleroo, Valhalla North and Asgard in 2015 used best available techniques and will have very low risk to country. The potential risks to groundwater and surface water were considered low due to both geological barriers and engineering controls in place and that below ground pathways pose a much lower risk than above ground operations such as transport of materials or surface spills.

At the end of the process, written reports from the independent specialists were provided to the Native Title group and Buru Energy.

At the end of the specialist review process for Noonkanbah community, the community unanimously voted to support Buru Energy's frac program at Asgard 1 and Valhalla North 1. Following the completion of the specialist review process with Yawuru, a PBC meeting was held to vote regarding Buru Energy's proposed 2015 frac program at Yulleroo. Following a vote of members, it was resolved that "Yawuru does not agree to the 2014/2015 fracking at Yulleroo, but if Buru Energy goes ahead with the fracking, Buru Energy must agree to meet environmental, cultural, social and economic conditions set by Yawuru".

6.2.3. Partnering with the Community during Fraccing Operations

In 2015, the Buru Energy/ Mitsubishi Corporation JV fracced the Asgard 1 and Valhalla North 1 wells on EP 371. The frac program was undertaken with the full support of the Noonkanbah community (Yungngora and Warlangurru) Native Title groups. Leading up to and during the program, Buru Energy worked closely with the community to ensure the economic, environmental, social and cultural objectives of the Native Title Parties in relation to the project were met.

6.2.3.1. Economic (Employment and Training)

The 2015 frac program at Noonkanbah was the first opportunity after the engagement program for Buru Energy to get Noonkanbah community involved in the operations. Prior to the program, the Buru Energy team and service providers met with the community members to identify potential work opportunities associated with the operations. Kimberley Training Institute (KTI) were also involved at this stage to identify training requirements for community members. As jobs were not available for all community members, people were nominated by a community committee for work and training opportunities with preference given to Yungngora people working at the Asgard site and Warlangurru people working at the Valhalla sites.

Operations associated with the frac program started in June 2015 with intensive operations occurring at site for approximately 15 weeks. During that period, 33 workers from the community worked more than 14,000 hours on the program. Work was in the following areas:

- Security and Access Control – Noonkanbah community members were responsible for providing security and access control at all sites for the whole frac program, in partnership with security specialists. This involved maintaining a 24-hour ranger presence across operational areas.
- Frac Spread – Noonkanbah workers were seconded to service companies during the program and worked alongside service company personnel doing equipment maintenance, loading sand, refuelling and related jobs.
- Civil Works – Noonkanbah community members were responsible for maintaining the access tracks and well sites during the frac program. This included watering of operational areas for dust suppression.
- Camp Services – Community members worked in the temporary camp during the frac program.

KTI were on site during the operations to train, assess and certify community members. Fifteen people were trained and ticketed in security, the operation of excavators, water carts, dump trucks, front end loaders and bobcats with 32 tickets awarded during the frac program.

6.2.3.2. Environmental

Buru Energy supported an environmental cadet program which was undertaken at Kimberley Training Institute in Broome in 2013 and 2014. The environmental cadetship program was created in partnership with KTI with the cadets trained in *Conservation and Land Management (Certificate II)* during the program. All four cadets from Noonkanbah community graduated from the program and became the Noonkanbah rangers.

Groundwater monitoring at the Asgard 1 and Valhalla North 1 well sites was undertaken with the Noonkanbah rangers. This provided transparency in groundwater monitoring. As results of the groundwater monitoring became available, these were provided to the Noonkanbah rangers and were also made available to the general public via the Company's website:
http://www.buruenergy.com/2015-tight-gas-pilot-exploration-program/

More recently, the Noonkanbah rangers have assisted Buru Energy and specialist environmental consultants with other surveys including rehabilitation monitoring and flora and fauna surveys on and around Noonkanbah pastoral station.

6.2.3.3. Social and Cultural

In addition to the cultural inductions provided to all contractors as described in Section 7, site visits were also provided for all interested community members during the frac program (Figure 27). Buru Energy provided buses to transfer people from the community to the well sites where they received refreshments and a tour of operations where they could ask questions about the operations occurring on site. During this time, operations were shut down and people were restricted to safe areas. A return bus trip then transferred people home.

Figure 27: Community visit to Asgard 1.

Around this time, Buru Energy also supported the re-establishment of the Noonkanbah community artists group (Figure 28). During the frac program, more than 250 artworks were painted by community members. These paintings centred around traditional dreamtime stories of their country with many sold to employees of Buru and Mitsubishi people, and also service company personnel. The art group is ongoing with materials provided by Buru Energy and Mitsubishi periodically.

Figure 28: Noonkanbah artists group.

6.2.4. Community Opinions

Coinciding with the end of the frac program in September 2015, Noonkanbah community made a press release, a copy of which is included on the following page.

Further, a videographer was on site during the frac program and collected footage of the fraccing operations and community engagement in the program. The footage was made into a short film on the frac program called “Noonkanbah – Proper Way”. The film is available via the below link:

https://www.youtube.com/watch?v=RoQpeZBI2fg

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11 September 2015

The following is a joint statement released today by Yungngora Chairwoman, Caroline Mulligan and Koolkarriya Committee Chairman, Ronnie Lormada.

We the Yungngora People are the recognized Native Title holders for Noonkanbah Station. Our lands around Noonkanbah have been our traditional lands for many thousands of years.

Buru Energy has recently completed their fraccing operation on our country. We allowed this to happen after speaking to many experts about the effect of this activity on our country and the environment. Our experts looked at Buru's plans and let us know this is a safe activity if it is done properly. We trust Buru to do this properly.

"My hope and dream for the community and for the people as well is mainly getting young people involved in the workforce, getting them involved in looking after their country and with Buru it has been a really strong start with us and for the future."

"It has been great to see our young people work closely with Buru and we have that connection."

The following is a statement from Thomas Skinner, Chairman of the Yungngora native title corporation.

We are the new generation of Aboriginal owners that speak for our country and have the support of our old people. We have set up Koolkarriya as a business council that represents the seven clan groups of our Traditional Lands. The council really connects with Buru Energy so that we can have future work and opportunity for our young people.

The reason we selected the people on the business council is so that they can feed back to their own people that they can have their own business going as well. If Buru Energy get cranked up, that is really good for us.

We really want to keep this place going. We want to keep our young people safe from alcohol and the new drugs coming into the Kimberley. This is what is killing our people. Mining is giving us job opportunities to work on our own land. We need training and job opportunities for our kids future.

A mining company like Buru Energy come in here, they give opportunity and work. We want this.

Alcohol and drugs is killing our people – not mining or oil and gas.

WE NEED THESE NEW OPPORTUNITIES.

We welcome Buru.

6.2.5. Current Status

Following the successful completion of the frac program in 2016, separate land use agreements were signed with Yungngora and Warlangurru Native Title groups. These agreements will provide Noonkanbah community and the JV with more certainty on the tight gas project. In May 2017, EP 371 was part of a transaction between Buru Energy and Mitsubishi Corporation whereby full interest in permit EP 371 was transferred to Mitsubishi Corporation entities.

Due to the current state government moratorium, appraisal and development activities are currently on hold and the wells are suspended (in care and maintenance). As a result, limited work opportunities are available for Noonkanbah community.

7. HERITAGE

7.1. Heritage Protection

Buru Energy has Heritage Protection Agreements (HPAs) in place with relevant Native Title Holders and Claimants across the areas of its exploration permits. The purpose of HPAs include:

- providing a workable and effective arrangement to avoid disputes and differences in relation to Aboriginal sites and other areas of significance to the Native Title group and give due recognition to the aspirations of the Native Title group with respect to the land;
- establish a protocol for the protection of heritage that is acceptable to all parties;
- enable informed decision making by Native Title members;
- assist in avoiding misunderstandings between Buru Energy and Native Title holders;
- foster good relations between the Native Title group, their representatives and Buru Energy;
- provide employment and economic opportunities to members of the Native Title group;
- minimise the social and environmental impact of petroleum activities;
- provide community benefits to the Native Title group; and
- prevent breaches of s.17 of the *Aboriginal Heritage Act 1972*.

For areas that are covered by Indigenous Land Use Agreements (ILUAs) such as the Ungani Production Licence areas, Cultural Heritage Management Plans (CHMPs) are in place and serve an equivalent purpose.

Buru Energy undertakes all petroleum activities in accordance with HPAs and CHMPs for the relevant permit. Typically, the following process is followed for the protection of heritage sites – i) heritage survey, and ii) heritage monitoring. More information on each of these processes is included below:

7.1.1. Heritage Surveys

Prior to new exploration activities occurring, Buru Energy consults with and conducts a heritage survey with relevant Native Title groups from where the proposed activities will occur, to avoid damaging any sites of significance.

Details of the proposed exploration activities are provided to the representatives of the Native Title groups. Buru Energy representatives also meet with the Native Title group representatives to provide more detail of the activities and address any concerns, before a heritage survey is organised.

Heritage surveys are organised by the representatives of the Native Title groups, and will involve an anthropologist, logistics staff, Traditional Owners familiar with the survey area and Buru Energy personnel. The heritage survey team will camp next to the location of the activities, and will walk, drive, and/or helicopter over the activity locations. This allows the Traditional Owners to assess if the proposed activities are likely to affect sites of significance. If necessary, amendments to the exploration activities will be made in consultation between Buru Energy representatives and Traditional Owners. Sites of significance may include cultural sites or species of cultural significance, such as the bilby, bush tucker and bush medicine.

7.1.2. Heritage Monitoring

Following the heritage survey and once the exploration activities are planned, Buru Energy will engage Traditional Owner monitors to observe the ground disturbing works as exploration activities are carried out. This provides an important backup to prevent any potential damage to sites of significance that could have been missed during the heritage survey or could be uncovered during ground disturbing works.

7.1.3. Outcome of Heritage Protection Process

Buru Energy has been actively exploring in the Canning Basin since 2009 with 19 seismic surveys and 28 petroleum wells drilled between 2009 and early 2018. These petroleum activities have been undertaken on lands of Traditional Owners including the Karajarri, Mawadjala Gadjigar, Ngurrara, Nyikina Mangala, Warrwa, Warlangurru, Yawuru, Yi-Martuwarra Ngurrara and Yungngora groups. Buru personnel have spent many hundreds of days on the ground working with these Traditional Owner groups, their anthropologists and archaeologists to protect heritage. This process has been highly effective as Buru Energy operations have had zero impact on heritage sites in the basin over the last decade.

7.2. Associated Benefits to Heritage

As well as having zero impacts on heritage sites over a decade, Buru Energy's presence in the basin has had associated benefits to heritage. These include: i) supporting specialist heritage projects, ii) protection of sensitive areas, and iii) increasing awareness of heritage. Typically, these initiatives have been undertaken by Buru Energy over and above regulatory requirements.

7.2.1. Specialist Heritage Surveys and Studies

In addition to completing between 70 and 75 heritage surveys over the last decade, the following specialist projects have been supported by Buru Energy, and have contributed to an increased understanding of heritage in the West Kimberley region.

7.2.1.1. Rock Art Survey

In 2013, Buru Energy commissioned Prof. Peter Veth and Jo McDonald to undertake a survey of rock art on two mesas known as Blue Hills (locally known as Yilakan), to the east of the Ungani Oilfield. A survey was undertaken in June 2013 by UWA along with eight Nyikina Mangala and Karajarri Traditional Owners, including three senior law holders. The survey recorded the rock art assemblages which were later documented in a confidential report for the Native Title groups. This survey was important to document a regionally significant rock art complex and likely would not have occurred without the support of Buru Energy.

7.2.1.2. Culturally Important Species

As outlined in Section 3.1.1, there is a persistent population of bilbies that occur in the Yulleroo area. This population has been the subject of considerable research and survey effort by Buru Energy centred on the support of a Murdoch University PhD project. As the bilby is a culturally important species and occurs on land that is shared across petroleum and Native Title interests, Buru and Murdoch have worked closely with the Yawuru people to survey and monitor bilby populations in the Yulleroo region, with all collected data made available to Yawuru land managers. Similar participation and data exchange has occurred with other Traditional Owner groups including the Nyikina Mangala, Karajarri and Ngurrara.

In 2012, a broad scale survey of bilbies in the Yulleroo region was undertaken in partnership with the Yawuru Native Title holders. In addition to collecting georeferenced information on bilby occurrence, the Yawuru participants in the survey also collected spatial information on other culturally important species occurring in the region. While Buru supported the overall survey, cultural information was collected by Yawuru, for Yawuru and will be important for Yawuru to understand the cultural attributes of the region and to implement their cultural management plan.

7.2.2. Protection of Sensitive Areas – Relinquishment of Petroleum Rights over Roebuck Bay

As outlined in Section 1.3.1.1 above, in May 2011, the Buru Energy-Mitsubishi Corporation Joint Venture voluntarily relinquished rights to explore for oil and gas in Roebuck Bay. This was initiated by Buru Energy and recognised the environmental and cultural importance of the Roebuck Bay area to the Yawuru people. As well as being a site of international environmental significance, Roebuck Bay is culturally important the Yawuru people and has been utilised by the Yawuru people for thousands of years, demonstrated by the numerous shellfish middens along the northern coastline of Roebuck Bay[73].

The decision by Buru Energy and Mitsubishi Corporation to relinquish their exploration rights over Roebuck Bay was progressive, pre-dating DMIRS adopting a similar approach to manage potential conflicts between petroleum exploration and conservation areas by approximately six years.

7.2.3. Increased Awareness of Heritage

Buru Energy promotes increased awareness of cultural heritage in the basin through a site-specific cultural induction that is delivered to all Buru Energy staff and contractors working on site. In the case of the most recent frac program at Asgard 1 and Valhalla North 1, cultural inductions were delivered by senior members of the community who spoke for the area where operations were occurring. It spelled out the community rules and described the importance of country to Aboriginal people, including culturally important plants, animals and sites in the area. Traditional Owners who delivered cultural inductions at each site were specifically affiliated with those areas – i.e. different Traditional Owners delivered cultural inductions at the Asgard 1 and Valhalla North 1 area.

Figure 29: Cultural induction at Asgard 1 during 2015 frac program.

[73] DEC (2009). Ecological character description for Roebuck Bay, Report prepared for the Department of Environment and Conservation by Bennelongia Pty Ltd. April 2009.

8. REGULATION

8.1. Current Regulatory Environment

WA has a long history of effectively regulating petroleum operations. The WA regulatory framework for petroleum activities has been developed alongside a globally significant petroleum industry and has been tailored to local experience and conditions, while considering industry best practice and experience from other jurisdictions.

The current regulatory framework for hydraulic fracturing in WA is well described in the *Guideline to the Regulatory Framework for Shale and Tight Gas in Western Australia – A Whole of Government Approach 2015*. In implementing the whole of government approach, DMIRS is the lead regulator responsible for regulating hydraulic fracturing which is regulated under the PGER Act and associated regulations. During the assessment of hydraulic fracturing proposals by DMIRS, input is provided from the following agencies, as relevant to the proposed activities: DWER, Office of the EPA (OEPA), Department of Biodiversity, Conservation and Attractions (DBCA) and the Department of Planning, Lands and Heritage (DPLH).

Under the whole of government approach, while DMIRS are the lead agency, DWER has responsibility for regulating emissions and discharges to the environment and the management of water resources. Management of water resources includes regulating proposed water bores, the extraction of water and protecting public drinking water source areas. The *Environmental Protection Act 1986* (EP Act) also applies to hydraulic fracturing in WA. Under Part IV of the EP Act, the EPA performs Environmental Impact Assessments (EIAs) for proposals that are likely to have significant impact on the environment.

The current regulatory framework is the result of seven to eight years of recent regulatory reform, which has been implemented to further strengthen the regulatory framework for petroleum activities, specifically in relation to hydraulic fracturing. The timeline of recent regulatory reform is set out in Appendix 7.

A key piece of regulatory reform during this period were the Environment Regulations, which were introduced in 2012 following an independent review of the WA regulatory framework by Dr Tina Hunter from Bond University[74]. The updated Environment Regulations included increased transparency of information associated with petroleum activities, such as the disclosure of a Summary Document at Environment Plan lodgement and full disclosure of chemicals used downhole. The Environment Regulations also strengthened obligations on industry in relation to impact and risk management, and improved the enforceability for petroleum activities in WA.

8.1.1. Comparison with Other Jurisdictions

No formal assessment has been undertaken comparing the WA regulatory framework with other jurisdictions. However, the following observations are relevant to this comparison:

- The Hunter Review (2011) determined that the process for the assessment and approval of an Environment Plan was rigorous, though the legal enforceability of Environment Plans required improvement.
    - The legal enforceability of Environment Plans was improved with the 2012 Environment Regulations.

[74] Hunter, T. (2011). Regulation of shale, coal seam and tight gas activities in Western Australia, Final. An analysis of the capacity of the Petroleum and Geothermal Energy Act 1967 (WA) to regulate onshore gas activities in Western Australia. Dr Tina Hunter, Faculty of Law, Bond University. July 2011.

- The Victorian Parliamentary Inquiry into onshore unconventional gas[75] noted that Queensland, New South Wales, South Australia and WA have developed individual frameworks to manage unconventional gas.
- The EP Act is the principle Act for environmental protection in WA and includes clear criteria for the formal assessment of proposals based on 'environmental significance'. Under the EP Act, where an inconsistent law is present, the EP Act prevails. The EP Act applies to all proposals in WA and provides a robust framework for regulating environmental impacts.
    - To date, the EPA has decided not to formally assess any of the six proposals involving hydraulic fracturing that have been referred, as they did not meet the threshold for 'environmental significance' and other statutory decision-making processes were present and adequate to regulate those proposals.
- Finding 2 of the WA Parliamentary Inquiry Report[76] determined that "*prior to the commencement of this inquiry, the Department of Mines and Petroleum had taken action to assess the readiness of the agency to deal effectively with the regulation of the onshore shale gas industry, including exploration and production and took action to strengthen its regulatory framework for onshore gas exploration"*.

8.1.2. Stakeholder Engagement

Involvement of stakeholders is a key component of best practice EIA, allowing economic, social and environmental objectives to be integrated into decision making while also safeguarding against poor or politically motivated decisions[77]. When undertaken effectively, stakeholder engagement can make a positive contribution to the EIA process.

There are legislated requirements for stakeholder engagement under both the Environment Regulations and the EP Act. Buru Energy recognises the importance of effective engagement with those stakeholders directly affected by hydraulic fracturing activities, in particular landholders and local communities. Buru Energy believes that the level of engagement with stakeholders should be commensurate with the scale, risk and potential impact of the proposed activity. As such, Buru Energy tailors engagement approaches to suit the local community, with engagement covering all aspects of the project. This includes environmental, cultural and social outcomes, and involvement of local people and communities in project operations to deliver real economic benefits. Examples of Buru Energy's stakeholder engagement programs in relation to the tight gas projects are described in Section 6.

8.2. Regulation of the 2015 Frac Program

The regulatory approvals process for the 2015 frac program ran for a period of approximately eight months, between November 2013 and June 2014. A summary of the regulatory approvals processes as they applied to the 2015 frac program is provided in Table 4.

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[75] Parliament of Victoria Legislative Council Environment and Planning Committee (2015). Inquiry into onshore unconventional gas in Victoria, Final Report. December 2015.

[76] Standing Committee on Environment and Public Affairs (2015). Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas. Report 42, November 2015

[77] Decadt, L. (2001). Public Participation in Environmental Impact Assessment. A Comparative Analysis of the United Kingdom, South Africa and the United States. MPA Thesis. University of Stellenbosch, South Africa.

Table 4: Application of regulatory framework to Buru Energy's 2015 frac program.

Legislation & Agency	Application to Buru Energy 2015 frac program
PGER (Resource Management and Administration) Regulations 2015 – DMIRS (formerly DMP)	The *Schedule of Onshore Petroleum Exploration and Production Requirements – 1991* (Onshore Schedule) applied to Buru Energy's 2015 frac program. Well Operations Programs were developed by Buru Energy for each phase of well operations and approved by DMIRS prior to the operations occurring. The Onshore Schedule has been superseded by the RMA Regulations. The regulations apply a risk based approach for the exploration for, and production of, petroleum. In accordance with the regulations, an approved Well Management Plan is required for all well operations, including drilling and hydraulic fracturing. The Well Management Plan ensures operations are undertaken in accordance with good oilfield practice and minimises the risk of aquifer contamination.
PGER (Environment) Regulations 2012 – DMIRS	An Environment Plan for the 2015 frac program was prepared in accordance with the Environment Regulations and associated guidelines. This demonstrated that risks were of an acceptable level and reduced to ALARP. The Environment Plan also documented the process and outcomes of the extensive consultation process with stakeholders that was undertaken. The Environment Plan was approved by DMIRS on 20 June 2014. An Environment Plan Bridging Document was provided to DMIRS in mid-2015, which updated operational details including the contractor and fluid system used for the program. The Bridging Document was approved by DMIRS on 20 August 2015.
Environmental Protection Act 1986 (Part IV) – EPA	Buru Energy referred the proposed frac program (eventually carried out in 2015) to the EPA on 26 November 2013. Following a public consultation period, during which 16 public comments were received, the EPA decided not to assess the proposal and provided public advice on 13 January 2014. The public advice covered the areas of hydrological processes, inland waters environmental quality, and rehabilitation and closure. The decision not to assess the proposal was made because the EPA considered the small scale, "proof of concept" fraccing proposal was unlikely to have a significant effect on the environment. Further, the EPA considered the presence of other statutory decision-making processes adequate – specifically the regulation of the proposal by DMIRS and DWER.
Environmental Protection Act 1986 (Part V) – DWER (formerly DER)	Buru Energy submitted an Application Enquiry to DWER in February 2014 to determine if a works approval or licence was required for the 2015 frac program under Schedule 1 (Category 10) of the *Environmental Protection Regulations 1987*. Advice received from DWER was that a works approval was not required for the frac program given the expected volumes of oil and gas produced. The general provisions of the EP Act (not causing or allowing pollution) and *Environmental Protection (Unauthorised Discharges) Regulations 2004* were still applicable during this project.
Environmental Protection Act 1986 – Office of Appeals Convenor	81 appeals were lodged against the EPA's decision not to assess Buru Energy's 2015 frac program. Of the 81 appeals, 33 appeals were invalid as the appellant did not pay the fee required to formally lodge the appeal, leaving 48 valid appeals.

Legislation & Agency	Application to Buru Energy 2015 frac program
	The Appeals Convenor considered the appeals with advice provided to the Minister for Environment. The Minister's Appeal Determination was provided on 16 June 2014 with the Minister dismissing all appeals.
Rights in Water and Irrigation Act 1914 – DWER (formerly DoW)	Licences for the take of water for hydraulic fracturing were granted by DWER under section 5C of the *Rights in Water and Irrigation Act 1914*. All water bores were metered with water used within licence entitlements. Water use during the 2015 frac program was reported to DWER in January 2016 along with results of water quality analysis on production water bores.
Environment Protection and Biodiversity Conservation Act 1999 – DoEE	No referral to the Commonwealth DoEE was required under the *Environment Protection and Biodiversity Conservation Act 1999,* as the program was considered unlikely to have a significant impact on Matters of National Environmental Significance.

8.3. Opportunities for Regulatory Reform

8.3.1. Regulatory Framework Reform

Buru Energy supports the application of an objective, risk-based regulatory approach for petroleum activities as specified by the PGER Act, the EP Act and associated regulations. Within that framework, Buru Energy has identified potential opportunities for reform, as outlined in the below Sections.

8.3.1.1. Assessment of Environmental Risk

In improving the current regulatory framework, Buru Energy would support the adoption of a process whereby proposed petroleum operations are classified as 'High', 'Medium' or 'Low' risk, based on an assessment of environmental and operational risk of the activities. Under such an approach, high risk activities would be subject to greater scrutiny during both the assessment phase and during operations (through audits and inspections) compared to low risk activities. A risk based approach such as this has been adopted by the South Australian government for regulating petroleum activities[78]. Adoption of such a risk-based approach would reduce the regulatory burden associated with low risk petroleum activities, allowing the regulator to focus a greater proportion of resources regulating higher risk activities.

8.3.1.2. Development of Standard Approaches

Further improvement to the efficiency of the regulatory system may also occur through the development of standard approaches (or reference cases) for certain activities. These would be for activities that are undertaken using standard industry methods with known risks, similar to the reference cases currently being developed for the offshore petroleum industry[79]. Relevant considerations regarding the development of reference cases include:

- reference cases would be developed and 'owned' by industry;
- reference cases would be required to be periodically reviewed to ensure continuous improvement in environmental management are incorporated into operations;
- in the first instance, reference cases would be developed for 'low risk activities' such as airborne surveys;

[78] Department of State Development (2015). Licensing and Approvals Process for Exploration, Retention and Production Activities in South Australia (SA). Last Accessed 15 March 2018. Available at: http://petroleum.statedevelopment.sa.gov.au/__data/assets/pdf_file/0007/256327/Exploration_and_Production_Flowchart_Ver_8_September_2015.pdf

[79] NOPSEMA (2018). Reference Case Project. Last Accessed 15 March 2018. Available at: https://referencecases.nopsema.gov.au/

- depending on the environmental risks, reference cases may be developed regionally (e.g. Canning Basin) or state-wide; and
- reference cases would be published publicly and would provide increased transparency regarding the management of environmental risks by the petroleum industry.

8.3.1.3. Water Quality Monitoring

Buru Energy supports the implementation of compulsory groundwater monitoring programs for hydraulic fracturing operations. Monitoring programs should be undertaken in accordance with the *DMIRS-DWER Guideline for Groundwater Monitoring in the Onshore Petroleum and Geothermal Industry, August 2016,* and should include sampling of groundwater prior to and after hydraulic fracturing activities (i.e. baseline and surveillance monitoring). Buru Energy also considers that wherever possible, groundwater monitoring programs should be undertaken in collaboration with local landholders such as Traditional Owners and/or pastoralists. This provides transparency with these key stakeholder groups.

8.3.1.4. Appeals Process under the EP Act

An independent appeals process as specified under Section 100(1)(a) of the EP Act is an important aspect to robust EIA. Appeals processes provide safeguards against procedural flaws in the EIA process, issues that the decision-maker failed to consider, or poor or politically motivated decisions and are therefore a critical aspect of a robust regulatory regime. However, the appeals process under the EP Act is increasingly being used by environmental activist groups to delay projects or proposals.

The appeals process would therefore benefit from the establishment of guidelines for appeal eligibility so that any objections or claims are legitimate.

8.3.2. Role of the Regulator

DMIRS is a mature regulator with a high level of in-house technical expertise reflecting their track record of regulating a large-scale petroleum industry in WA over a long period of time. In addition to regulating petroleum activities, DMIRS is responsible for promoting petroleum prospectivity in WA through their acreage release process. Acreage releases occur either once or twice a year with allocation of acreage based on a competitive bid process.

The dual responsibility of the regulator as both a promotor and regulator of the industry has led to statements that the 'fox is guarding the henhouse' and led to some public distrust of the regulator. While this is unwarranted given the separation of the respective functions within DMIRS, this perception is widely propagated by opponents to hydraulic fracturing and is now an issue of concern amongst some members of the general public. If it can be demonstrated that separation of the promotion and regulatory functions would lead to an increase in public confidence in the regulator, Buru Energy would support this change.

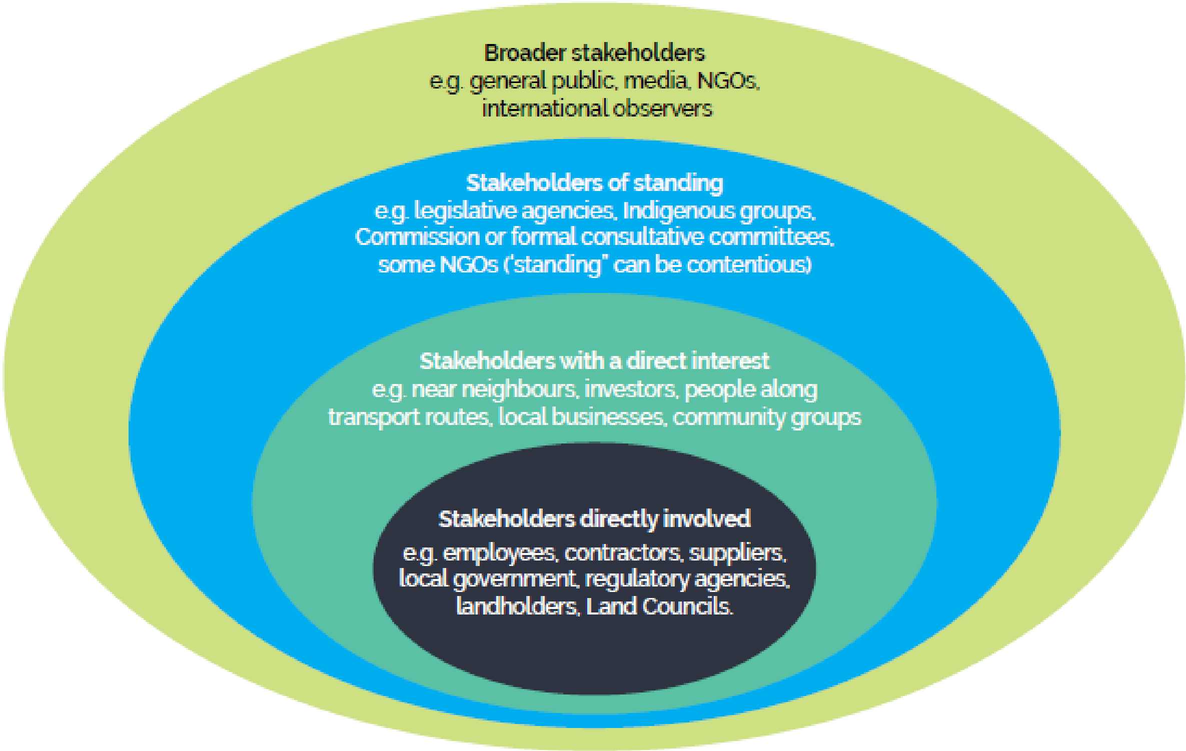
8.3.3. Improved Definition of Stakeholders

Regulation 11(1)(f) of the Environment Regulations requires that for an Environment Plan to be approved, operators are required to "*demonstrate that there has been an appropriate level of consultation with relevant authorities and interested persons and organisations*".

This regulation does not expressly take into account the level of risk of the proposed activity and does not distinguish between those stakeholders with a direct interest in a proposal and those that will be largely unaffected by a proposal. As a consequence, this expression has been interpreted as requiring a proponent with a short duration (less than 14 days) low risk activity to have to consult widely including with organisations based in other states; and for the proponent to have regard to the views of those organisations in a similar way it will have regard to the views of someone living adjacent to a proposal

who is directly affected by or might benefit from the proposal. Improved clarity around this regulation would greatly assist the design and implementation of effective engagement programs with stakeholders commensurate with the scale and risk of the proposed activity.

Leading practice stakeholder identification approaches adopt a 'nested' approach to identify stakeholders that may be directly and indirectly affected stakeholders and interested parties. An example of a nested approach that was developed for the Northern Territory Scientific Inquiry into Hydraulic Fracturing is provided in Figure 30. Following this nested approach, more engagement is focussed on those stakeholders who are directly involved in the project followed by those with a direct interest in projects. Similarly, the views of these stakeholders should be given greater weight in engagement compared to stakeholders in who are indirectly affected or are simply interested parties.



Source: NT Scientific Inquiry Report[80]

Figure 30: Stakeholder identification tool that will assist with the identification of relevant stakeholders in relation to a tight gas project.

8.3.4. Transparency Reforms

Increased transparency of petroleum activities has been seen by government agencies as a key aspect for increased confidence and trust in the community through greater understanding and awareness and is reflected in DMIRS' Transparency Policy[81]. This is reflected by DMIRS considering full public disclosure of Environment Plans, monitoring data and compliance reports.

Making all environmental information publicly available assumes opposition to the petroleum industry by activist groups is premised on protecting the local environment and groundwater in particular.

[80] Witt, K., Vivoda, V., Everingham, J. and Bainton, N. (2017). DRAFT A framework for social impact assessment of shale gas development in the Northern Territory. Centre for Social Responsibility in Mining, University of Queensland. Presented as Figure 12.3 in Draft Final Report into Hydraulic Fracturing in the Northern Territory.
[81] DMP (2017). Transparency Policy. Department of Mines and Petroleum, February 2017.

Increasingly, it is becoming apparent that opposition to the petroleum industry reflects anti-fossil fuels positions that have been adopted by these activist groups[82].

In this case, increasing transparency of environmental documentation and associated data will not increase public confidence in the petroleum industry. In certain instances, when environmental and other information has been publicly released, activist groups have taken selective parts of the released information and used it out of context to suggest that a problem might exist when that is not the case. The selective use and publication of environmental information can lead to further erosion in public confidence in the petroleum sector as well as with the regulator.

Based on the objective of using transparency to increase confidence and trust relating to petroleum activities, Buru Energy has implemented the following transparency initiatives. In the most part, these are focussed on local landholders who were directly involved in the 2015 frac program:

- full disclosure of all approvals documentation to relevant Traditional Owner groups as part of the independent specialist review process for fraccing (refer to Section 6.2.2);
- full involvement of relevant Traditional Owner groups (Yungngora and Warlangurru) in the groundwater monitoring program undertaken at Asgard 1 and Valhalla North 1 associated with the 2015 frac program (refer to Section 6.2.3);
- full disclosure of groundwater quality results to Traditional Owner groups associated with the 2015 frac program (refer to Section 6.2.3.2);
- providing independent environmental information to pastoral stations, as requested, including water bore or water monitoring data; and
- publication of groundwater data on Buru Energy's website prior to, during and after the 2015 frac program.

Buru Energy considers that transparency initiatives such as these provide more value to stakeholders, particularly key stakeholders, than 'blanket' transparency reforms that involve untargeted release of bulk information of a highly technical nature to the general public.

8.4. General Stakeholder Engagement

There is considerable opposition to unconventional activities in WA. While this opposition to unconventional activities is largely driven and funded by groups with anti-fossil fuel agendas, improving the general public's confidence in the sector will be important for the future success of unconventional projects (and the wider petroleum industry). Reflecting the comments made in Section 8.3.3, the primary focus of engagement should be with directly affected local stakeholders. Ensuring independent advice is available to those stakeholders to address issues of concern has been effective in supporting local community engagement in WA. Examples where such approaches have been successfully employed include Buru Energy's independent specialist review process (Section 6.2.2) and the independently facilitated community roundtable model employed by the Shire of Irwin and AWE for the Waitsia Project in the mid-west[83].

Beyond local community engagement, some advocacy and engagement with the wider community will also be important to address concerns, increase understanding and increase support for the onshore gas industry. Industry associations and government will have a greater role to play in this community engagement rather than individual operators. Wider community engagement may also present the social, economic and environmental benefits of an onshore gas industry to the state, including increased energy security.

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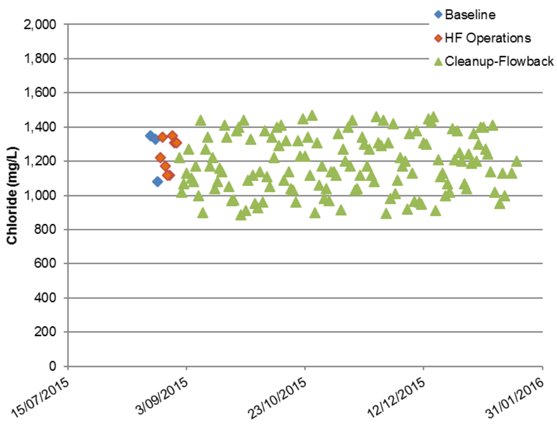
[82] The Wilderness Society (no date). Act on climate. Last Accessed 15 March 2018. Available at: https://www.wilderness.org.au/campaigns/act-climate

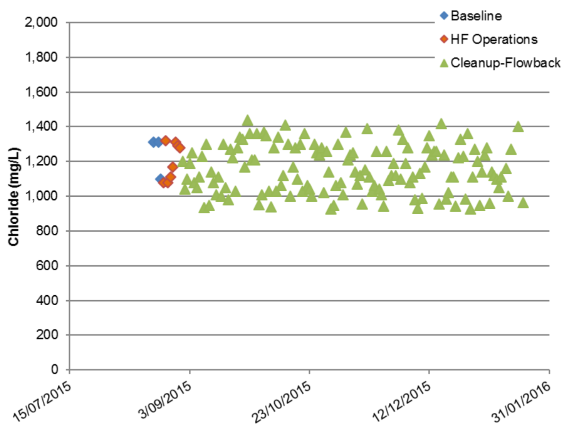
[83] Meet2Create (no date). Community Roundtable. Last Accessed 15 March 2018. Available at: http://www.meet2create.com/shireofirwincommunityroundtable.html

Appendix 1 – Monitoring Results from the 2015 Frac Program (Daily Monitoring of Chloride)

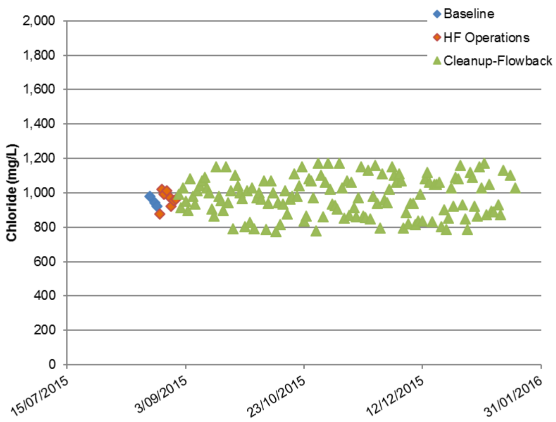
Asgard 1



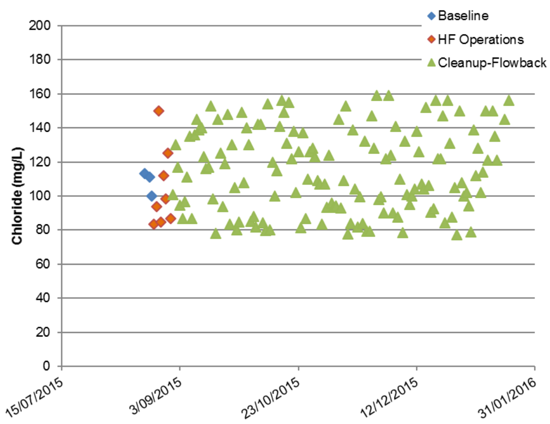
Nested Deep Bore (Up-gradient/Control)



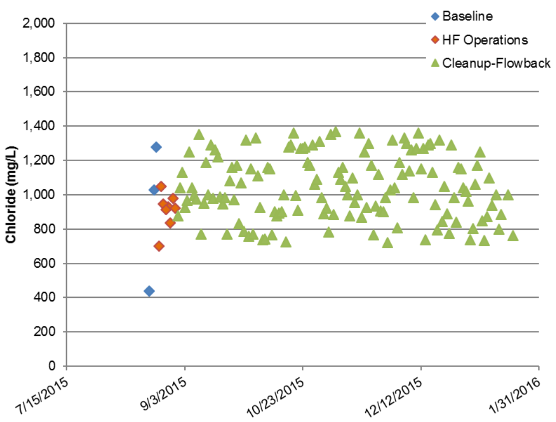
Nested Shallow Bore (Up-gradient/Control)



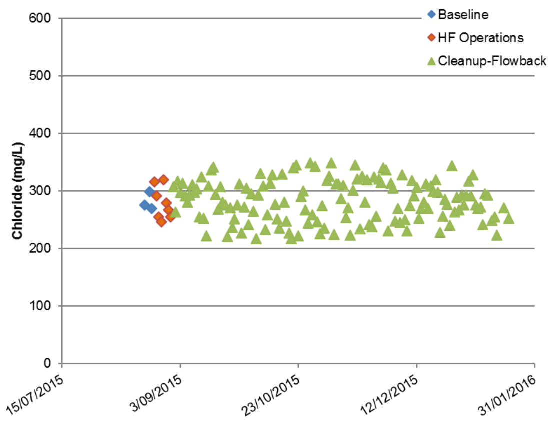
Nested Deep Bore down-gradient of well head



Nested Shallow Bore down-gradient of well head



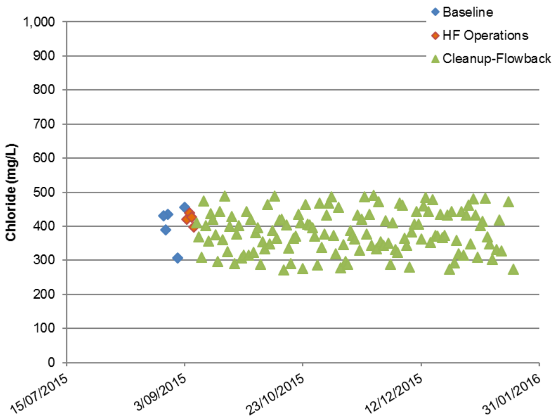
Shallow bore down-gradient of flowback pond

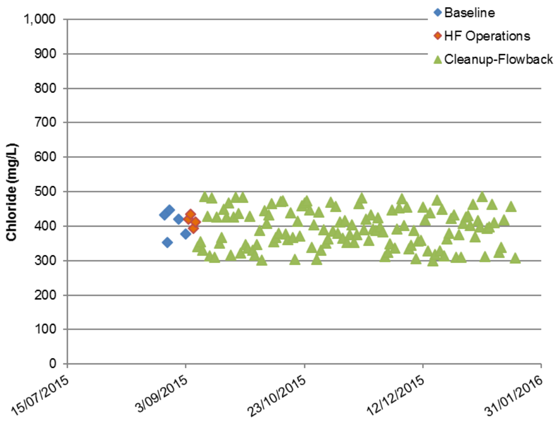


Shallow bore down-gradient of retention pond

Figure A1-1: Results of daily monitoring at the Asgard 1 well site during the baseline, HF operations and well cleanup-flowback phases of the 2015 frac program.

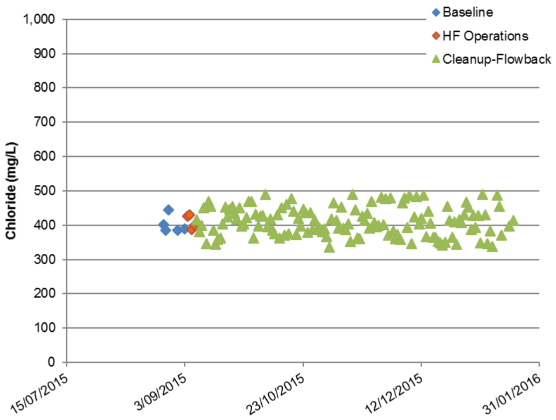
Valhalla North 1

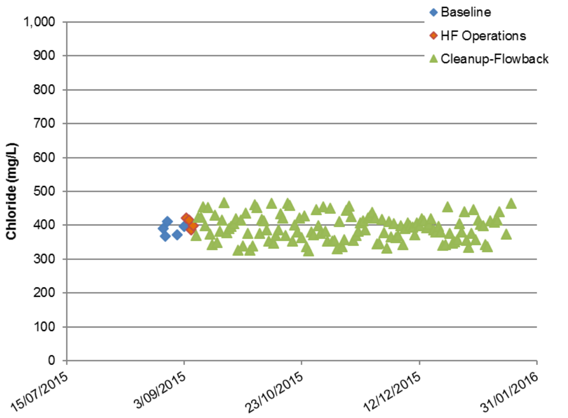




Nested Deep Bore (Up-gradient/Control)

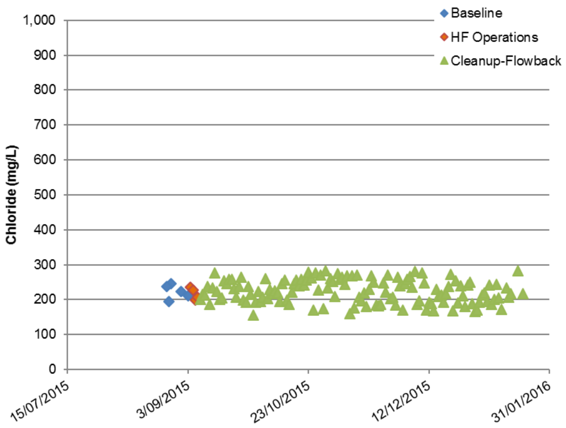
Nested Shallow Bore (Up-gradient/Control)

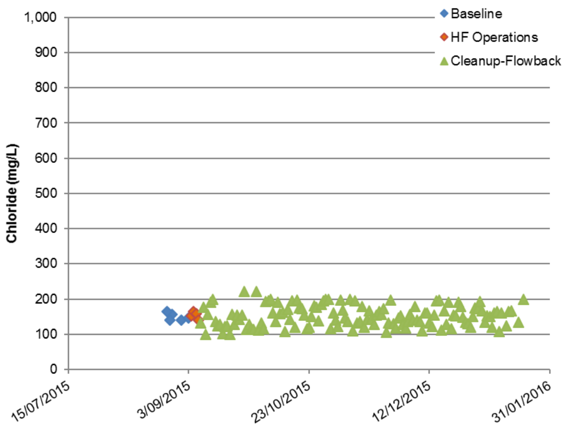




Nested Deep Bore down-gradient of well head

Nested Shallow Bore down-gradient of well head





Shallow bore down-gradient of flowback pond

Shallow bore downstream of retention pond

Figure A1-2: Results of daily monitoring at the Valhalla North 1 well site during the baseline, HF operations and well cleanup-flowback phases of the 2015 frac program.

Appendix 2 – Monitoring Results from the 2015 Frac Program (Full Suite of Analytes)

Groundwater monitoring at each of the well sites was undertaken according to the schedule outlined in Table A2-1.

Table A2-1: Schedule of monitoring from dedicated environmental monitoring bores prior to, during and following the frac program.

Location	Jan. 2015	Feb. 2015	March 2015	May 2015	June 2015	July 2015	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015	Dec. 2015	Jan. 2016	April 2016	July 2016	May 2017	Nov. 2017
Asgard 1	*	B	B	B	B	B	B/S†	S†	S	S	S	*	P	P	P	P
Valhalla North 1	*	B	B	B	B	B	B†	S†	S	S	S	S	P	P	P	P

B = Baseline; S = Surveillance, P = Post Operations.

* Site inaccessible due to weather. DMIRS Petroleum Environment Branch notified accordingly.

† Water sampling from mid-August to mid-September 2015 occurred two-weekly.

Chloride

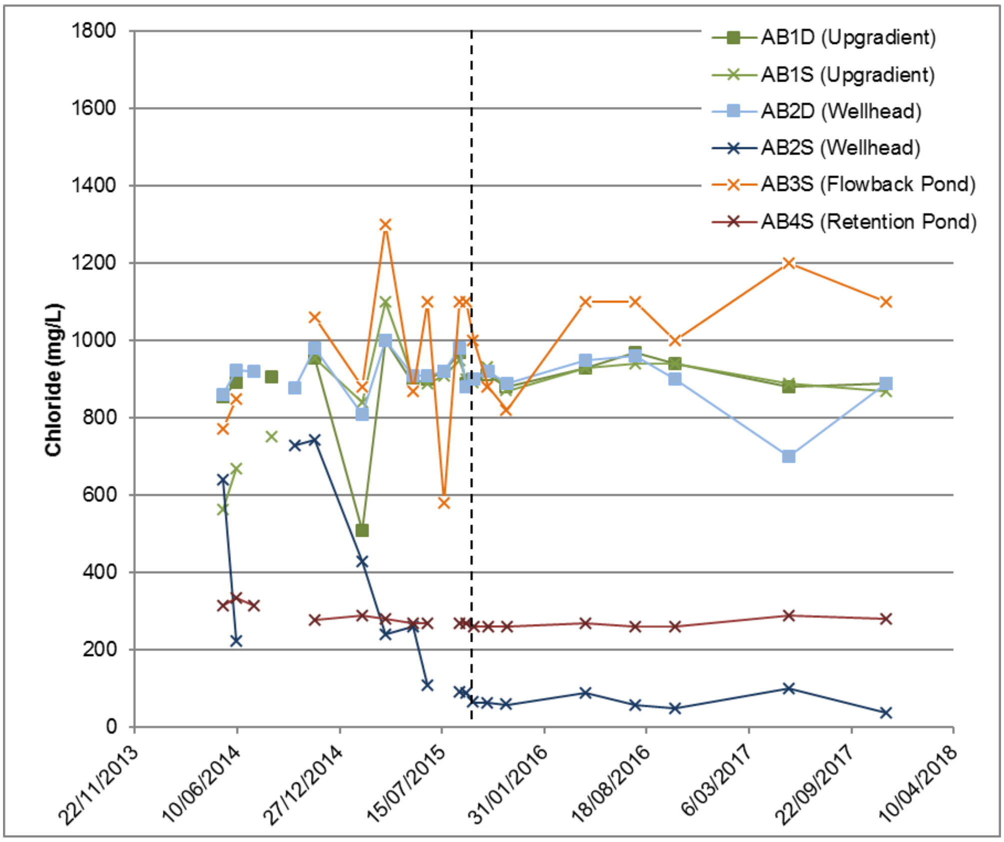


Figure A2-1: Results of baseline and surveillance monitoring of chloride at the Asgard 1 well site. The dashed line represents the occurrence of HF operations.

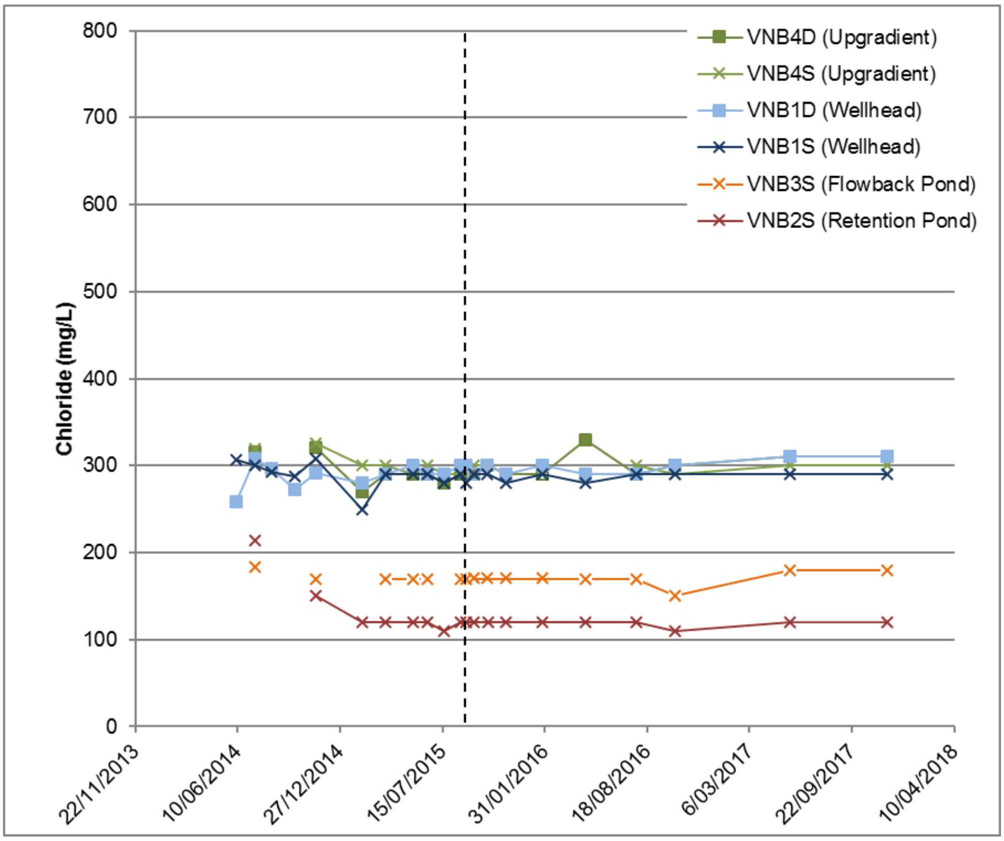


Figure A2-2: Results of baseline and surveillance monitoring of chloride at the Valhalla North 1 well site. The dashed line represents the occurrence of HF operations.

Dissolved Methane

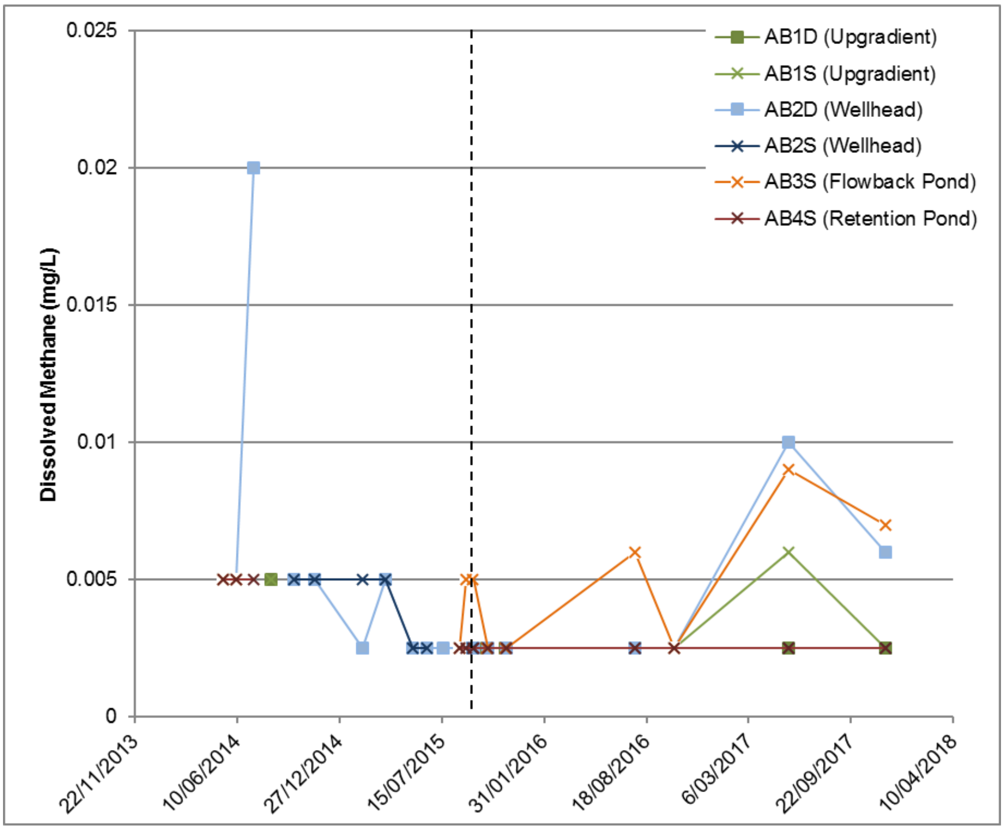


Figure A2-3: Results of baseline and surveillance monitoring of dissolved methane at the Asgard 1 well site. The dashed line represents the start of HF operations.

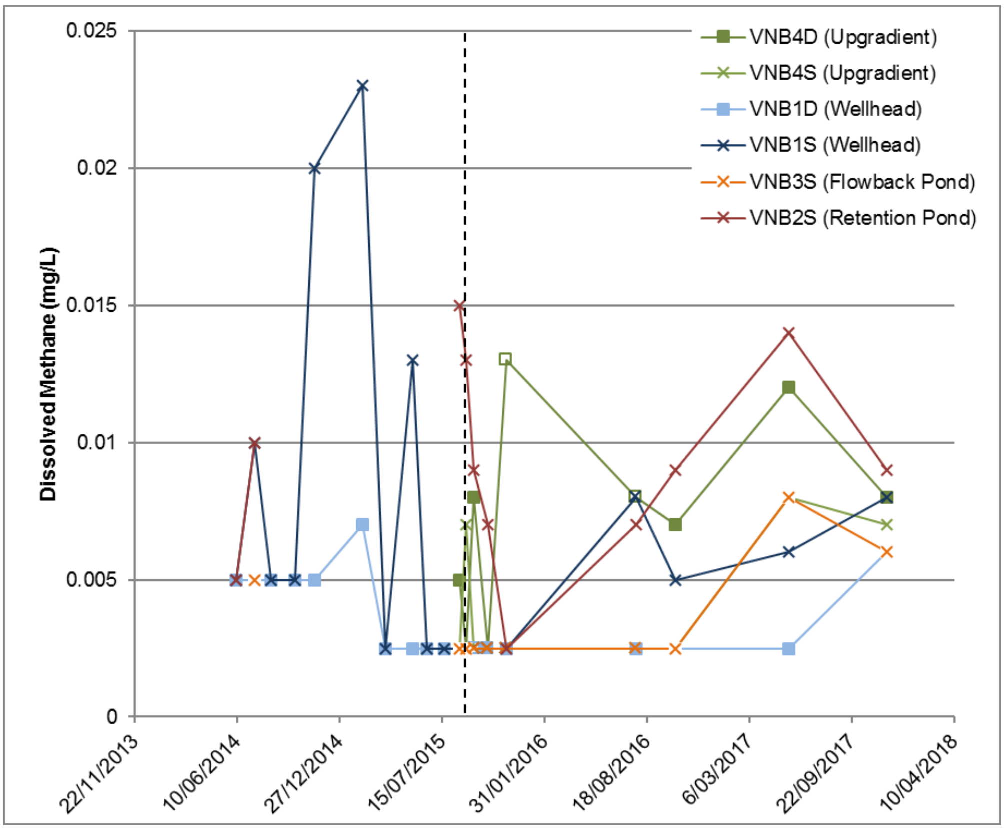


Figure A2-4: Results of baseline and surveillance monitoring of dissolved methane at the Valhalla North 1 well site. The dashed line represents the start of HF operations.

Dissolved Ethane

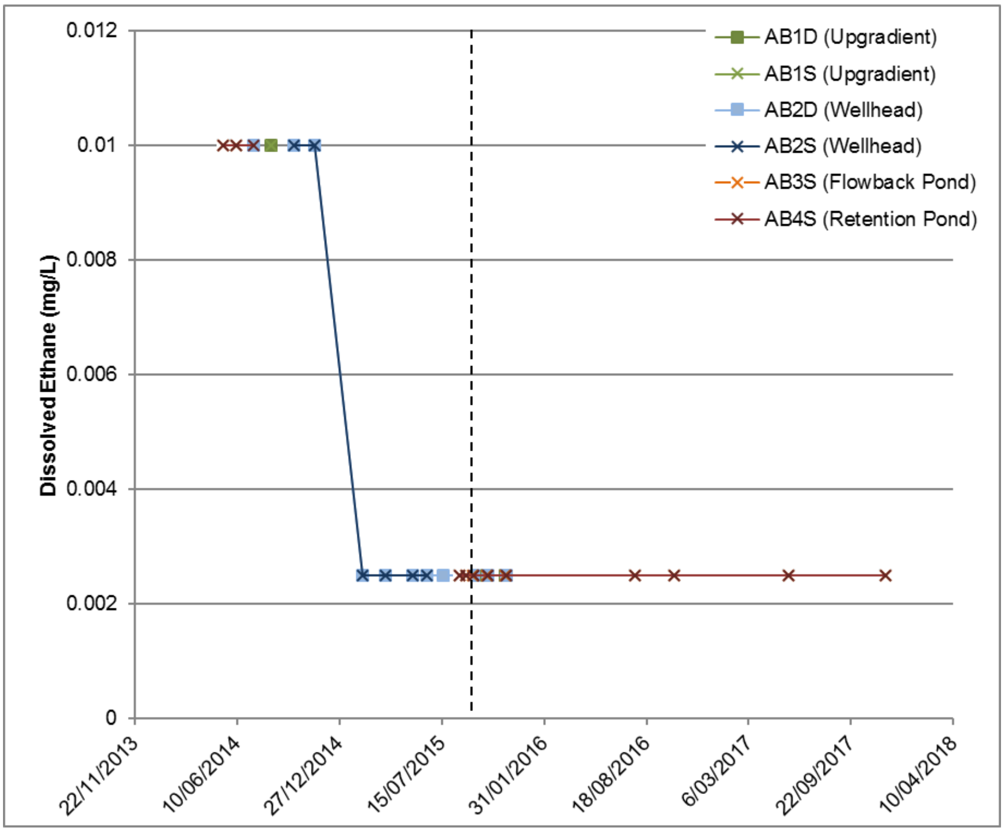


Figure A2-5: Results of baseline and surveillance monitoring of dissolved ethane at the Asgard 1 well site. The dashed line represents the start of HF operations.

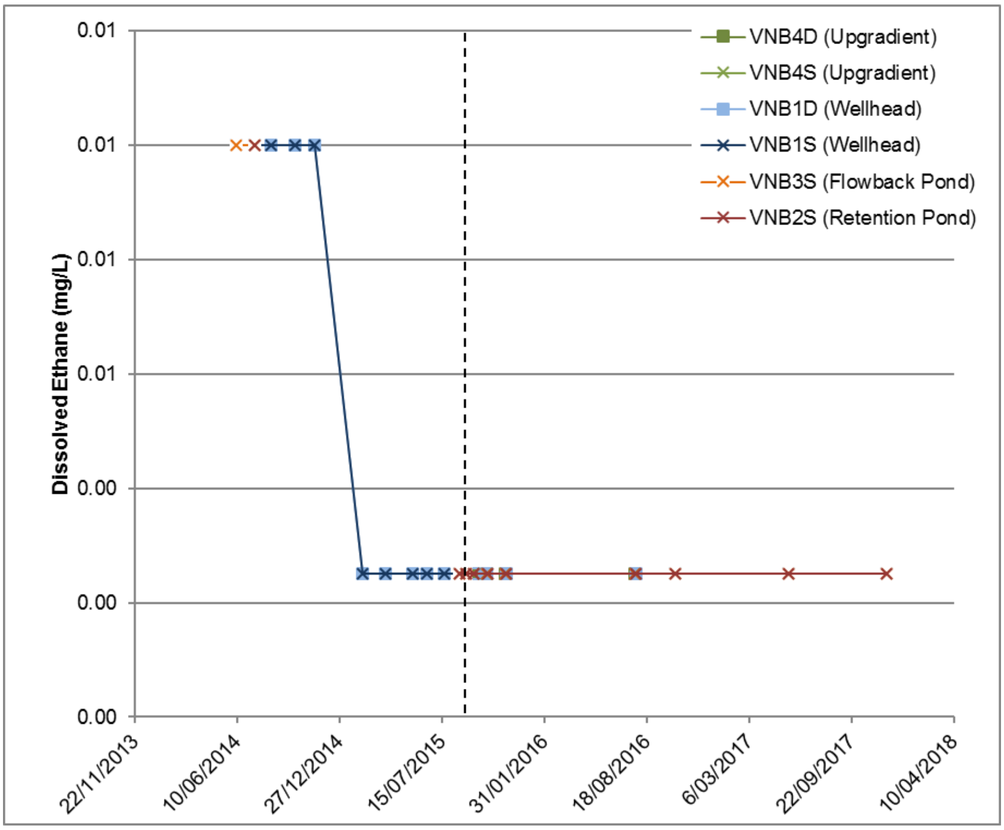


Figure A2-6: Results of baseline and surveillance monitoring of dissolved ethane at the Valhalla North 1 well site. The dashed line represents the start of HF operations.

Dissolved Propane

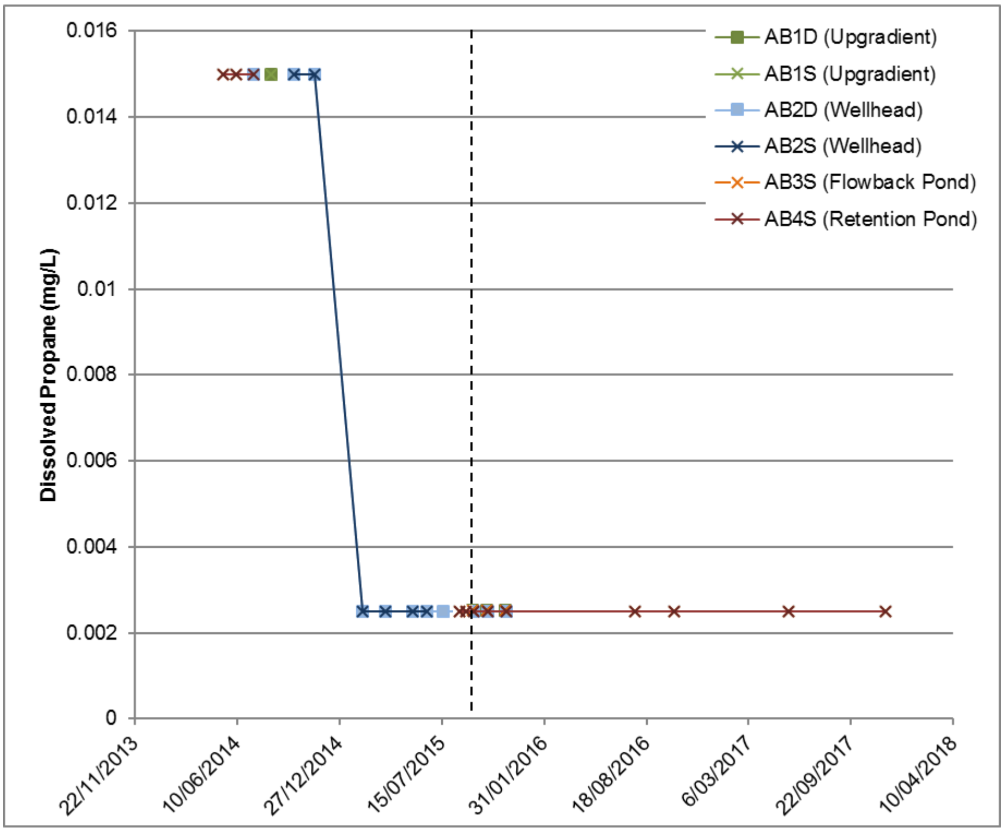


Figure A2-7: Results of baseline and surveillance monitoring of dissolved propane at the Asgard 1 well site. The dashed line represents the start of HF operations.

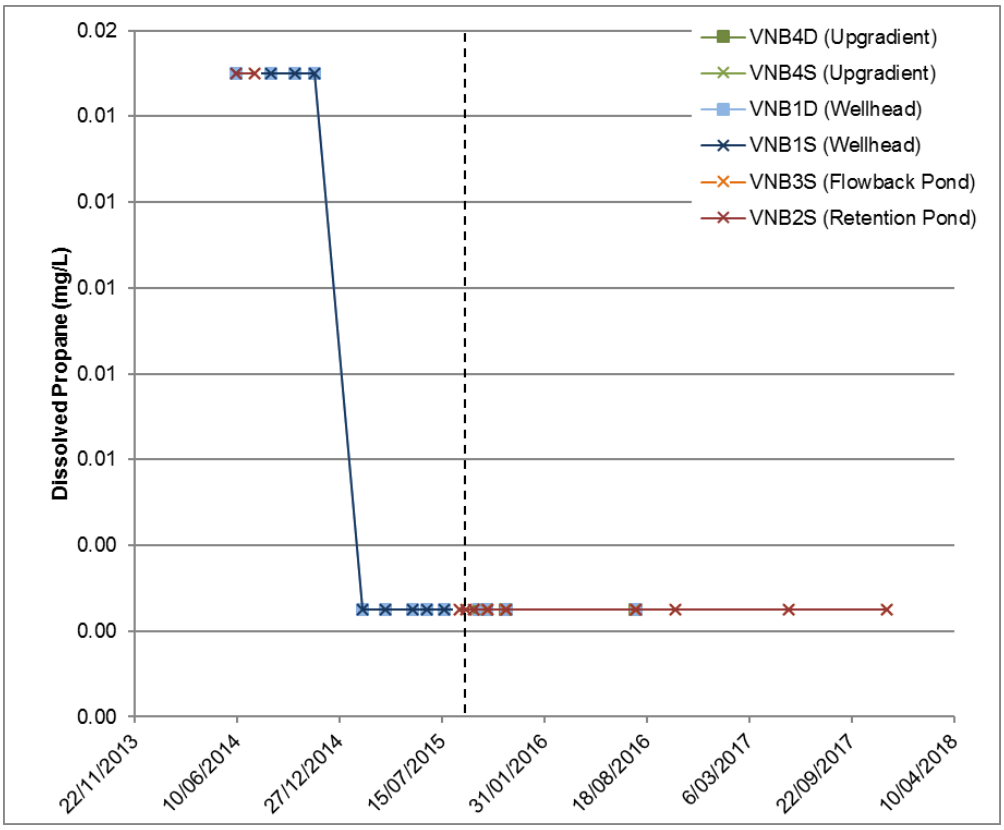


Figure A2-8: Results of baseline and surveillance monitoring of dissolved propane at the Valhalla North 1 well site. The dashed line represents the start of HF operations

Appendix 3 – Flowback Water Sample Results from the 2015 Frac Program

Flowback Water Composition

Flowback water is comprised of the frac fluid injected into the well during fraccing mixed with fluid from the target rock formation/s (formation fluid). During the flowback phase, the injected frac fluid is typically returned to surface before formation fluids.

The volumes of fluid injected into each well and the volume of water flowed back during the 2015 frac program is provided in Table A3-1 below. Approximately 10.8 ML of water was injected during the program with 4.98 ML flowed back. There was considerable variation in the percentage flowed back with 37% flowback from Asgard 1 and 78% from Valhalla North 1.

Table A3-1: Volumes of water injected and flowed back during 2015 frac program.

Well	Number of frac zones	Volume Injected (ML)	Volume Flowed Back (ML)
Asgard 1	7	7.35	2.72
Valhalla North 1	4	3.45	2.68
Total	**11**	**10.8**	**4.98**

Selection of Representative Samples

Due to differences in chloride content of fraccing fluid and formation water, salinity is a useful indicator for tracking the contribution of these components in flowback water. Salinity is measured as Total Dissolved Solids (TDS). During the initial stages of flowback (approximately three weeks), samples for salinity measurements were collected every six hours. After this time, the sampling frequency was reduced to 12-hourly as the salinity of flowback water had stabilised. Where substantial changes in the salinity of flowback water were identified, a representative sample was collected for laboratory analysis, allowing the composition of flowback water to be accurately characterised.

Flowback water collected for laboratory analysis was analysed according to the parameters outlined in the approved Environment Plan and Table A3-2 below, at a NATA accredited laboratory. Representative samples were also selected for analysis for Naturally Occurring Radioactive Materials (NORMs).

Table A3-2: Parameters measured during flowback.

General	Anions	Cations		Metals
pH	Chloride	Calcium	Manganese	Arsenic
Conductivity	Sulfate	Chromium	Mercury	Barium
TDS	Nitrate	Copper	Potassium	Boron
Alkalinity	Nitrite	Iron	Silver	Cadmium
		Lead	Sodium	Selenium
		Magnesium	Zinc	Silica
				Strontium

The time series of salinity from flowback at each well site is shown in Figure A3-1 for Asgard 1 and Figure A3-2 for Valhalla North 1. For both wells, the salinity of the flowback water increases as the proportion of frac fluid returning reduces, and a higher proportion of formation water is received.

The representative samples selected for laboratory analysis are also shown in Figure A3-1 and Figure A3-2 ("Chemical Analysis" series).

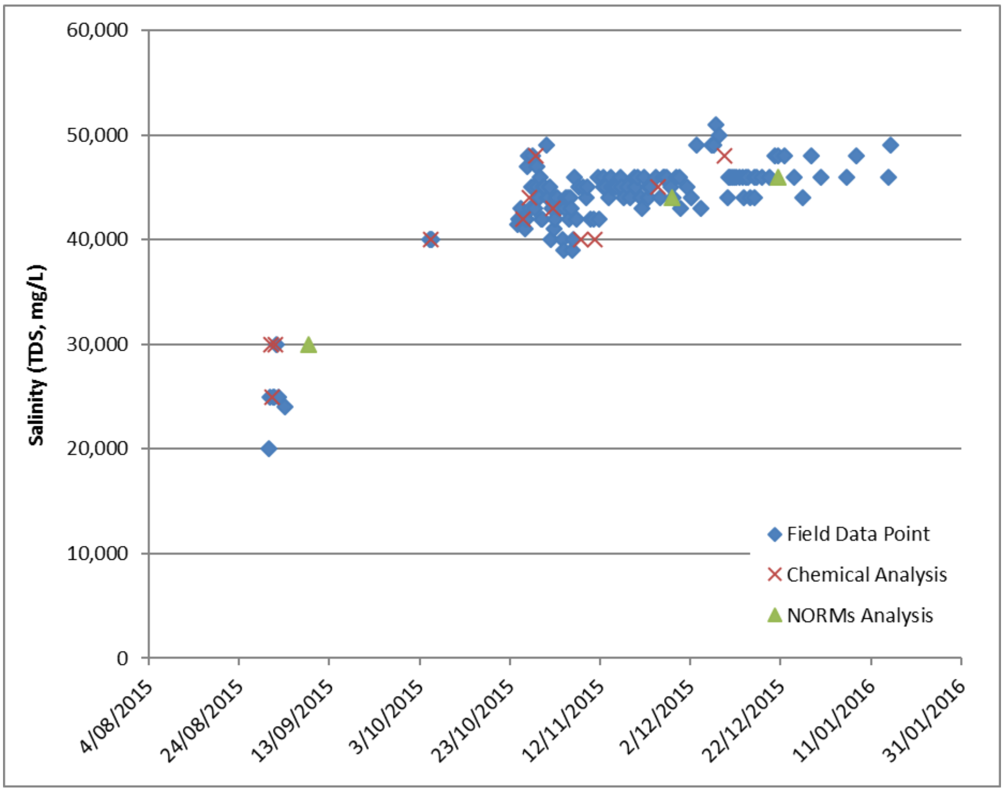


Figure A3-1: Time series of flowback water salinity (TDS) at Asgard 1 showing field salinity measurements and representative samples collected for laboratory analysis and NORMs analysis.

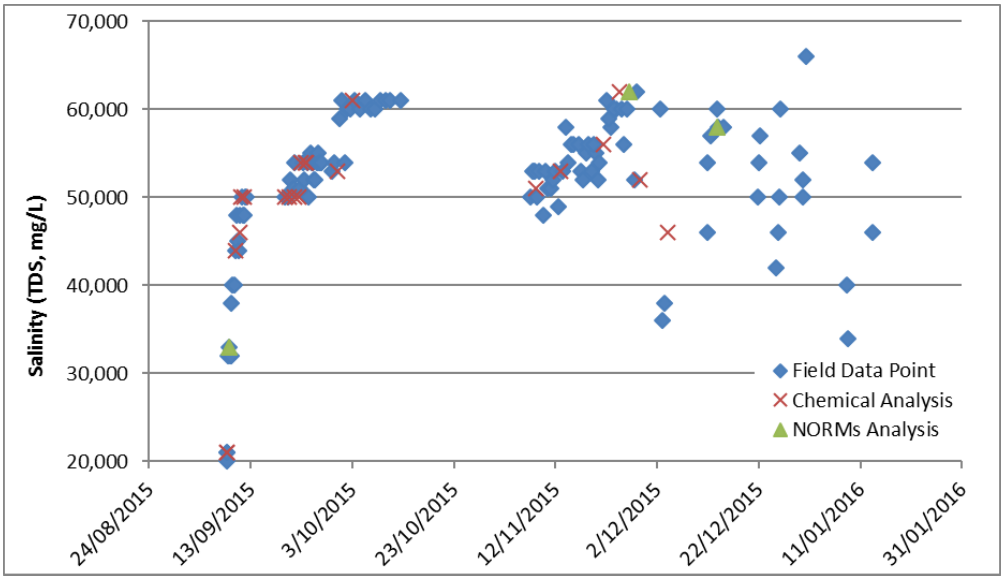


Figure A3-2: Time series of flowback water salinity (TDS) at Valhalla North 1 showing field salinity measurements and representative samples collected for laboratory analysis and NORMs analysis.

Analytical Results

Laboratory results for all samples analysed are provided in Table A3-3 for Asgard 1 and Table A3-4 for Valhalla North 1. Radiological results are provided in Table A3-5. Laboratory results from sampling of the flowback ponds at completion of the operations are provided in Table A3-6 and A3-7.

A discussion of results is provided in 3.4.6.2 above.

Table A3-3: Asgard 1 Flowback Water Sample Results.

Parameter	Unit	Sample ID and Date										
		4	6	21	31	39	45	60	80	86	112	135
		31/8/15	31/8/15	5/10/15	25/10/15	27/10/15	28/10/15	1/11/15	7/11/15	10/11/15	24/11/15	9/12/15
pH	pH	7.8	8.0	7.4	7.6	7.2	7.5	7.2	7.3	7.6	7.8	7.7
Conductivity	µS/cm	42,000	45,000	64,000	68,000	68,000	69,000	69,000	71,000	68,000	68,000	74,000
Total Dissolved Solids	mg/L	25,000	27,000	42,000	42,000	43,000	44,000	45,000	46,000	49,000	50,000	55,000
Total Alkalinity	mg/L	440	460	450	420	410	410	420	400	350	430	330
Fluoride	mg/L	1.1	1.1	0.9	0.9	0.9	0.9	0.9	0.9	-	-	-
Chloride	mg/L	15,000	16,000	24,000	28,000	27,000	28,000	28,000	29,000	27,000	28,000	30,000
Sulphate	mg/L	260	190	52	38	35	34	35	30	32	32	21
Reactive Silica	mg/L	88	88	79	70	66	69	67	69	59	41	33
Total Nitrogen	mg/L	39	36	31	31	32	33	35	32	35	33	35
Total Phosphorus	mg/L	0.55	0.48	0.07	0.05	0.06	0.03	<0.01	0.04	0.08	0.14	0.21
Calcium	mg/L	340	410	880	990	990	1,000	1,000	1,100	1,100	1,100	1,400
Magnesium	mg/L	39	45	83	86	86	87	84	93	100	100	140
Sodium	mg/L	9,500	10,000	15,000	16,000	17,000	17,000	17,000	17,000	16,000	16,000	17,000
Potassium	mg/L	71	81	130	110	110	110	100	110	120	120	140
Aluminium	mg/L	0.41	0.26	<0.1	<0.25	<0.25	<0.25	<0.25	<0.25	<0.1	<0.1	<0.1
Arsenic	mg/L	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.02
Barium	mg/L	18	22	46	52	52	56	52	59	56	56	71
Boron	mg/L	8.7	11	20	21	21	22	22	20	21	24	19
Cadmium	mg/L	<0.002	<0.002	<0.002	<0.005	<0.005	<0.005	<0.005	<0.005	<0.002	<0.002	<0.002
Chromium	mg/L	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.02
Copper	mg/L	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.02
Lead	mg/L	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.02
Manganese	mg/L	1.5	1.4	2.3	3	3	3	3	3	3.1	3.7	4.0
Nickel	mg/L	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	0.052
Selenium	mg/L	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.02
Zinc	mg/L	<0.1	<0.1	<0.1	<0.25	<0.25	<0.25	<0.25	<0.25	<0.1	<0.1	<0.1
Silver	mg/L	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.02
Iron	mg/L	10	11	0.77	6	7	1	13	20	1.9	4.3	0.56
Strontium	mg/L	50	61	120	140	140	150	150	150	140	150	180
Mercury	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Table A3-4: Valhalla North 1 Flowback Water Sample Results.

		Sample ID and Date																		
		2	5	8	15	20	22	26	30	32	35	44	60	66	82	92	109	115	121	125B
Parameter	**Unit**	8/9/15	9/9/15	9/9/15	10/9/15	11/9/15	19/9/15	20/9/15	22/9/15	22/9/15	23/9/15	23/9/15	30/9/15	3/10/15	8/11/15	13/11/15	21/11/15	24/11/15	28/11/15	8/11/15
pH	pH	-	-	-	-	-	-	-	-	-	-	7.5	7.5	-	7.0	7.3	7.4	7.4	7.1	7.2
Conductivity	µS/cm	60,000	65,000	68,000	72,000	74,000	74,000	80,000	81,000	83,000	84,000	83,000	87,000	-	79,000	81,000	85,000	86,000	87,000	81,000
Total Dissolved Solids	mg/L	39,000	41,000	44,000	47,000	48,000	49,000	54,000	55,000	55,000	56,000	53,000	56,000	-	50,000	64,000	67,000	67,000	70,000	65,000
Total Alkalinity	mg/L	500	440	410	410	350	360	310	350	340	320	310	290	-	320	210	210	200	270	280
Fluoride	mg/L	1.2	1.2	1.1	1.1	1.1	1.0	1.1	1.1	1.2	1.1	1.1	1.0	-	0.8	-	-	-	-	-
Chloride	mg/L	24,000	27,000	28,000	30,000	31,000	31,000	32,000	34,000	35,000	35,000	34,000	37,000	-	33,000	34,000	34,000	37,000	38,000	35,000
Sulphate	mg/L	530	490	430	370	330	330	310	360	320	290	280	230	-	74	27	21	17	14	220
Reactive Silica	mg/L	120	100	91	82	72	41	75	61	67	62	62	54	-	63	57	46	44	43	77
Total Nitrogen	mg/L	54	55	58	63	60	59	68	69	70	68	61	66	-	47	49	52	54	55	54
Total Phosphorus	mg/L	0.25	0.29	0.27	1.6	0.32	0.43	0.09	0.03	0.11	0.25	<0.01	<0.01	-	<0.01	0.38	0.32	0.28	0.22	0.22
Calcium	mg/L	1,000	1,200	1,300	1,400	1,600	1,500	2,000	1,900	2,100	2,100	1,800	1,900	2,100	1,600	1,900	2,200	2,300	2,300	2,100
Magnesium	mg/L	120	140	150	150	170	160	210	200	230	230	180	180	200	140	180	200	200	210	210
Sodium	mg/L	14,000	15,000	16,000	16,000	16,000	17,000	18,000	18,000	19,000	19,000	18,000	20,000	21,000	19,000	18,000	19,000	20,000	20,000	19,000
Potassium	mg/L	160	160	150	150	140	150	170	170	170	170	140	140	150	120	130	150	150	150	140
Aluminium	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.25	<0.25	0.28	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
Arsenic	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Barium	mg/L	15	16	20	20	9.2	4.4	13	4.0	13	13	4	31	24	50	32	20	20	24	5.7
Boron	mg/L	35	37	37	36	38	38	38	40	42	40	36	35	39	25	28	32	31	33	37
Cadmium	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	mg/L	0.022	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lead	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.24	<0.05	<0.05	<0.05	<0.05
Manganese	mg/L	3.3	3.3	3.1	3.3	3.6	5.7	5.1	5.3	4.6	4.6	5	6	7	4	2.4	3.0	2.9	3.4	3.9
Nickel	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Zinc	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
Silver	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	mg/L	12	19	14	25	26	31	24	2.4	16	9.8	8	43	160	31	56	33	14	59	55
Strontium	mg/L	120	140	160	170	180	180	210	210	220	220	220	270	290	250	260	310	310	330	260
Mercury	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Table A3-5: Radiological results of flowback fluid from the Asgard 1 (As) and Valhalla North 1 (VN) wells and composite samples from the flowback ponds (FBP) at the end of the flowback period.

		Radionuclides							Metals		
			Uranium Series			Thorium Series					
Sample ID	**Date**	**Unit**	**Uranium-238**	**Radium-226**	**Lead-210**	**Thorium-232**	**Radium-228**	**Thorium-228**	**Unit**	**Uranium**	**Thorium**
VN #8	9/9/15	Bq/L	0.14 ±0.01	1.38 ±0.2	<0.57	<0.005	1.55 ±0.26	<0.16	mg/L	0.011 ±0.001	<0.001
VN #118	26/11/15	Bq/L	<0.02	1.37 ±0.13	<0.75	<0.005	1.44 ±0.15	<0.12	mg/L	<0.001	<0.001
VN #136	13/12/15	Bq/L	<0.02	0.257 ±0.07	<1.1	<0.005	0.31 ±0.13	<0.17	mg/L	<0.001	<0.001
As #5	31/8/15	Bq/L	0.02 ±0.01	0.80 ±0.10	<0.54	<0.005	0.79 ±0.15	<0.11	mg/L	0.002 ±0.001	<0.001
As #122	30/11/15	Bq/L	<0.02	3.44 ±0.29	<1.4	<0.005	4.5 ±0.4	<0.23	mg/L	<0.001	<0.001
As #160	2/1/16	Bq/L	<0.02	3.76 ±0.29	<0.29	<0.005	5.18 ±0.39	<0.053	mg/L	<0.001	<0.001
As FBP	25/2/16	Bq/L	0.01 ±0.01	1.113 ±0.093	<0.22	<0.005	1.35 ±0.12	<0.034	mg/L	0.001 ±0.001	<0.001
VN FBP	28/1/16	Bq/L	<0.02	1.046 ±0.085	<0.14	<0.005	1.32 ±0.11	<0.025	mg/L	<0.001	<0.001

Table A3-6: Laboratory results of fluid from the Asgard 1 flowback pond pre- and post-flowback compared to guideline levels. Elevated levels are shown in bold.

COPC	Units	Onsite Management Levels (Fluid)	Asgard 1 pond pre-flowback	Asgard 1 pond post-flowback
Aluminium	mg/L	5^	3.6	<0.1
Arsenic	mg/L	0.5^	<0.02	<0.02
Barium	mg/L	2∞	**3.8**	**20**
Chloride	mg/L	30,000	570	16,000
Boron	mg/L	5^	0.88	**9.4**
Cadmium	mg/L	0.01^	<0.001	<0.002
Chromium VI	mg/L	0.05∞	<0.02	<0.02
Copper	mg/L	1^	<0.005	<0.02
Lead	mg/L	0.1^	<0.02	<0.02
Manganese	mg/L	0.5∞	0.2	0.15
Nickel	mg/L	1^	0.018	<0.02
Nitrate	mg/L	50∞	-	<0.05
Nitrite	mg/L	3∞	-	<0.05
Selenium	mg/L	0.02^	<0.05	<0.02
Silver	mg/L	0.1∞	-	<0.02
Zinc	mg/L	20^	0.12	<0.1
Mercury	mg/L	0.002^	<0.0001	<0.0001

^ Stock water: Australian and New Zealand guidelines for fresh and marine water quality (ANZECC 2000)
∞ Health Values: Australian Drinking Water Guidelines Version 3.1 (NHMRC and NRMMC 2011).

Table A3-7: Laboratory results of fluid from the Valhalla North 1 flowback pond pre- and post-flowback compared to guideline levels. Elevated levels are shown in bold.

COPC	Units	Onsite Management Levels (Fluid)	Valhalla North 1 Pond pre-flowback	Valhalla North 1 Pond post-flowback
Aluminium	mg/L	5^	0.05	0.54
Arsenic	mg/L	0.5^	<0.02	<0.02
Barium	mg/L	2∞	0.054	**12**
Chloride	mg/L	30,000	400	17,000
Boron	mg/L	5^	0.43	**14**
Cadmium	mg/L	0.01^	<0.001	<0.002
Chromium VI	mg/L	0.05∞	<0.005	<0.02
Copper	mg/L	1^	<0.005	<0.02
Lead	mg/L	0.1^	<0.02	<0.02
Manganese	mg/L	0.5∞	0.01	0.51
Nickel	mg/L	1^	0.006	<0.02
Nitrate	mg/L	50∞	-	<0.05
Nitrite	mg/L	3∞	-	<0.05
Selenium	mg/L	0.02^	<0.05	<0.02
Silver	mg/L	0.1∞	-	<0.02
Zinc	mg/L	20^	<0.01	<0.1
Mercury	mg/L	0.002^	<0.0001	<0.0001

^ Stock water: Australian and New Zealand guidelines for fresh and marine water quality (ANZECC 2000)
∞ Health Values: Australian Drinking Water Guidelines Version 3.1 (NHMRC and NRMMC 2011).

Appendix 4 – Management of Well Integrity

Overview

Wells used to target tight and shale gas resources are typically more than 3 km deep. There are several aspects to ensuring well integrity including well design, well construction and monitoring of well parameters over time. At the end of the productive life of a well, the well is decommissioned with multiple cement plugs downhole.

Well Design

Petroleum wells are designed to meet the highest safety standards and withstand reservoir pressures and temperatures, fluid flow regimes and corrosion. When constructing a petroleum well, a number of international standards defining good oilfield practice are required to be taken into account under the RMA Regulations.

Petroleum wells targeting tight and shale gas resources are typically constructed using three strings of steel casing cemented in place, not including the conductor casing which is generally set to around 30 m depth. Each string of steel casing is set inside the previous, shallower string so that the final well consists of progressively smaller casing strings extending deeper into the ground – much like an inverted telescope. This means there are more barriers at shallower depths, isolating productive aquifers from the well bore (Figure A4-1). Wells are designed with a minimum of two independent and verified barriers are in place to isolate productive aquifers from exposure to the well bore or well fluids (including stimulation fluids). The well is constructed to withstand reservoir pressures, with good well construction being imperative in maintaining safety, as well as protecting the environment.

Well Construction

Well construction (or drilling) commences when the drill bit penetrates the ground (the well is spudded) and continues until the target depth is reached. During the drilling process, the shallowest hole section is drilled to the designated depth before the drill bit is retrieved and the casing run to this depth. The casing is then cemented in place with cement applied between the outside of the casing and the formation, before a casing pressure test and leak-off test is undertaken to verify the casing integrity and cement integrity. A formation integrity test (FIT) may also be undertaken to provide an assessment of the strength of the rock formation in that zone.

This process of drilling, setting and cementing casing, then verifying integrity is then repeated for subsequent hole sections.

The typical casing strings used in Buru Energy's tight gas wells and their nominal depths are outlined below:

Conductor Casing (508 mm/ 20" diameter): Outermost casing string is set to a depth of ~30 m below ground level and cemented in place. The purpose of the conductor casing is to hold back overburden deposits, isolate shallow groundwater, prevent corrosion of the inner casings and support well head load.

Surface Casing (340 mm/ 13&3/8" diameter): Casing string set to isolate the deepest potable aquifer. The surface casing in Buru Energy's tight gas wells is set from the surface to between ~540 and ~880 m BGL with a shoe in the Anderson Formation (Yulleroo) or Noonkanbah Formation (Asgard/Valhalla). This casing section is therefore isolated from the overlying potable aquifers by a formation seal (aquiclude) and cement seal, which prevents upward migration of fluids from the lower formations.

Intermediate Casing (244 mm/ 9 &5/8" diameter): Casing string set to isolate subsurface formations that may cause borehole instability and to provide protection from abnormally pressured subsurface formations. In Buru Energy's tight gas wells, this casing string is set to between ~1,950 m and ~2,300 m.

Production Casing (178 mm/ 7" diameter): Casing string that extends from the surface into the natural gas producing zone (target formation). This casing string isolates the natural gas producing zone from all other subsurface formations and allows pumping of frac fluids into the target zone. Once fraccing is complete, hydrocarbons and flowback fluid may be flowed back up the production string to the surface; however, a "completion string" of smaller diameter casing is often installed within the production string to allow the flowback of zones separately.

In a horizontal well, it is the production casing that extends horizontally into the target formation.

Verification of Well Construction

Generally once drilling is complete, a Cement Bond Log (CBL) is run down the well to evaluate the presence of cement between the casing and formation, or layers or casing, along different sections of the well bore. The CBL is undertaken using a sonic tool that is lowered into the well on cable (wireline). Pressure tests are also undertaken to confirm the integrity of the cement and any other barriers.

Well design parameters such as the rating of the well head and the casing used determine the pressure rating of the well. Various pressure tests undertaken during well construction also confirm the pressure rating for the well. The well design and the results of pressure tests determine the "maximum treating pressure" for a hydraulic fracture, which is the maximum surface pump pressure used during the hydraulic fracturing operations.

Monitoring Well Integrity

Demonstration of ongoing well integrity is a key area of regulatory focus and source of community concern. A key focus of routine monitoring of well integrity is the monitoring of well and annulus pressures. The objective of monitoring annulus pressures is to ensure those sections of the well that are meant to be isolated from one another are not in pressure communication, an occurrence known as a barrier failure. Should a barrier failure be detected, well remediation may be undertaken using techniques such as cement squeezes.

Routine monitoring also includes function and leak testing of valves and leak testing of plugs to verify that these barriers are functioning properly. If required, maintenance such as greasing or replacement of valves can be undertaken.

It is important to note that a failure of a single barrier does not result in a leak of well fluids to the environment, due to the dual barrier philosophy of petroleum well design and construction. Well integrity failure is where all barriers fail and a leak to the environment is possible. True well integrity failure rates are two to three orders of magnitude lower than single barrier failure rates[84].

It is important to note that the potential for leaks to the environment diminishes during the production life of a well, as the reservoir pressure is drawn down. In these circumstances, low pressure wells do not have the driving force to oppose the constant hydrostatic pressure of fluids outside the wellbore; hence, if a leak path is formed through the sequence of barriers, the highest potential is for exterior fluids (usually salt water) to leak into the wellbore[84].

[84] King, G.E. and King, D.E. (2013). 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).

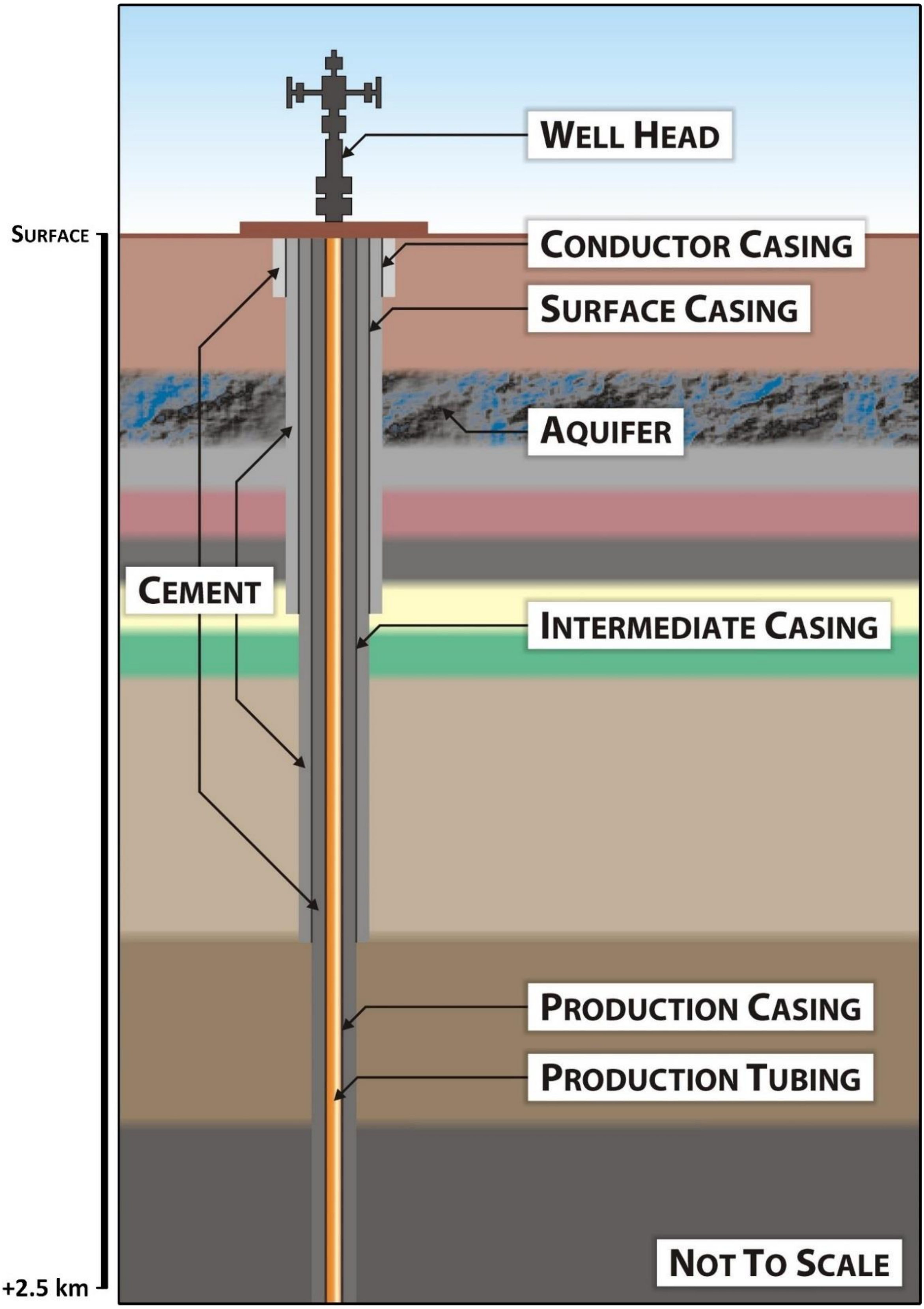


Figure A4-1: Typical Buru Energy well construction.

Well Decommissioning

At the end of the productive life of the well, the well is decommissioned (plugged and abandoned). Decommissioning petroleum wells typically involves using a drilling rig to remove any equipment in the wells such as rods, pumps and tubing. The rig then pumps cement into the well to isolate hydrocarbon bearing zones from overlying formations. Mechanical plugs may also be used in the well to provide additional protection from formation pressures while sections of the well bore in between the plugs are filled with inhibited water (containing chemicals such as corrosion inhibitor) to ensure the integrity of the casing. Requirements for decommissioning are determined by the relevant regulator. In WA, approaches are required to be in accordance with good oil-field practice as required under the RMA Regulations.

Good oil-field practice typically involves the setting of two independently tested and verified cement plugs downhole. Typically, one plug is set across the hydrocarbon bearing zone with a cement plug extending at least 30 m above and 30 m below the perforated section. A similar approach is taken for uncased portions of wells in sections where there are significant oil, gas or freshwater zones. Another independently verified plug is set midway up the well across the shoe of the intermediate string where cement behind the casing is also required. Finally, a minimum 15 m long cement surface plug is set. Once the cement plugs are set the well head is removed and a steel plate installed to mark the location of the well head.

Appendix 5 – Numerical Groundwater Models

Asgard and Valhalla

Following the completion of the 2015 frac program at Asgard and Valhalla North, the conceptual hydrogeological model for this region was upgraded to a numerical model, utilising the data collected during the program[85].

Model Parameters and Calibration

A simple groundwater model was constructed to predict potential groundwater level drawdowns around a production bore in the Valhalla region. The model consisted of a rectangular grid of 57 rows, 57 columns and two layers covering an area of 5 km x 5 km centred on the production bore. There were two layers – one extending to 50 m depth and the other extending to 170 m depth. Model cell sizes ranged from 25 m x 25 m near the production bore to 100 m x 100 m in peripheral areas.

The model utilises Processing Modflow Pro version 8.0.45, which incorporates MODFLOW, groundwater modelling software designed by the US Geological Survey. The model was set up initially with parameters that are typical of a minor aquifer such as the Liveringa Formation, and then parameters were adjusted to calibrate the model to drawdowns observed in the two (relatively) deep monitoring bores at Valhalla North from 3 July to 8 July 2015, after which groundwater levels recovered rapidly to pre-pumping levels.

Water meter readings indicate that a total of 1,955 kL was pumped to 26 July 2015 – if all that was pumped over the five-day period that would be an average of 390 kL/d, and that rate was simulated in the model. Drawdowns increased to 0.08 m in bore VNB1D located 55 m west of the production bore, and to 0.07 m in VNB4D, 27 m east of the bore. The production bore was modelled in Layer 2, and the monitoring bores in Layer 1. A close correspondence (within 0.01 m) was achieved between measured and model calculated drawdowns with the parameters given in Table A5-1.

Table A5-1: Calibration parameters of Asgard/Valhalla groundwater model (Liveringa Aquifer).

Parameter	Unit	Layer 1	Layer 2
Horizontal Hydraulic Conductivity	m/d	0.05	0.12
Vertical Hydraulic Conductivity	m/d	0.005	0.01
Specific Yield	v/v	0.05	NA
Storage Coefficient	v/v	NA	0.0003

Modelling Outcomes

Following calibration, the numerical model was used to predict groundwater-level drawdowns from pumping a production bore over a six-month period at the rate required to produce the total allocation for Valhalla North (33,400 kL) – being 183 kL/day. The calculated drawdowns after six months are shown for each model layer in Figure A5-1.

Outcomes of the modelling indicate drawdowns of 1 m or more may extend up to 410 m from the production bore in the deep layer. Drawdowns in the shallow layer will be much smaller – 1.2 m close to the production bore decreasing to 1 m ~56 m from the bore and 0.1 m at 690 m. The calculated drawdowns are consistent with groundwater monitoring results at Valhalla North and Asgard where drawdowns at shallow depths (albeit with lower pumping rates) are small and difficult to distinguish from normal seasonal fluctuations of about 0.2 m to 1 m.

[85] Rockwater (2016). Hydrogeological Assessment of Paradise-Valhalla-Asgard Project Areas. Report for Buru Energy. September 2016.

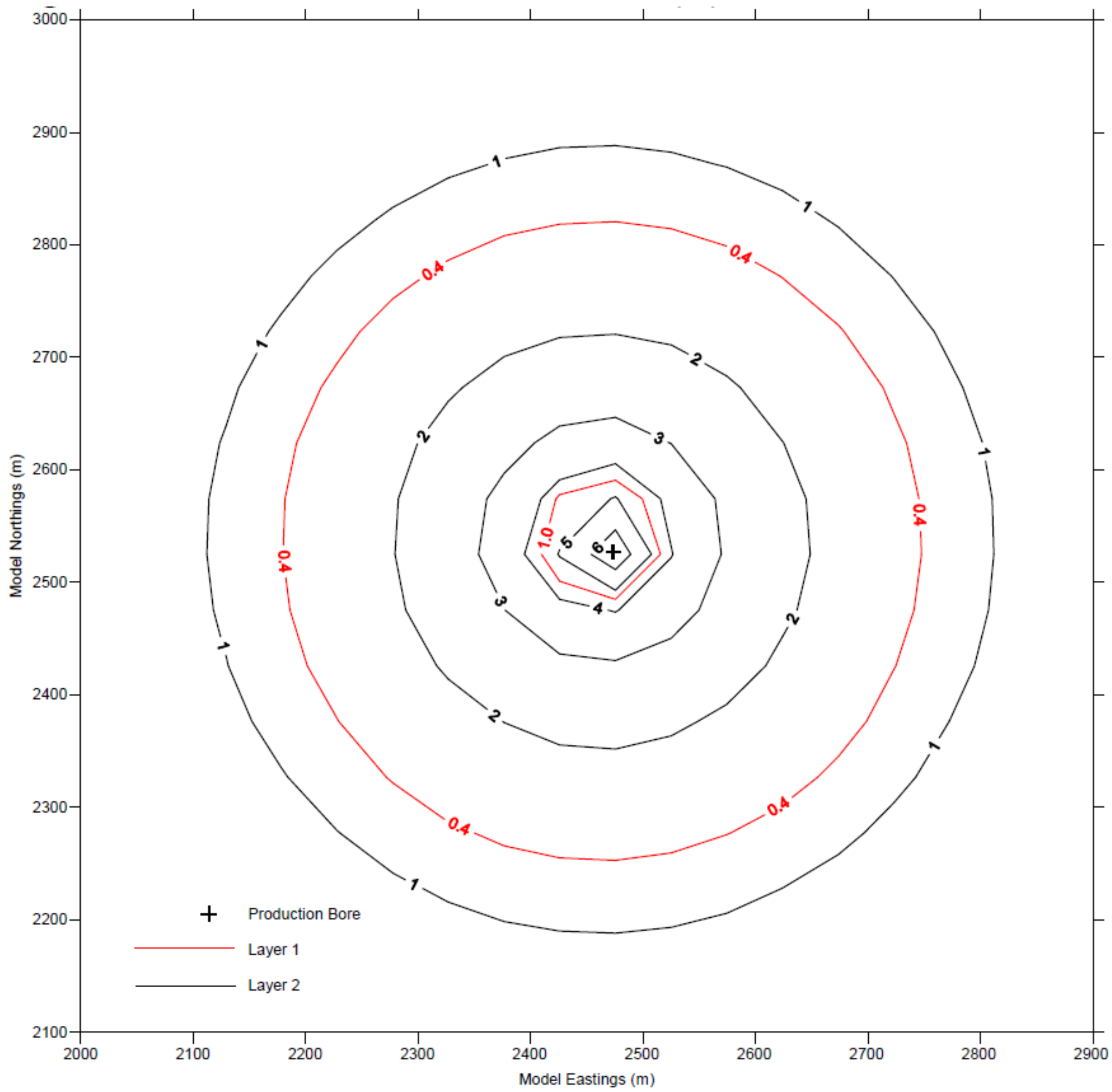


Figure A5-1: Modelled drawdowns (m) after six months of pumping in the Valhalla region.

Modelling Extraction Scenarios

The numerical model was then used to determine groundwater drawdown for pumping over six months to produce a volume of 10,000 kL corresponding to the volume used in the 2015 frac program and to produce 100,000 kL, a nominal high-use scenario. Modelling results are presented in Table A5-2 along with the results from modelling the licenced allocation.

Table A5-2: Groundwater drawdown based on various volumes of water extracted (model output).

Modelled Scenario	Max. Drawdown at Bore (m)		Distance from bore of 1 m drawdown (m)	
Extraction Volume (kL)	**Layer 1**	**Layer 2**	**Layer 1**	**Layer 2**
10,000	0.35	2.8	N/A	106
33,400	1.2	9.5	56	410
100,000	3.5	28	340	780

Outcomes from modelling show that even with extracting the maximum volume from a bore on site, groundwater levels would be expected to recover to within 0.2 m of the static water level without hours of pumping ceasing and to fully recover within weeks.

Yulleroo

During engagement with the Yawuru Traditional Owners in 2014, a numerical groundwater model was constructed for the Broome Sandstone Aquifer in the Yulleroo area[86]. This model considered the impact of groundwater extraction associated with exploration activities on the Broome Sandstone aquifer. The model has since been re-run to consider the impact of water extraction associated with the Yulleroo conceptual field on the Broome Sandstone aquifer (Section 2.3.8.1)[87].

The results of the modelling are summarised in Section 3.7.3.2. This section includes further information on the modelling parameters and calibration.

Model Parameters and Calibration

The Yulleroo numerical groundwater model consists of a rectangular grid of 100 rows, 112 columns and two layers covering an area of 112 km east–west and 110 km north–south centred on Yulleroo. The model extends from Broome in the west to the eastern limit of the Broome Sandstone, and to where the formation is unsaturated in the north.

Preliminary calibration of the model to groundwater levels measured at various times has been completed; and the model will be verified in the future by monitoring data to be collected in the project area.

Water will be required over approximately 16 years at Yulleroo during a commercial field development. Groundwater use will be highest rates in the first three years of operation. It is assumed, with the relatively low pumping rates required, that the pumping will be from a single bore located near the planned central processing area.

The model utilises Processing Modflow Pro version 8.0.29 (Simcore Software) which incorporates Modflow-96 to Modflow-2005, finite-difference groundwater flow modelling software designed by the U.S. Geological Survey and MT3DMS solute-transport modelling software. Model parameters are provided in Table A5-3.

Table A5-3: Calibration parameters of Yulleroo groundwater model (Broome Aquifer).

Parameter	Unit	Layer 1	Layer 2
Horizontal Hydraulic Conductivity	m/d	8-30	9-40
Vertical Hydraulic Conductivity	m/d	1	1
Specific Yield	NA	0.1	0.1
Storage Coefficient	NA	NA	0.001
Recharge	m/d	04000045, 0.00005*	
Max. Evapotranspiration Rate	m/d	0.0055	NA

* = Zero on Roebuck Plains

Modelling Outcomes

The numerical groundwater model which was constructed and calibrated in 2014, was run to predict peak drawdowns arising from the estimated extraction associated with the Yulleroo conceptual field (Table A5-4).

The maximum extent of drawdowns is indicated to occur at the end of Year 3, when drawdowns of 0.01 m or more will extend about 4.8 km from the bore (Figure A5-2). The drawdowns within the

[86] Rockwater (2014). Numerical flow and solute transport modelling, for Yulleroo project. Report for Buru Energy Ltd. March 2014.
[87] Rockwater (2018). Results of Groundwater Modelling, and Subterranean Fauna Risk Assessment. Report for Buru Energy Ltd. March 2018.

impacted area around the bore will be small, with a maximum of 0.1 m (average) within the model cell that where the bore is located. At the nearest water bore – Bohemia Bore located 1.7 km to the south-east, drawdown is likely to be approximately 0.04 m (or 4 cm) which will not reduce the pumping capacity of the bore.

Table A5-4: Annual and average daily water use figures used in Yulleroo numerical model.

Year	Total Water Use		Average Use
	ML	kL	kL/day
1	212.2	212,162	581
2	131.1	131,081	359
3	131.1	131,081	359
4	46.2	46,216	127
5	78.6	78,649	215
6	78.6	78,649	215
7	78.6	78,649	215
8	57.4	57,432	157
9	65.5	65,541	180
10	44.3	44,324	121
11	10.0	10,000	27
12	26.2	26,216	72
13	26.2	26,216	72
14	26.2	26,216	72
15	26.2	26,216	72
16	26.2	26,216	72

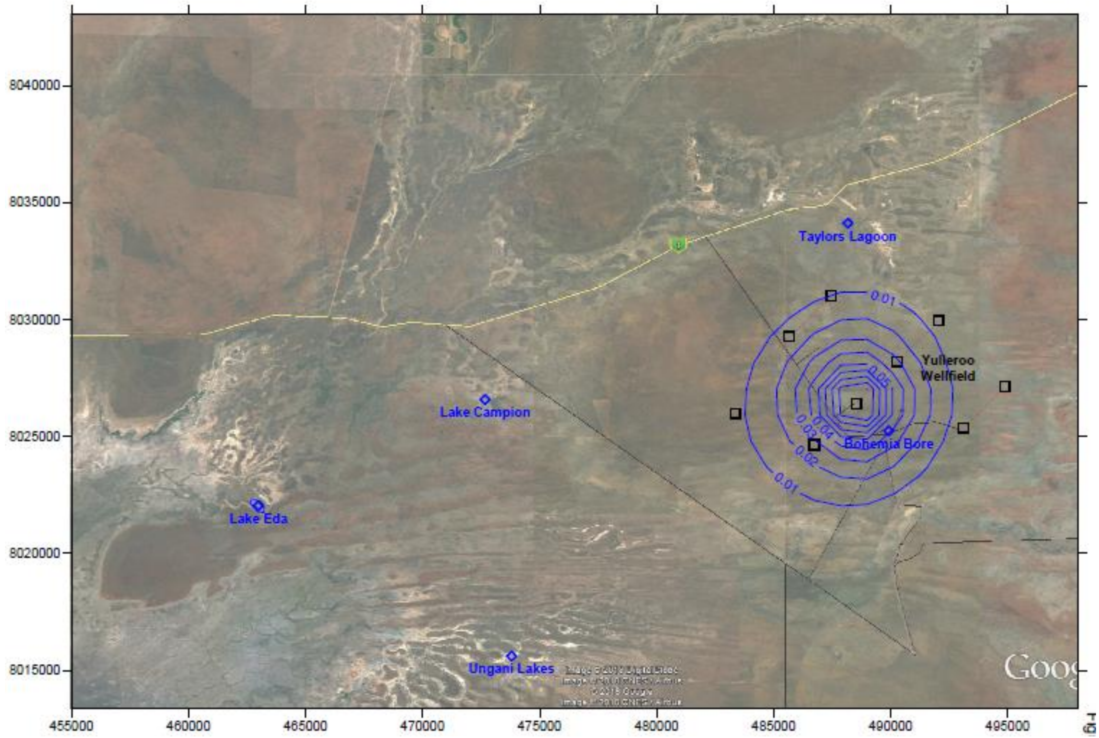


Figure A5-2: Modelled peak drawdowns (m) around a Yulleroo groundwater production bore.

Even if short-term pumping rates are higher, or hydraulic conductivity or specific yield values are lower than assumed, there will be only minor change to the magnitude and extent of drawdowns, and there will be no impact on Taylors Lagoon to the north.

Appendix 6 – Independent Review Process

Yawuru Independent Specialist Review

Buru Energy initiated the specialist review process with Yawuru in mid-November 2013. The specialists shown in Figure A6-1 below were selected by Yawuru to provide independent specialist advice regarding the environmental risks associated with fraccing.

Figure A6-1: Specialists selected by Yawuru to provide independent advice.

All environmental approvals and related documentation was provided to the Yawuru specialist reviewers to allow them to review the risks of the proposed fraccing operations. The following documents were provided to the specialist reviewers to assist them in their review:

- Buru Environment Policy;
- Buru Safety Management System;
- Buru Canning Basin Emergency Response Plan;
- Buru Environmental Management System Documents;
- Buru Risk Matrix;
- Buru Canning Basin Oil Spill Contingency Plan;
- Hydrogeological Assessment (Rockwater);
- Groundwater Characterisation and Assessment Program;
- Water Management Strategy (MWH);
- Water Resources Peer Review (UWA);
- Chemical Risk Assessment (Ecosus);
- Chemical MSDSs;
- Geological Environment Peer Review (Prof. Peter Styles, Keele University);
- Well Operations and Integrity Review (Dr Chris Green, GFrac);
- Geological Environment Risk Assessment;
- HF Operations Environmental Assessment (Dr Chris Green, GFrac); and
- Compliance Table with relevant Codes of Practice and Guidelines.

The Yawuru PBC established a subcommittee which included Micklo Corpus, Rowena Puertollano and Susan Edgar. The purpose of the subcommittee was to communicate the outcomes of the specialist

review process to the broader Yawuru community. Unfortunately, members of the subcommittee did not effectively engage with the broader community while the specialist review was underway. The Yawuru specialist review process is summarised in Table A6-1.

Table A6-1: Summary of Yawuru independent specialist review process.

Date	Engagement Type	Description
15 November 2013	Information exchange	Buru provided available information to Yawuru specialists for review.
22 November 2013	Workshop	Workshop regarding frac program and proposed civil works involving Yawuru specialist reviewers, Yawuru subcommittee and Buru Energy. Workshop was followed by a site visit to Yulleroo.
5/6 February 2014	Workshop	Technical risk workshop involving Yawuru specialist reviewers, Yawuru subcommittee and Buru Energy.
7 February 2014	Community meeting	Yawuru community meeting including specialist reviewers, Yawuru subcommittee and DMP staff. Buru personnel did not attend.
7 February 2014	Information exchange	Queries provided to Buru from Yawuru specialist reviewers.
31 March 2014	Information exchange	Buru provided responses to Yawuru regarding queries received on 7/2/2014.
1 May 2014	Workshop	Technical risk workshop involving Yawuru specialist reviewers and Yawuru subcommittee.
2 May 2014	Information exchange	Queries provided to Buru from Yawuru specialist reviewers.
20 May 2014	Information exchange	Buru provided responses to Yawuru regarding queries received on 2 May 2014.
22 May 2014	Information exchange	Specialist peer review report regarding Yulleroo 2 frac provided to Buru Energy.
30 May 2014	Community meeting	Yawuru community meeting held at the Yulleroo well sites involving community members, Yawuru specialist reviewers, Yawuru subcommittee and Buru personnel.
10 June 2014	Information exchange	Buru provided responses to Yawuru regarding queries received 22 May 2014.
13 June 2014	Community meeting	Yawuru community meeting including specialist reviewers and Yawuru subcommittee. Buru personnel did not attend.
20 June 2014	Information exchange	Queries provided to Buru from Yawuru specialist reviewers.
25 June 2014	Presentation	Buru presentation to Yawuru PBC board regarding Yulleroo 3 and Yulleroo 4 works.
30 June 2014	Information exchange	Buru provided responses to Yawuru regarding queries received 20 June 2014.

Following Buru Energy's response to the Yawuru specialist reviewers on 30 June 2014, all matters raised by the specialist reviewers had largely been resolved. The exception was a query regarding the cement bond log results on the production casing of the Yulleroo 4 petroleum well. This matter was not able to be resolved during the specialist review process as it required the running of a cement bond log in the well. Re-running a cement bond log (sonic tool) to confirm zonal isolation of the Yulleroo 4 well is therefore required prior to fraccing the well.

The findings of the review were published on the Yawuru website in July 2014[88]. The Yawuru specialist reviewers determined the Environment Plan used best available techniques and met the requirements of the Environment Regulations, the object of which is to reduce environmental impacts and risks to ALARP.

Outcomes

Following the completion of the specialist review process, a Yawuru PBC General meeting was held on 18 July 2014. At this meeting, Yawuru PBC members were asked to vote regarding Buru Energy's proposed fraccing program at Yulleroo. The following options were provided to Yawuru members:

- Yawuru does not agree to the 2014/2015 fracking at Yulleroo, but if Buru Energy goes ahead with the fracking, Buru Energy must agree to meet environmental, cultural, social and economic conditions set by Yawuru.
- Yawuru agrees to the 2014/2015 fracking at Yulleroo if Buru Energy agrees to meet environmental, cultural, social and economic conditions set by Yawuru.
- Yawuru does not agree with 2014/2015 fracking at Yulleroo and should stop engaging with Buru Energy on the 2014/2015 Yulleroo project.

The majority of Yawuru members voted for Option 1. Buru Energy is currently discussing conditions with Yawuru that will provide economic benefits to Yawuru and its members, while protecting environmental, cultural and social values.

[88] Yawuru Expert Group (2014). Yulleroo 3 and 4 Hydraulic Fracturing Project Canning Basin, Western Australia. Report prepared for Nyamba Buru Yawuru Limited. Available at: http://www.yawuru.com/wp-content/uploads/2014/07/Yawuru-Expert-Group-Consolidated-Report-on-Buru-Energys-TGS14-program-ID-48650.pdf

KRED Enterprises Specialist Review Process

KRED Enterprises Pty Ltd (KRED) represent the Nyikina Mangala people, the Karajarri people and the Ngurrara people among other groups in the Canning Basin. The Native Title lands of these groups overlap a large portion of Buru Energy's acreage in the Canning Basin.

Buru Energy has no hydraulic fracturing plans on Native Title areas of the groups represented by KRED. However, Buru recognised the importance of all people in the West Kimberley region having access to the same information and so undertook a specialist review process with KRED.

The specialist reviewers selected by KRED to assist them with their review are shown in Figure A6-2. All of the environmental approvals and related documentation listed above was provided to the KRED specialist reviewers.

Compared to the Yawuru review process, the process implemented by KRED was largely run independently of Buru Energy with no request received for Buru Energy to attend risk workshops or coordinate site visits. The KRED specialist review process is summarised in Table A6-2 below.

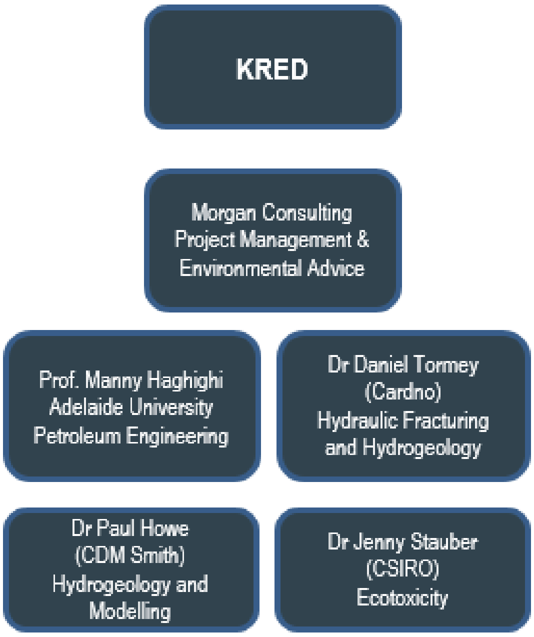


Figure A6-2: Specialists selected by KRED to provide independent advice.

Table A6-2: Summary of KRED independent specialist review process.

Date	Engagement Type	Description
27 September 2014	Information exchange	Buru provided documents to KRED specialists for review.
24 December 2014	Information exchange	Comments and queries received from KRED specialist reviewers.
25 March 2015	Information exchange	Buru provided responses to KRED comments and queries received on 24 December 2014.
12 May 2015	Information exchange	Comments and queries received from KRED specialist reviewers.
2 June 2015	Information exchange	Buru provided responses to KRED comments and queries received on 12 May 2015.
19 June 2015	Information exchange	Comments and queries received from KRED specialist reviewers.
6 July 2015	Information exchange	Buru provided responses to KRED comments and queries received on 19 June 2015.

Date	Engagement Type	Description
August 2015	Community meetings	Two meetings held for independent specialists to present to Traditional Owners represented by KRED. Meetings were held in Derby and Yakanarra.
10 November 2015	Information exchange	Final report received from KRED Independent specialists.
21 December 2015	Information exchange	Buru provided response to KRED regarding final report and thanked KRED for their participation.

Outcomes

The findings of the independent specialist review are provided in the document "*Buru Energy Limited's Hydraulic Fracturing Proposed for Laurel Formation Tight Gas Pilot Exploration Program – Final Report to the Ngurrara People, the Nyikina Mangala People and the Karajarri People*", 4 November 2015.

The report contained the following general findings:

- The environmental documentation provided has in many cases been peer reviewed. This peer review is welcomed as it adds rigor to some of the company's predictions and conclusions regarding risks to the environment.
- Buru Energy undertook a comprehensive environmental assessment appropriate to the scale of the exploration project. The plan included proposed actions to mitigate the identified risks and to limit the exposure pathways to the hazardous chemicals.
- There is general confidence that the well design provides the necessary control measures for fraccing.
- The presentation of the reports and the data they contain could be significantly improved which would support a greater understanding by the reader of the assessment undertaken and the predicted environmental risks that they present.
- The activity is highly unlikely to result in increased seismic activity.
- The key issues in relation to protection of groundwater resources (i.e. existing beneficial use and Environmental Values associated with groundwater) are adequately addressed within the Environment Plan.
- Potential risks to ground and surface water are considered to be low due to both geological barriers and engineering controls.
- Provided the proposed best practice is used so that there are no surface and groundwater exposure pathways, residual risks from chemicals and flowback water should be minimal.
- No robust ecotox testing has been undertaken, however, the risks to sensitive receptors is considered low because exposure to the chemical mixtures is unlikely.
- Robust monitoring and management during exploration and future production will be required to ensure the environmental safeguards put in place are being effective.
- We believe there is a bigger risk associated with on ground operations than below ground.
- No allowance has been made for cumulative impacts should multiple wells and multiple fraccing activity take place in the future.

Noonkanbah Specialist Review

The Noonkanbah community includes members of the Yungngora and Warlangurru Native Title groups. The Yungngora group have Native Title over Noonkanbah Pastoral Station while the Warlangurru group have a Native Title Claim over the area where the Valhalla wells are located.

The Noonkanbah specialist review was commenced in November 2013. The same set of environmental approvals and related documentation listed above was provided to the Noonkanbah specialist reviewers. Noonkanbah specialist reviewers are shown in Figure A6-3 below, with the specialist review process summarised in Table A6-3.

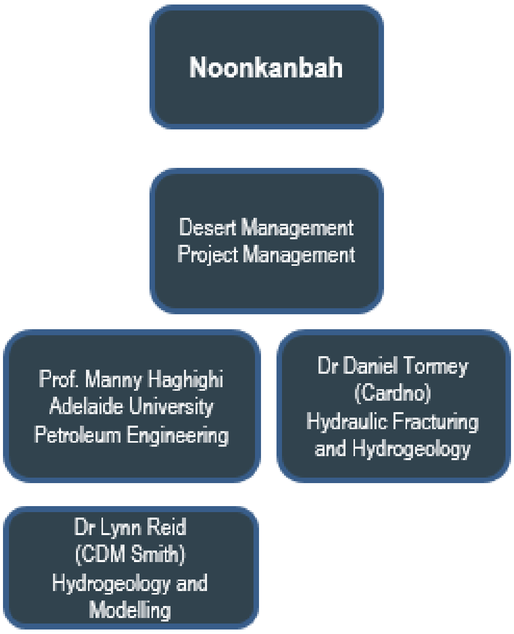


Figure A6-3: Noonkanbah specialist reviewers.

Table A6-3: Summary of Yungngora independent specialist review process.

Date	Engagement Type	Description
25 November 2013	Information exchange	Buru provided available information to Yungngora specialists for review.
26 March 2014	Community meeting	Meeting between Yungngora community members, Project Managers for specialist reviewers and Buru Energy to discuss gas roadmap process, specialist review, employment and contracting opportunities, environmental science cadets, baseline monitoring and synergies of Buru operations with pastoral operations.
28 March 2014	Workshop	Technical risk workshop involving Yungngora specialist reviewers, Project Managers for specialist review and Buru Energy personnel.
31 March 2014	Information exchange	Queries provided to Buru Energy from Yungngora specialists following risk workshop.
15 April 2014	Information exchange	Buru provided responses to Yungngora regarding queries received 31 March 2014.
28/29 April 2014	Community meeting	Two days of community and specialist review meetings at Yungngora community involving Yungngora community members, specialist reviewers and Buru Energy personnel. Included

Date	Engagement Type	Description
		visit to Asgard site for Yungngora community members.
12 May 2014	Information exchange	Reporting of baseline monitoring results to Yungngora community members.
24 June 2014	Community meeting	Community meeting with Yungngora community, specialist reviewers and Buru Energy personnel. Format of meeting was as follows: • Buru Energy presents to community, • Specialist reviewers present to community (Buru Energy not in attendance). • Community vote regarding support for Buru Energy frac program at Noonkanbah.
24 June 2014	Information exchange	Final Yungngora specialist review reports provided to Buru Energy.

Outcomes – Hydrogeology

Conclusions from the hydrogeology review are provided below. This review was undertaken by Dr Lynn Reid from CDM Smith. The outcomes are provided below.

"*This review finds that Buru Energy Ltd has thoroughly addressed environmental risks to groundwater and surface water supplies related to gas exploration and testing activities in the TGS14 campaign. The Environment Plan and associated Appendices have been developed by Buru and subcontractors and reviewed by independent experts. Risks have been identified and appropriate measures implemented to reduce the severity or likelihood of detrimental activities. Some risks above ALARP still remain, and have been identified. Mitigation measures described in the Environment Plan to reduce risks should be scrupulously followed.*"

"This review finds that Buru's plans represent best practice for protection of surface water and groundwater in the field of tight gas development. Analysis provided by Buru and analysis performed by CDM Smith suggests that the quantity of groundwater will not be significantly affected by pilot fraccing operations, and that any potential contamination will be identified through operations and monitoring. Hydrofracturing will take place at sufficient depths that it should not impact shallower groundwater supplies. Surface operations, such as storage of flowback water in well-designed retention ponds, and safely storing potentially hazardous fraccing materials such as biocides will help ensure protection of shallow groundwater and Station surface waters. Buru has expressed their intention to work towards future minimisation of water usage, and beneficial reuse of produced water. Buru's TGS14 operations fulfil the worldwide standards suggested by the IEA Golden Rules which apply to surface water and groundwater and community engagement and transparency. If Buru's plans are followed by Buru and subcontractors, risks to the Yungngora Community's human and animal water supply and to surface water streams and rivers will be minimised."

Outcomes – Petroleum Engineering

A summary of the review in the field of petroleum engineering is provided below. This review was undertaken by A/Professor Manny Haghighi from Adelaide University. The outcomes are provided below.

"Multi-stage hydraulic fracturing in shale gas reservoirs involves the following potential subsurface environmental risks:

1. ***Wellbore stability and integrity which cause inability to complete the well or leakage including gas leakage to aquifers.***

Based on well design, well integrity tests and risk management guidelines, the risk of leakage from wellbore is very low.

2. ***Cap rock failure which causes water resources contamination.***

   Based on the distance between the targeted shale formation to the shallow beneficial aquifer zones which has the minimum distance of more than 1000 m, the risk of water resources contamination by cap rock failure is negligible.

3. ***Producing some toxic material during flow-back from shales such as heavy metals.***

   Since Buru have planned the disposal of flow-back fluids in injection wells, this plan is the most effective means of safely isolating these fluids from the near- surface environment.

4. ***Small earthquake.***

   According to Professor Peter Styles' report provided for Buru Energy, the felt seismicity associated with hydraulic fracturing is very rare."

Outcomes – Hydraulic Fracturing and Hydrogeology

Expert opinion from Dr Daniel Tormey from Tormey Enterprises is presented below. Dr Tormey's review covered the areas of community engagement, induced seismicity, surface impacts and chemical additives. The outcomes are provided below.

1. ***Community Engagement Roadmap.***

   "The engagement plan as currently specified should be an effective means to identify the concerns and needs of the local population, and provide a framework to responding to these questions and concerns. The plan includes the following elements that have proven to be effective in community engagement in general, and with indigenous populations in particular:

   - *Identification of community leaders and concerned community members*
   - *Clear identification of areas of potential environmental and community risk, and direct analysis and responses to these areas of concern*
   - *Describe the project, including its current stage of exploration, and potential later phases of development to avoid surprises*
   - *Different means of communication and engagement: written, oral, company, outside experts, comparison to world standards for best practice, combined with a focus on local questions and concerns*
   - *Transparent process whereby data and supporting analysis are provided for review by outside experts and community members*
   - *After presentation of the project (its benefits, risks, and protections) focus on the stated concerns and questions of the local population.*

   From the description of the first steps of the engagement plan, Buru has developed and begun to implement a world-class program of community engagement. The program should be diligently maintained throughout the project in order to maintain the trust that has been developed to this point. Providing experts in the technical and community issues is an especially good step, as it provides a non-company perspective to the local populations.

   The Community Engagement Roadmap is well done, and should be used in all of the public meetings to indicate the overall exploration and development process that may occur, and how the community can remain engaged."

2. Induced Seismicity.

"The work presented in the Environment Plan related to induced seismicity goes beyond what is required internationally, and beyond what is typically analyzed. The data indicate that the geological factors that could lead to induced seismicity are not present in this area. Furthermore, there is a minor amount of water injection that may occur with this Project. Since water injection is the only factor that has led to induced seismicity in some other, rare, cases, that factor does not exist in this project.

Taken together, the baseline work and the geological and project features indicate that there is very little chance or induced seismicity in this area from the proposed activities."

3. Surface Impacts.

"The study as described minimizes new surface impact by using existing roads, well pads, and wells. The duration of the hydraulic fracturing is very short, so any minor impacts are temporary in nature. The analysis demonstrating this is in line with international standards.

The expert advice of Dr. Reid describes some of the spill-related risks associated with the project, and finds that the protections provided suitably address this risk. I agree with this finding.

The intention to measure environmental conditions before, during and after the hydraulic fracturing goes well beyond existing requirements and practice. To date, my study of the environmental effects at a large oil and gas field in the center of the city of Los Angeles, California, USA, is the only such study in the world. Buru's work can be interpreted in the context of this earlier study in the USA (published October 2012)."

4. Chemical Additives.

"Buru's chemical disclosure meets international standards. The additional ecotoxicological study and the chemical risk study exceed these standards, and provide additional assurance that the chemical additives do not pose an adverse risk to humans or the environment. I have conducted similar ecotoxicological studies of this type, for a development in Northern New South Wales, and at that time such additional studies were unusual.

Among the types of chemical additives with which I am familiar through my work on this subject, Buru has chosen one of the most environmental benign mixtures available at this time."

Appendix 7 – Timeline of Regulatory Reform

2011

- DMIRS commissioned an independent review of WA regulatory framework (Hunter Review). This review identified:
  - WA regulatory framework is robust but opportunities for improvement were identified
  - Recommended improving legal enforceability of regulations
- EPA released EPB No. 15 – Hydraulic fracturing of gas reserves
- APPEA Code of Practice for hydraulic fracturing in WA was released
- State Government Interagency Working Group was established to coordinate a whole of government approach for the regulation of fracking

2012

- In response to Hunter Review, new PGER (Environment) Regulations 2012 were released. These provided increased transparency and enforceability for petroleum activities in WA
- Regulations also strengthened obligations on industry in relation to water use, management and chemical disclosure

2013

- End of transition period for PGER (Environment) Regulations.
- Chemical Disclosure Guideline was released outlining requirements for full disclosure of down-hole chemicals
- WA Parliamentary Inquiry into hydraulic fracturing commenced

2014

•WA Parliamentary Inquiry progressed

- •Submissions received
- •Public hearings held
- •International and WA site visits undertaken

•EPA released EPB No. 22 – Hydraulic fracturing for onshore natural gas from shale and tight rocks.

- EPB No. 22 provided further guidance on the circumstances under which the EPA would regulate proposals that involve hydraulic fracturing.

2015

- WA Parliamentary Inquiry report published. Overall, the inquiry determined that hydraulic fracturing in Western Australia poses negligible risk to the environment and with careful regulation can be undertaken safely
- 'Guide to Regulatory Framework for Shale and Tight Gas in WA – A Whole of Government Approach' published by DMIRS. This outlined the role of respective state government agencies in regulating hydraulic fracturing.
- PGER (Resource Management and Administration) Regulations 2015 released

2016

- Interagency MOUs signed and further guidance released to complement "whole of government framework for regulating shale and tight gas' including:
  - Interagency MOUs signed between (DMP & EPA, DMP & DoW, DMP & DSD
  - Overview of Guide to Regulatory Framework released by DMP
- Guideline for Groundwater Monitoring in the Onshore Petroleum and Geothermal Industry jointly released by DMIRS & DWER

2017

- Change of government
- •PGER (Hydraulic Fracturing) Regulations released. Regulations included a ban on fracking in metropolitan, Peel and South West region and moratorium in remainder of state
- Independent Scientific Inquiry into fracking announced
  - •Scope and terms of reference released
  - •Panellists appointed for inquiry
  - •Background and issues papers released via inquiry website

2018

Independent Scientific HFS Inquiry underway

- •Public meetings in Perth and key regions
- •Call for written submissions addressing terms of reference
- •Report due August 2018