Northern Territory Environment Protection Authority

Onshore Petroleum Activity – NT EPA Advice

ORIGIN ENERGY B2 PTY LTD – ENVIRONMENT MANAGEMENT PLAN (EMP) FOR THE BEETALOO SUB-BASIN VELKERRI 2019 – 2024 DRILLING, HYDRAULIC FRACTURING AND WELL TESTING EXPLORATION PERMIT (EP) 76

BACKGROUND

The Minister for Environment and Natural Resources has formally requested under section 29B of the *Northern Territory Environment Protection Authority Act 2012* (NT EPA Act) that the Northern Territory Environment Protection Authority (NT EPA) provide advice on all Environment Management Plans (EMPs) received under regulation 6 of the Petroleum (Environment) Regulations 2016.

That advice must include a recommendation on whether the EMP should be approved or not, supported by a detailed justification that considers:

- whether the EMP is appropriate for the nature and scale of the regulated activity to which the EMP relates (regulation 9(1)(b))
- whether the EMP demonstrates that the activity will be carried out in a manner by which the environmental impacts and environmental risks of the activity will be reduced to a level that is as low as reasonably practicable and acceptable (regulation 9(1)(c))
- the principles of ecologically sustainable development (regulation 9(2)(a)), and
- any relevant matters raised through the public submission process

In providing that advice, the NT EPA Act provides that the NT EPA may also have regard to any other matters it considers relevant.

ACTIVITY

Interest Holder	Origin Energy B2 Pty Ltd
Petroleum interest(s)	Exploration Permit 76 (EP76)
Environment Management Plan (EMP) title	Beetaloo Sub-basin Velkerri 2019 – 2024 drilling, hydraulic fracturing and well testing EP76
EMP document reference	Beetaloo Sub-basin Velkerri 2019 – 2024 drilling, hydraulic fracturing and well testing EMP, NT-2050-15-MP-032 Revision 1.2, 3 December 2019
Regulated activity	This EMP covers the activities required to enable Origin to drill, hydraulic fracture, test, maintain and suspend or decommission one horizontal petroleum exploration well within the 2019 – 2024 period. The program will occur at one existing well site location (S2-1), on Velkerri EP76, and includes the following regulated activities associated with petroleum exploration: drilling of a vertical well section to 2,000 m – 3,000 m below ground level; drilling of a horizontal well section up to 3,000 m in length;

	hydraulic fracturing of a horizontal exploration well; exploration well completion and testing including completion of up to 12 months of well testing; storage and treatment of up to 12 ML of wastewater flowback fluids onsite; disposal of wastewater at an authorised offsite location; exploration well suspension and decommissioning; construction and operation of a temporary camp; asset maintenance and monitoring activities; site decommissioning and rehabilitation on or before December 2024.
Public consultation	Public consultation on the EMP was required under 8A(1)(b) of the Petroleum (Environment) Regulations as the EMP proposes the drilling and hydraulic fracturing of a well. The EMP was made available for public comment for a period of 28 days from 5 October to 1 November 2019.

NT EPA ADVICE

1. Is the EMP appropriate for the nature and scale of the regulated activity (regulation 9(1)(b))

Information relating to the nature and scale of the regulated activity is provided in the EMP in a clear format. The technical works program includes drilling, hydraulic fracture and well testing one horizontal petroleum exploration well within the 2019 – 2024 period. On completion of well evaluation (testing hydrocarbon flows), the well will either be suspended for future re-entry or decommissioned with permanent cement plugs, in accordance with the requirements outlined in the Code of Practice: Onshore Petroleum Activities in the Northern Territory (the Code). Decommissioning and rehabilitation are planned for on or before December 2024. A progressive rehabilitation plan has been developed for the activity, to minimise the risk of site erosion and return the disturbed land to an environment similar to the original conditions.

A number of well evaluation techniques will be conducted prior to, during and on completion of hydraulic fracture of the Velkerri shale and are adequately described in the EMP. Key information and data required across the phases of the activity are outlined below.

1.1 Basis of well design

Critical inputs include identification of downhole formations that need to be isolated (i.e. aquifers) or hydrocarbon-bearing zones that could be encountered during drilling operations; the subsurface well objective (production and / or reservoir evaluation); the fracture gradient, which describes how much pressure is required to fracture a specific formation; pore pressure, which is the in-situ fluid pressure within a reservoir; other conditions that may affect the integrity of the well (formation fluid composition, stress regime, etc).

1.2 Drilling

Drilling comprises four casing strings, each cemented in place to isolate and seal-off the shallow aquifers from the rest of the well bore, to prevent fluid crossflow between formations. A number of well evaluation techniques will be conducted during and/or on completion of drilling at the well site including mudlogging, logging while drilling, wireline logging, formation testing, core acquisition and fluid sampling.

1.3 Wire logging

Wireline logging during the drilling phase is proposed for the lower (deeper) target formations within the production hole section of the well, to provide continuous measurement of the formation properties. Properties measured during wire line logging, include:

- electrical properties (resistivity and conductivity)
- aspects of the reservoir fluids and rocks, such as their natural radiation signature and porosity;
- assessment of geohazards – e.g. cave-ins, faults, water invasion

- sidewall coring, a process that allows small cores/rock samples to be cut from the side of the hole using wireline tools

Analysis of wireline logging data assists with the decision-making during drilling. A traffic light system will be implemented to monitor anomalous seismicity (tremors) during the hydraulic fracturing operations at the well site. The overall objective of the seismic monitoring is to determine the degree of horizontal fracture propagation as well as vertical fracture orientation in the target reservoir during the hydraulic fracturing operations and to enable microseismic mapping of fracturing extent (height, length, and orientation) for each hydraulic fracture stage.

1.4 Diagnostic fracture injection testing (DFIT)

A Diagnostic Fracture Injection Test (DFIT) will be run to further investigate rock properties. The DFIT has become the primary safety and transient test for ultra-low permeability shales. It involves injecting small volumes of water at low rates to create small fractures, allowing the resulting pressure to fall naturally.

This test involves pumping small volumes (<10,000 L) of water, with salts (mostly sodium chloride - NaCl) and biocide through small perforations made in the well casing, located at a selected depth level of the Velkerri shale, to create small hairline fractures in the shale, and then allowing the resulting pressure to fall naturally after stopping the pump. Proppant (sand) is not used during the DFIT; hence the fracture relaxes and closes naturally when the pumping pressure at surface is released. The pressure decline is monitored at the surface and this decline data is analysed to assist reservoir characterisation and inform subsequent modelling of the hydraulic fracturing operation. The purpose of a DFIT is to obtain information on reservoir properties to help determine subsequent hydraulic fracture design parameters in a reservoir modelling process. Modelling is completed prior to the commencement of hydraulic fracturing activities to establish the best hydraulic fracturing fluid mixture and pumping schedule necessary to propagate the fracture network to maximise the stimulated rock volume (SRV) (or fracture network) in the Velkerri shale and at the same time contain the fracture network in the Velkerri shale to reduce cost and maximise efficiency of pumping resources.

1.5 Hydraulic fracturing

This will involve perforating the 5 ½" steel casing section of the well at the depth of the Velkerri shale and hydraulic fracturing in up to 20 stages for the S2-1 well along the 3,000 m horizontal production casing. (The "kick-off" point for the horizontal production casing is predicted to be at -1485 m.) The process commences at the end (toe) of the horizontal section of the well and the stages work back towards the "heel". Each hydraulic fracturing stage consists of perforating the well bore in that stage section; pressure pumping a slurry, primarily consisting of water and sand (proppant), plus a small percentage of chemicals, at high pressure down the well and through the perforated well bore into the target section of the Velkerri shale approximately 2,000 m – 3,000 m below ground level, depending on the well; and then plugging that stage. Typically, 95% or higher of the total volume in hydraulic fracturing fluids is a combination of fresh water and proppant (e.g. sand), with the remainder of approximately 1% as fluid-conditioning additive chemicals.

Hydraulic fracturing activities will not occur until the integrity of a well has been confirmed. Real-time continuous monitoring of the pumping pressure is conducted during hydraulic fracturing operations to ensure the Maximum Allowable Operating Pressure (MAOP) of 10,000 psi is not exceeded. In addition, anomalous pressure behaviour in the well annulus at surface is also monitored in real-time. The fracture network created in the Velkerri shale during the pumping operation (which may last 2 or more hours) is carefully monitored at the surface using pumping volume and pressure and a range of other measures in the control room of the operation. Each hydraulic fracturing stage will be plugged in the well bore prior to perforation and pumping of the subsequent stage and is anticipated to take one day to complete.

1.6 Completion and Extended Production Test (EPT)

Following conclusion of the hydraulic fracturing operation the equipment for hydraulic fracturing (consisting of pump trucks and other equipment) will be demobilised and a smaller completion rig will be brought to the well site. A production wellhead will be installed. Flowback fluid is then initiated by milling out the mechanical isolation plugs that were set during the fracturing operations between each hydraulic fracture stage. The existing over-burden pressure on the Velkerri shale causes water to return or "flowback" to the surface through the petroleum well. The proppant remains in the shale "propping open" the hairline fracture network that was developed during the hydraulic fracturing pumping operation. It is this principle in hydraulic fracturing that has enabled reservoir engineers to develop "artificial permeability" in shales, enabling hydrocarbons to be liberated from shale formations that would have otherwise taken tens of millions of years to have occurred.[1]

Subject to a successful reservoir outcome (good gas flow rates for example), the well will be flow tested for an initial EPT period of approximately 3 months to 12 months. Flowback fluid wastewater will be directed through a separator at surface to capture wastewater and separate gas to flare. Liquid hydrocarbons (longer chain hydrocarbons such as crude oil) are not expected from the Velkerri Formation targets in EP76; dry gas (methane) is most likely with the potential for "wet gas" (e.g. some ethane and propane) which will be gas at surface conditions and flare efficiently. The EPT will consist of characterising and measuring the gas qualities and quantity and any liquid hydrocarbon production as well as other "reservoir" characteristics.

1.7 Well site closure operations

On completion of technical evaluation of the results from the hydraulic fracturing activity, each exploration well will either be suspended for future re-entry, or in a non-success case, a decision made to decommission the exploration well with permanent cement plugs in accordance with the Code. At the completion of operations all surface infrastructure will be removed (excluding the well head).

1.8 Sub-surface geology

The stratigraphic formations intersected by the petroleum wells have been adequately described in the EMP, informed by 9,500 km of 2D seismic data used to screen for large scale, regional faults or structures prior to the finalisation of any exploration well location. Current data for the broader Beetaloo exploration area indicates there are very few major faults present and that the strata within the Basin (i.e. away from the steep flanks) are relatively gently dipping.[2] Data gained during well drilling, and from stratigraphic boreholes and groundwater bores in the area, will also inform the planning and design of the well construction to isolate and protect the regional aquifers.[3] The groundwater monitoring bores were required to be installed to the base of the regional Cambrian Limestone Aquifer (CLA) system, in compliance with the Code. Additional sources of data used to define contact between aquifers, include offset geological data from the control-monitoring bore installed 100 m from the exploration well; analysis of the gamma ray signature, and correlation with the basin-wide Gum Ridge Formation gamma ray signature; and, onsite analysis of the drill cuttings.

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1 Shale (mudstone) is the "source rock" from which almost all petroleum originates. It is the sedimentary rock in which organic matter that forms petroleum was deposited and subsequently buried, usually in a depositional nearshore marine environment; over one billion years ago in the case of the Beetaloo Sub-basin shales. "Conventional" petroleum reservoirs are more permeable rock formations such as sandstone or lime deposits (that don't require hydraulic fracturing) which were able to "trap" petroleum due to stratigraphy over tens of millions of years that was migrating very slowly from the shale to the surface.

2 Scrimgeour I. (2016) Summary of current knowledge of petroleum geology, shale gas resources and exploration in the Beetaloo Sub-basin. Information Provided by the Northern Territory Geological Survey to the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory. [Scrimgeour]

3 Aquifer defined in the Code as: A body of rock that is sufficiently permeable to conduct groundwater and currently supplying, or potentially being able to supply, water for environmental, cultural or consumptive (stock or domestic) uses, as determined by the Northern Territory Government.

1.9 Activity scope and duration

The EMP clearly describes the scope of the activity and its duration. The duration of the drilling, hydraulic fracture stimulation and testing activities is expected to be approximately 12 – 18 months (indicative), subject to approval of the regulated activity and seasonal access. On completion of exploration well drilling and technical evaluation the exploration well will either be suspended for future re-entry, or in a non-success case, a decision made to decommission the exploration well with permanent cement plugs in accordance with the Code.

Estimations of consumables (e.g. water, sand and chemical additives) discussed in the EMP are based on a maximum 20 stage hydraulic fracturing program for the horizontal well. Water and sand make up the bulk of the materials of the hydraulic fracturing fluids per stage. The preliminary hydraulic fracturing design will involve pumping approximately 1.3 ML of fluids and 180 tonnes of proppant per stage. The final designs will be determined after the Diagnostic Fracture Injection Test (DFIT) is performed. Total volume of flowback fluid wastewater from hydraulic fracturing required for offsite disposal is estimated to be less than 1 ML (after evaporation).

A temporary 60 person camp site will be established for the hydraulic fracturing stages of the activity. A smaller crew will be required during the longer well completion and testing stage. The traffic impact assessment indicates additional peak project vehicle movement is 44 vehicles per day in addition to the existing peak dry season traffic volumes of 827 vehicles/day, resulting in an additional 1.2% of large combination vehicles when compared to the total volume composition.

Information on the location and scale of the proposal is provided in the EMP. The existing environment has been adequately described through baseline surveys and is sufficiently understood. There are no areas of high conservation value or cultural significance in the vicinity of the regulated activity. The closest restricted work area is 7 km from the regulated activity. The EMP includes an impact and risk assessment based on information gathered during environmental baseline surveys and data collection 2005 – 2018, and previous exploration experience of the Interest Holder in EP76. The potential impacts and risks of the regulated activity have been identified and relevant environmental outcomes, performance standards and measurement criteria have been provided in the EMP. Where appropriate the NT EPA has also provided advice relating to Ministerial conditions for this preliminary stage of exploration in the Beetaloo Sub-basin at the end of this advice.

1.10 General compliance with Code

The EMP demonstrates how the Interest Holder will comply with relevant requirements of the Code in undertaking this regulated activity. This includes a list of applicable ISO/API standards that have been adopted for the selection of materials for use in well construction; hydraulic fracturing program environmental controls and related engineering controls contained in the Well Operations Management Plan (WOMP); a summary of which is provided in the EMP (Appendix T). The risk assessment provided in the EMP cross references relevant sections of the Code that apply to the mitigation and management measures to enable the reviewer to identify and confirm that the proposed drilling, hydraulic fracturing and well testing activities comply with the Code. The EMP also provides the following plans which are compliant with the Code:

- Chemical Risk Assessment of chemicals to be used in the hydraulic fracturing activity
- Wastewater Management Plan – including management of flowback wastewater
- Spill Management Plan – including spill risk assessment and response strategy
- Emergency Response Plan
- Methane Emissions Management Plan
- Weed Management Plan
- Bushfire Management Plan
- Stakeholder Engagement Plan

Additional mitigation measures for the protection of groundwater include the installation of a groundwater monitoring bore system. This consists of a control monitoring bore array, located up-

gradient and within 100 m of the planned or existing location of a petroleum well pad; and an impact monitoring bore array, screened at similar depths to the control monitoring bore array, 20 m down-gradient of the location of the petroleum well. This layout enables ongoing comparison of background groundwater quality with that immediately downstream of the petroleum well. One monitoring bore is required for each discrete aquifer unit, which is screened near the top, middle and bottom of the vertical extent of that unit. In the Beetaloo Sub-basin this may include the Anthony Lagoon aquifer unit and the deeper regional Gum Ridge Aquifer. Water is sampled from each of these monitoring bores on a quarterly basis and analysed at a NATA accredited laboratory for an array of analytes, including Total Dissolved Solids, chloride, electrical conductivity, boron, strontium, barium, naturally occurring radionuclide material (NORM) and dissolved methane.

As required in the Code and the Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin, the Interest Holder must undertake ongoing groundwater monitoring for three years from the approval date of the EMP, to demonstrate 'no change' to groundwater quality and results will be published on the DENR website.[4]

The level of detail and quality of information provided in the EMP is sufficient to inform the evaluation and assessment of potential environmental impacts and risks, and meets the EMP approval criteria under Regulation 9(1)(b).

2. Principles of ecologically sustainable development (regulation 9(2)(a))

2.1 Conservation of biological diversity and ecological integrity

The potential impacts and risks to threatened flora and fauna species from clearing were assessed in the EMP for the Origin Velkerri civil construction EP76, approved on 26 September 2019.[5] That EMP identified 20 listed threatened species as likely to occur on EP76 based on availability of suitable habitat. Of these, only five species were considered to have a 'medium' likelihood of occurrence on EP76: crested shrike tit, grey falcon, Gouldian finch, painted honeyeater and yellow-spotted monitor. The Origin Velkerri civil construction EMP outlined mitigation measures associated with construction activities to minimise impacts on threatened species and on affected environmental values including the management of threatening processes such as weeds and fire. The NT EPA advised that it considered the conservation of biological diversity and integrity of threatened species would be maintained in the area if the EMP is complied with.

The potential impacts and risks of the activity identified in the current EMP relate primarily to animal welfare and do not pose a significant risk to threatened species at a population level due to the low likelihood of threatened species inhabiting the area and implementation of control measures to avoid impacts to fauna.

The EMP identifies other potential impacts and risks to biodiversity arising from vehicle strike, increased weeds, and ingestion of flowback fluid wastewater generated during the activity. The fauna impact mitigation measures for risk sources from hydraulic fracture activities, flaring and entrapment are compliant with the Code and include:

- appropriate separation distances between flares and surrounding vegetation that provides fauna habitat (45 m)
- driving is only permitted on designated access roads
- speeds on unsealed roads will be limited, with to a maximum of 60 km/hr
- all tank pads are above ground, with steep sides, to prevent ease of animal entry
- all wastewater will be stored in tanks more than 2 m high
- fauna ladders will be installed at all open pits

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4 DENR 2019. *Groundwater monitoring results.* https://denr.nt.gov.au/onshore-gas/onshore-gas-in-the-northern-territory/industry-compliance-and-reporting/groundwater-monitoring-results. [DENR]

5 The EMP and assessment are available on the DENR website at: https://denr.nt.gov.au/onshore-gas/environment-management-plan/approved-emps.

- all hydraulic fracture work tanks will be enclosed
- daily checks of tank pads throughout the hydraulic fracturing program

In relation to wastewater, it will likely have a salinity that is more than 3 times that of seawater as evidenced in the flowback fluid data analysis published by DENR,[6] for two previously hydraulically fractured wells in the Beetaloo Sub-basin (Shenandoah-1 and Amungee NW-1). Cumulative impacts to flora and fauna from the regulated activity and the approved civils activities are not considered to be significant. The EMP has assessed the risk to groundwater dependent ecosystems (GDEs) as 'low'. The well pad is located ~200 km from known GDEs and away from major flow paths, wetlands or permanent water courses. The NT EPA considers that implementation and compliance with the EMP will ensure the conservation of biological diversity and ecological integrity is not impacted by the regulated activity.

2.2 Integration of long-term and short-term economic, environmental, social and equitable considerations

The EMP has considered environmental controls in well design for drilling and hydraulic fracturing that ensures well integrity and long-term protection of aquifers. These controls include conservative four casing string well design, which provides a minimum of two well barriers between the hydrocarbon bearing zone, and any aquifer and the surface. In addition, a well integrity report is prepared by a suitably qualified person in accordance with the Code, which must be checked and verified by the regulator. These controls and a range of other routine procedures have been identified in the EMP, are compliant with the Code and can be checked and audited against the Well Operations Management Plan (WOMP) throughout the life-cycle of the well.

The regulated activity is low impact, small scale and has a duration of activity of up to 18 months, which includes flowback and tests for gas production. It forms one component of a broader exploration program to inform the Interest Holder on the potential for commercial gas production in the Beetaloo Sub-basin from the Velkerri shale. Cumulative estimated volumes of groundwater extraction and greenhouse gas (GHG) emissions from the regulated activity, previously approved civils activities and groundwater monitoring activities, have been included in the EMP.

The regulated activity has potential to impact on groundwater drawdown associated with groundwater extraction. The total estimated groundwater volume required for the proposed activities is 38 ML and will be sourced from existing bores in accordance with the water extraction licence. Based on transmissivity analysis, the total water extraction requirement is well within sustainable recharge levels in the Gum Ridge aquifer. Standing water level of the Gum Ridge aquifer is continuously measured using a logger at the well site. The Bukulara aquifer is not expected to be present at this location.

An extraction licence has been granted to the Interest Holder for 175 ML per year for 3 years from May 2019 to December 2023 (GRF10285). The total cumulative volume of groundwater to be extracted is within this volume. Groundwater extraction is informed by the NT Water Allocation Planning Framework, which indicates the volume of groundwater held in storage in the Gum Ridge aquifer is estimated to range from 1,766,000 GL to 3,532,000 GL. Cumulative groundwater extraction from the Gum Ridge aquifer over the period May 2019 to December 2023 is approximately 1,492.5 ML, significantly less than the estimated water available for extraction under the framework and within the extraction licence. The Interest Holder's licence allocation is less than 0.01% of the estimated sustainable yield of the Gum Ridge aquifer. Standing water level of the Gum Ridge aquifer will be continuously measured using a logger at the well site. Groundwater extraction volumes will be recorded and submitted to the DENR Water Resources Division, in accordance with the requirements of the groundwater extraction licence.

Standard GHG mitigation measures outlined in the Code such as combustion flaring will be implemented. Combustion flaring is expected to reduce the emissions by approximately 85% compared to venting. A Methane Emissions Monitoring Plan is contained in the EMP in

6 DENR *supra* note 4.

compliance with the Code. As a further precautionary step, the NT EPA has provided advice requiring the Interest Holder to undertake leak detection monitoring of equipment that is in hydrocarbon service and under pressure to an auditable standard within seven days of commissioning.

The Interest Holder has calculated the total GHG emissions generated for the duration of the activity (hydraulic fracturing, well completion and EPT) to be approximately 66,000 tCO_2e (tonnes of carbon dioxide equivalent); assuming a conservative well testing period of 12 months. The NT EPA notes that the EPT which involves measuring hydrocarbon flow from the exploration well over an extended period is the major component (93%) of total emissions for the regulated activity. An EPT is only required to be conducted during the exploration phase of petroleum operations to characterise the reservoir. Fugitive emissions of methane from well completion in the activity (excluding flare tip inefficiency) is estimated to be 2% of total estimated GHG emissions. Assumed flare tip efficiency in these GHG calculations has been back calculated using published values and is reasonably conservative.

Combined total cumulative GHG emissions for the approved activities in the Origin 2019-20 exploration program on EP76 and EP117 are estimated to be 148,300 tCO_2-e, assuming a worst case EPT period of 12 months. The total estimated GHG emissions for the Origin 2019 exploration program will likely result in an overall increase in NT GHG emissions of 0.9%, noting that this is largely incurred as a result of the EPT and only required in the exploration phase. Under these circumstances of preliminary exploration activity, the NT EPA considers that cumulative emissions are not significant when considered in context of 2017 NT and Australian emissions,[7] which were approximately 16.5 million tonnes and 535 million tonnes respectively.

As a precautionary measure, the NT EPA has provided advice that the Interest Holder undertake an analysis of offsite disposal and beneficial use options (other than flaring) for liquid hydrocarbons, if the combustion of liquid hydrocarbons at the flare exceeds an average of 5,000 L per day during the first month or following months of flaring.

The EMP adequately assesses the environmental impacts and risks associated with the regulated activity and outlines appropriate avoidance and mitigation measures. This includes the assessment and management of social impacts and risks, including the appropriate management of cultural heritage. The Interest Holder has demonstrated ongoing stakeholder engagement in the EMP as required by the Regulations with landholders and land managers, traditional owners, the Northern Land Council (NLC) and NT Government agencies.

The regulated activity will be subject to requirements of the Aboriginal Areas Protection Authority Certificate C2019/039. There are no significant economic, environmental, equitable adverse effects from the regulated activity.

2.3 Precautionary principle

The NT EPA considers there is a low threat of serious or irreversible damage from the regulated activity.

The Interest Holder's investigations into the physical, biological and cultural environment provide a satisfactory scientific basis to assess potential environmental impacts and risks for the activity, and to identify measures to avoid or minimise those impacts and risks and address scientific uncertainty. The risks of drilling and hydraulic fracturing are well understood and there are internationally recognised standards and established best practice management measures for hydraulic fracturing operations in geological surveying, well design, operational engineering safeguards and well integrity monitoring to ensure aquifer protection; these are reflected in the mandatory requirements of the Code. The EMP also presents commitments to the precautionary

[7] DOEE (2019) *State and Territory Greenhouse Gas Inventories 2017*. http://www.environment.gov.au/system/files/resources/917a98ab-85cd-45e4-ae7a-bcd1b914cfb2/files/state-territory-inventories-2017.pdf

controls and monitoring that have been adopted in the Code, in this preliminary stage of exploration using hydraulic fracturing in the Beetaloo Sub-basin.

The assessment of large scale subsurface geohazards is informed by 9,500 km of 2D seismic data. Wireline logging is proposed for the lower (deeper) formations that lay within the production hole section of the well, to provide continuous measurement of the formation properties. Wells are located away from known geohazards. Given the lack of major faults and structures across the deeper areas of the Beetaloo Sub-basin there is a low geohazard risk associated with through-going faults, therefore a very low likelihood of contamination to shallow aquifers occurring via this mechanism.[8]

At this stage the Interest Holder has conducted hydraulic fracturing in the Beetaloo Sub-basin at the Amungee NW-1 well and has provided laboratory analysis of the flowback water quality; it is anticipated that flowback quality at the Velkerri S2-1 well will be similar. Reports on flowback wastewater from two previously hydraulically fractured wells (Amungee and Shenandoah) in the Beetaloo Sub-basin and relatively nearby to the proposed Velkerri well site, are available on the DENR website.

The NT EPA is of the view that the precautionary principle has been considered in assessing the regulated activity and has not been triggered due to the low threat of serious or irreversible damage existing and the presence of a satisfactory scientific basis to assess potential impacts and risks. In addition, the environmental and engineering monitoring commitments contained in the EMP are compliant with the Code and based on data analysis from two previously hydraulically fractured wells in the Beetaloo Sub-basin.

2.4 Principle of inter-generational equity

The potential environmental impacts and risks associated with the regulated activity can be adequately avoided or managed through the management measures and monitoring programs proposed in the EMP. The NT EPA considers that environmental values will be protected in the short and long term and that the health, diversity and productivity of the environment will be maintained for the benefit of future generations.

Cumulative GHG emissions from Origin exploration activities at Velkerri and Kyalla are not considered significant, as discussed at section 2.2.

The Interest Holder's licence allocation is less than 0.01% of the ESY of the Gum Ridge aquifer. Groundwater extraction volumes will be recorded and submitted to the DENR Water Resources Division, in accordance with the requirements of the groundwater extraction licence.

The regulated activity will be subject to requirements of an Aboriginal Areas Protection Authority Certificate. Appropriate measures are proposed for the management of items of heritage value should they be discovered.

2.5 Promotion of improved valuation, pricing and incentive mechanisms

The Interest Holder would be required to prevent, manage, mitigate and make good any contamination or pollution arising from the regulated activity, including contamination of soils, groundwater and surface waters through accidental spills.

All stages of the regulated activity, including progressive rehabilitation of all disturbed areas to an acceptable standard, would be at the cost of the Interest Holder. The Interest Holder will be required to provide an adequate environmental rehabilitation security bond to indemnify the NT government. This is based on an assessment by DENR and approval of the rehabilitation security costs associated with the proposed activity in the EMP provided by the Interest Holder.

8 Scrimgeour, *supra* note 2.

3. Relevant matters raised through public submissions

The regulated activity includes the hydraulic fracturing of one petroleum exploration well, and in accordance with the Petroleum (Environment) Regulations 2016, the EMP was made available for public comment for a period of 28 days from 5 October to 1 November 2019. DENR received a total of 29 submissions: 23 from community members, 5 from non-government organisations and one from a business. Sixteen (16) submissions were identified as originating from within the NT.

All submissions were opposed to onshore gas development. Submissions raised similar issues to those considered during: a) the Scientific Inquiry into Hydraulic Fracturing of Onshore Unconventional Reservoirs in the Northern Territory (HFI) and subsequently being addressed through NT government implementation of the 135 HFI recommendations; and b) raised during the assessment of recent drilling and hydraulic fracturing EMPs, including:

- Santos: McArthur Basin Hydraulic Fracturing 2019-20 Program EP161, approved 23/10/19
- Origin: Beetaloo Sub-basin Kyalla drilling hydraulic fracture stimulation and well testing program EP117 N2, approved 13/08/19
- Santos: McArthur Basin drilling Program EP161, approved 19/07/19[9]

This NT EPA Advice draws on this EMP, the findings of the HFI and other relevant published technical references and information to respond to issues raised in submissions. The sources of this referenced information are cited where appropriate in this Advice.

Public submissions covered a range of social, environmental and regulatory issues (Table 1). Many of the issues raised in the public submissions are dealt with in other sections of this advice. Cross reference to the relevant sections is provided in Table 1 to avoid repetition. Where a matter has not been discussed elsewhere in this advice, it is considered below.

Table 1: Issues raised in public submissions

Theme	Issue	Response Reference
Regulation and compliance	• HFI Implementation strategy not complete • potential risks fail to take into account ESD principles • lack of assessment of cumulative impacts in accordance with HFI recommendation 14.21 • lack of security during initial exploration	Sec. 3.8 Sec. 3.8 Sec. 2.2, 2.4 Sec. 2.5
Social	• adequacy of stakeholder engagement with neighboring and downstream landholders, potentially affected business operators, affected Aboriginal communities • lack of social licence in the NT for onshore shale oil and hydraulic fracturing • lack of consideration of intergenerational economics and equity, the precautionary principle • impacts to public and tourism from increased traffic • polluter pays	Sec. 3.7 Sec. 3.7 Sec. 2.2, 2.3, 2,4 Sec 1.9 Sec. 2.5
Chemicals	• toxicity and harmfulness of chemicals • adequacy of the chemical risk assessment to protect the community • naturally occurring radionuclide material (NORM) • synergistic effects of hydraulic fracturing fluid chemical mixtures	Sec. 3.2, 3.3, 3.4 Sec. 3.2, 3.3, 3.4, 3.5 Sec. 3.3 Sec 3.4

[9] Approved EMPs are available on the DENR website at: https://denr.nt.gov.au/onshore-gas/environment-management-plan/approved-emps

Theme	Issue	Response Reference
Water	**Surface water** • potential impacts to downstream areas from spills and/or loss of containment, particularly during the wet season	Sec 3.5
	Groundwater • scarcity of the groundwater resource and impacts of the industry groundwater use on the resource	Sec. 2.4
	• lack of information on monitoring of fracture distances and potential groundwater contamination from hydraulic fracturing fluids	Sec. 3.1, 3.2, 3.3, 3.6
	• implications of low estimated flowback water volumes of hydraulic fracturing fluids	Sec. 3.1, 3.2
	Hydrogeology • inadequate understanding of the hydrogeology of the NT	Sec 1.8, 2.2, 3.6
	• potential for hydraulic fracturing fluids to contaminate aquifers via faults and fractures; upward migration of brines	Sec. 1.1 – 1.4, 1.8, 3.6
Flora and fauna environment	**Animal welfare** • fauna entrapment in sumps/tanks or ingestion of contaminated water/materials collected during drilling and hydraulic fracturing	Sec. 2.1, 2.3, 3.2
	• deleterious impacts of land and/or water contamination on fauna in general, and threatened and migratory species	Sec. 2.1, 2.3, 4.1, 4.3
	• spread of feral pests (e.g. cane toads due to accessibility to wastewater tanks)	Sec. 2.1, 3.5
	Baseline studies • lack of comprehensive environmental baseline studies to demonstrate the level of impact that may be incurred by development of the onshore gas industry, including consideration of impacts to groundwater dependent ecosystems	Sec. 1.3, 1.4, 1.5, 1.8, 1.9, 1.10, 2.1, 2.2
Climate change	• development of an industry that will result in increased GHG emissions and contribute to Australia's impact on climate change	Sec. 2.2
	• the EMP does not propose emission offsets as per HFI recommendation 9.8	Sec. 2.2
	• hydraulic fracturing may lead to undetected methane leaks occurring	Sec. 2.2
Human health	• lack of demonstrated experience regarding the regulatory framework to protect human health from of impact of activity	Sec. 3.1, 3.2, 3.3, 3.4
	• risk the chemicals used pose when human exposure pathway occurs	Sec. 3.2, 3.3, 3.4

3.1 Subsurface geohazards

Seismic control and well control information that supports the identification of sub-surface geohazards obtained predominantly during drilling at the well site have been previously discussed in sections 1.1 and 1.6.

To reduce the risk of hydraulic fractures reaching the base of existing aquifers to an acceptable level, the Code adopts an internationally accepted minimum offset distance between the target hydrocarbon formation and the base of the nearest aquifer of 600 m. This internationally accepted minimum offset, or protection distance, is based on extensive published research on how high

hydraulic fractures can plausibly extend in shale formations.[10] In the case of this well activity, a physical separation distance of approximately 1,400 m between the Gum Ridge Aquifer and the Velkerri Formation (target) prevents any migration of stimulation fluid to aquifer units.

The target zones for hydraulic fracturing consist of clay rich, organically lean layers which act as impermeable aquitards to fluid migration, as illustrated by the organic-enriched layers still containing gas hundreds of millions of years after it was generated. They also provide effective barriers to vertical fracture growth during hydraulic fracture operations.

3.2 Hydraulic fracturing chemicals

A tiered chemical risk assessment was conducted on the hydraulic fracturing chemicals. The assessment involved a screening of the potential human health and ecological hazards that should be considered for potential exposure to the hydraulic fracturing fluids during transportation, hydraulic fracturing activities (including storage), and subsequent treatment and disposal of flowback water. The assessment includes the following steps:

- Tier 1 - Identify chemicals of low human health and ecological concern that do not require additional chemical risk assessment in the tier assessment process.
- Tier 2 – Chemicals that are not identified as a low human health and ecological concern, and therefore require additional risk assessment to characterise potential risks. This is done using a quantitative evaluation of the risks based on the potential complete exposure pathways and Tier 1 assessment.

The majority of the chemicals were identified not to be persistent and bioaccumulative and in very low concentrations. The flowback fluid consists chiefly of salts, metals and petroleum products (which are separated or flared) that originate in the reservoir. Management of bacteria during the well suspension phase must be undertaken in accordance with the Code.

All of the drilling and hydraulic fracturing chemicals proposed were classed as Tier 1 – low human health and ecological concern except one chemical, Hydrotreated light petroleum distillate (CAS # 64742-47-8). Hydrotreated light petroleum distillate was classified as a bioaccumulative and toxic substance and subsequently assessed under a human health Tier 2 risk assessment across all exposure pathways (i.e. transport and storage, mixing/blending drilling of hydraulic fracturing chemicals, injection of drilling chemicals and cleaning and maintenance). Inorganic chemicals such as acid are quickly neutralised in the reservoir and organic chemicals (such as biocide to prevent introduction of groundwater bacteria to the petroleum reservoir) are quickly denatured at the very high temperature and pressure in the reservoir. Hydrotreated light petroleum distillate used during hydraulic fracturing is in low concentrations in the drilling fluids. The chemical risk assessment concluded that exposure to the chemical via these fluids is of low concern for workers.

The chemical risk assessment also identified 18 chemicals used in the hydraulic fracture stimulation fluid that may potentially be contained in the flowback due to their volume of use and elevated concentrations that were above ecotoxicity values. These chemicals are addressed in the wastewater management and disposal program and are used for various purposes, including but not limited to: surfactants, scale inhibitors, corrosion inhibitors, crosslinkers, and biocides. None of these chemicals were identified to be persistent and bioaccumulative and are considered to be low risk provided they are stored and managed in accordance with the requirements of the Code for management of chemicals onsite, ALARP, the Wastewater Management Plan, Spill Management Plan and disposal program.

3.3 Biocides

The purpose of biocides in hydraulic fracturing fluid is to ensure that bacteria are not introduced into the hydrocarbon reservoir. Biocides are also used in drilling muds for the same reason. The

[10] Fisher, K, and N Warpinksi. (2012), 'Hydraulic-Fracture-Height Growth: Real Data.' *SPE Production & Operations* 27 (1): 8-19.

key biocides in the HF fluid system, Tributyl tetradecyl phosphonium chloride (TTPC) (CAS number 81741-28-8) and Glutaraldehyde (CAS number 111-30-8) are used at concentrations of 28 mg/L and 0.001 mg/L, respectively. At these low concentrations in the "whole fluid' system the biocidal effects are directed to aquatic organisms (e.g. bacteria) but will not affect terrestrial organisms through consumption.

TTPC is particularly effective, potent and targeted in its longer lasting biocidal effects on microbial biofilm forming microorganisms at low concentrations and is therefore also commonly used in other applications where this is desirable, such as building air conditioning plants to control potentially fatal *Legionella* outbreaks. The chemical risk assessment noted that TTPC is stable over a wide pH range and is not susceptible to photo-degradation. TTPC is biodegradable, but not readily biodegradable.[11] It will strongly adsorb to soil and sediment. TTPC is not expected to bioaccumulate. The overall conclusion was that TTPC is not Persistent, Bioaccumulative and Toxic (PBT). Flowback fluid wastewater must be stored and managed appropriately while degradation of the biocide occurs, demonstrating environmental impacts and risks are reduced to a level that is ALARP and acceptable.

The flowback fluid wastewater contains the dissociation or breakdown products of the injected hydraulic fracturing fluid plus naturally occurring geogenic compounds i.e. hydrocarbons, minerals, radionuclides and other substances that are dissolved in the process from the shale reservoir.[12] These geogenic compounds must also be considered for potential health or environmental impact in the management of flowback water. While the vast bulk of these compounds are actually chloride brines such as salt (NaCl) other compounds such as heavy metals and radionuclides are sometimes present. Radium has been documented in the formation waters in many sedimentary basins and is often positively correlated with chlorinity.[13] In surface and shallow subsurface environments, radium can be relatively soluble and, therefore, mobile in groundwater. As a radioactive element, radium may represent a potential health hazard if it exceeds threshold levels of exposure. Radioactive isotopes are commonly quantified in terms of "activity concentration" or simply "activity," which in this context refers to a number of disintegrations per unit time. For normal exposure situations in Australia, it is usually unnecessary to regulate materials with radionuclides of natural origin with activity concentrations below 1,000 Bq/kg.[14]

Based on shale industry experience in the US, the concentration of chemical constituents in the flow back has been observed to be 50% or less of the injected fluid chemical concentration. In the early stages of flowback some of the water (~30%) that was pumped into the reservoir is expected to be returned to surface together with dissolved brine from the host shale rock. After several weeks the production of flowback water will have exponentially declined to less than 1% of first week of flowback. At the same time there is usually a marked increase in salinity with time, interpreted to represent a decreasing proportion of the lower salinity injected fluid and an increasing proportion of the saline formation water returning to the surface.

3.4 Potential synergistic effects of hydraulic fracture chemical mixtures

Synergistic interactions of chemicals in mixtures were raised in public comments. The concern being whether some chemicals can enhance the effect of other chemicals, resulting in a combined effect that is larger than predicted. The three main groups of toxicants that have received considerable attention are pesticides, metals and antifoulants.[15] The reason that these three main groups have received attention is because of their Persistent, Bio-accumulative and Toxic (PBT)

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[11] A die-away [simulation] test was conducted with radiolabelled TTPC for 168 hours at the expected HF fluid concentration of 0.31 mg/L. The first-order rate constant was 0.69/hour and the half-life was 6.6 hours. After 24 and 168 hours, degradation was >81% and >98%, respectively (Buru Energy)

[12] Hayes, T. 2009. *Sampling and Analysis of Water Streams Associated with the Development of Marcellus Shale Gas*, Final Report, 31 December 2009.

[13] Stephen Fisher, R. 1998. Geologic and Geochemical Controls on Naturally Occurring Radioactive Materials (NORM) in Produced Water from Oil, Gas, and Geothermal Operations 5(3): 139-150

[14] ARPANSA 2008. *Safety Guide for the Management of Naturally Occurring Radioactive Material (NORM), Radiation Protection Series No. 15*. Commonwealth of Australia.

[15] Cedergreen N (2014) Quantifying Synergy: A Systematic Review of Mixture Toxicity Studies within Environmental Toxicology. PLoS ONE 9(5): e96580. doi:10.1371/journal.pone.0096580

nature in the environment. All three groups have orders of magnitude (100's to 1000's) greater toxicity and persistence and potential to bio-accumulate in the environment than the chemicals used in hydraulic fracturing.

Addressing the cumulative effect of co-occurring chemicals is the first and most important step in determining the hazard.[157] Hydraulic fracturing fluid is pumped down into an impermeable shale formation more than 2 km below the surface and returns from inside a petroleum well (with multiple verified mechanical barriers that isolate the fluid from aquifers and other non-target formations). Therefore, the focus is on the risks associated with the management of wastewater at the surface to ensure it remains isolated from the environment. These risks are addressed in the Code, and the EMP has outlined how it will comply with the wastewater management requirements of the Code.

3.5 Wastewater management

Wastewater recovered from the well during the flowback phase is stored in above ground storage tanks which are double lined, located in a purpose designed bunded containment tank pad area with real-time, continuous leak detection and water control structures, thereby reducing reaction time to potential impacts from leaks / spills and improving efficiencies in water management. The activity has capacity to treat and store approximately 12 ML of flowback fluid wastewater within four tanks on the tank pad area, which is surrounded by a bund with a holding capacity of 21 ML. Tank levels are continuously monitored to ensure minimum freeboard is maintained. As a precautionary measure all wastewater must be stored in enclosed tanks in the event of significant rainfall. Open tanks on the tank pad will be used to reduce the volume of wastewater by evaporation. In compliance with the Code, open tanks must be operated with a sufficient freeboard to not overflow with an annual exceedance probability (AEP)[16] for a total 90-day rainfall event[17] that might be expected to occur once in a thousand years for the period that treatment infrastructure contains wastewater. This is a statistically derived probability from rainfall records and in the Beetaloo Sub-basin region. The analysis provided in the WWMP for a 3-month wet season containment period minimum freeboard requirement is 1,300 mm and 3-month dry season containment period minimum freeboard requirement is 300 mm. These figures do not include any evaporation and are therefore conservative. The wet season freeboard requirement is more than twice the average total annual rainfall (684 mm) for the Beetaloo and almost equal to the highest 12-month rainfall total reported in the 130-year rainfall record used in the analysis for the region. Wastewater can be transferred from open (evaporation) tanks to the enclosed tanks and vice versa within 8 hours as required by the Code. As a further precautionary measure, the NT EPA has provided advice that the Interest Holder be required to provide to DENR ongoing weather forecasts for early onset of wet weather for the duration of the regulated activity during the wet season.

As outlined above, the lease pad will be surrounded by a bund of sufficient volume to contain and prevent potential release of contaminants from the lease pad in the event of a major spill. The drill cutting and drilling mud sump is lined with a composite, 5-layer impermeable barrier that will meet the standards specified in the Code. The drill cuttings sump has a useable volume in excess of 2,400 m^3 and will be operated with a minimum 1,300 mm freeboard to manage extreme rainfall events. The estimated volume of drilling mud and cuttings that will be generated by the activity is 750 m^3.

The NT EPA has provided advice relating to reporting and clean-up requirements of any impacted soil in the event of an accidental release (spill or leak) of flowback fluid or wastewater that exceeds 200 L.

3.6 Potential for upward migration of brine to surface aquifers

The NT EPA notes that issues of well integrity have been dealt with in the NT EPA Statement of Reason and NT EPA Advice to the Minister for previously approved EMPs, including the potential

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16 The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.

17 The shorthand for this is 0.1% 90-day AEP.

impact to the integrity of wells over the long term in high salinity formations that overlay the Velkerri shale in the Beetaloo Sub-basin.

As discussed in previous EMP assessments, increasing salinity with depth is a general feature of all sedimentary basins including the Beetaloo Sub-basin. In conventional petroleum reservoirs a salt "top seal" is a common feature of the stratigraphic trap that causes hydrocarbons to accumulate. This risk is therefore not unique to unconventional (e.g. shale) petroleum exploration and production. The concern raised is that over time, a failure in well integrity due to corrosion by salinity and/or bacteria may lead to upward migration of deeper saline water and other constituents into the shallower Gum Ridge Aquifer. A review by the US EPA (2016) into hydraulic fracturing operations found that multiple barriers, such as well casing and cement sheaths can block the subsurface movement of well fluids into the surrounding environment.[18] Further, that there was no evidence to suggest that these barriers failed.

The risk of contamination of surface water aquifers due failure in well integrity at Velkerri is low for the following reasons:

- In sedimentary basin hydrogeology, the necessary requirement for upward flow from any formation is an upward head gradient. In order for upward flow to occur, the head gradient existing in the formation must also be large enough to overcome density gradients associated with increasing salinity with depth. These upward head gradients would need to be sustained over thick sequences (in this case >1,000 m) of highly permeable bedrock to drive a significant amount of brine into shallow fresh groundwater, such as the Gum Ridge Aquifer.
- The target zones in the Velkerri formation for hydraulic fracturing consist of clay rich, organically lean layers containing gas, which act as an impermeable aquitard[19] to fluid migration. They also provide effective barriers to vertical fracture growth during hydraulic fracturing operations. The Hayfield Mudstone and Kyalla formation overlying the Moroak Sandstone, are notable thick aquitards in this region. As a result, any potential for upward migration of hydraulic fracturing fluid and brine is largely controlled by pre-existing hydraulic gradients (non-existent in the Moroak) and overlying bedrock permeability, which in the case of formations above the Moroak including the Kyalla formation is extremely low due to the effects of very fine grain-size distribution, effective stress, cementation, and partial saturation.
- The Moroak Sandstone has been tested on opposite sides of the basin in which Origin is exploring, at the Amungee NW-1, Elliott-1 and Ronald-1 well bores. Inflow testing at Amungee NW-1, Elliott-1 and Ronald-1 well bores indicated no pressure in the reservoir (i.e. no hydraulic head).

3.7 Stakeholder engagement

The EMP provides detail on the stakeholder engagement process undertaken to date, including ongoing engagement strategies (Appendices I – M). The EMP sets out stakeholder engagement summarising the method of contact and matters raised during consultation with land owners in the vicinity of the regulated activity. Stakeholder engagement has been undertaken in accordance with:

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[18] US EPA (2016). *Review of Well Operator Files for Hydraulically Fractured Oil and Gas Production Wells: Hydraulic Fracturing Operations*. https://www.epa.gov/sites/production/files/2016-07/documents/wfr2_final_07-28-16_508.pdf.

[19] Permeability is the ability of a rock to transmit fluids. Aquitards are low permeability rock formations. The grain-size distribution is the dominant control on permeability; however, other factors are also important at depth, including effective stress, partial saturation, and cementation, often reducing permeability by orders of magnitude. Overall, the preponderance of fine-grained rocks (i.e., shale, siltstone, and mudstone) and the layered structure of sedimentary basins will constrain the vertical permeability of bedrock above black shales toward the low end of measured values. Low permeability layers at depth in sedimentary basins are common, due to the effects of effective stress, cementation, and partial saturation.

a) Regulation 7 of the Petroleum (Environment) Regulations 2016, during the preparation of an EMP, which outlines the minimum requirements that an Interest Holder must meet when undertaking stakeholder engagement.

b) Regulation 9 of the Petroleum (Environment) Regulations 2016, which requires the EMP to include an Authority Certificate in accordance with section 3 of the *Northern Territory Aboriginal Sacred Sites Act 1984*. Engagement with traditional owners is co-ordinated through the NLC.

The relevant stakeholder groups were identified and informed of the proposed activities and the associated risks and to help build an understanding of petroleum exploration in the Beetaloo. This included face-to-face briefing sessions with key stakeholders one-on-one and at local community events. Key relevant stakeholder groups include community, landholders, traditional owners and Aboriginal peoples, and the NT Government agencies. Appendices J – L detail the information that has been provided to key stakeholders, including the type of information and date of engagement. The EMP provides detail on the management process for complaint resolution and commits to ongoing stakeholder engagement throughout 2019 and 2020. Concerns were raised in some public submissions regarding perceived lack of stakeholder engagement; these concerns are adequately addressed in the EMP.

The NT EPA notes that stakeholder engagement is a matter for the Minister to consider in deciding whether to approve the EMP.

3.8 Regulation and compliance

The NT EPA notes there have been a number of regulatory reform recommendations implemented following the *Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory, 2018.* This includes the separate responsibility for approval of EMPs and environmental regulation now with the Minister for Environment and Natural Resources.

Amendments were made to the *Water Act 1992* so that petroleum activities require water extraction licences under the Act, to safeguard water and the environment. All bores used for the regulated activities must be metered and reported. Other regulatory reforms are ongoing. The Code has been finalised and is available on the DENR website. Experts, industry and the community were engaged in developing the Code. The NT EPA notes that the mandatory requirements of the Code have been applied to this regulated activated activity, demonstrating environmental impacts and risks are reduced to a level that is ALARP and acceptable.

The Well Operations Management Plan (WOMP) is a specialised engineering management plan that has been prepared and submitted for approval by well engineers of DPIR. Key elements of the WOMP to ensure ongoing environmental protection of aquifers during and following hydraulic fracturing operations are included in the EMP and are summarised in Appendix T.

<u>ESD principles</u>

The NT EPA's assessment of this EMP, its potential impacts (positive and negative) and the management measures used to enhance positive and reduce negative impacts has considered the ESD principles. Exploration activities are necessary to enable commercial appraisal of resources. In the absence of reliable data regarding the shale resource, exploration will take a number of years to complete, in order to assess the viability of the resource prior to production. Ongoing design, development and implementation of management and monitoring programs by the Interest Holder, should all aim to meet the objectives of ESD.

4. Environmental impacts and risks reduced to a level that is as low as reasonably practicable (ALARP) and acceptable (regulation 9(1)(c))

The Interest Holder has undertaken a process to avoid impacts on environmental values, informed by appropriate baseline studies and surveys. The timing of works will be managed to ensure the risks arising from inclement wet weather and severe bushfire periods, including compliance with the Code, as a means of demonstrating environmental impacts and risks are reduced to a level

that is ALARP. The fire management plan included in the EMP provides adequate mitigation and management measures to reduce the risk of bushfires occurring as a result of the regulated activity. These measures are ongoing in relation to the EPT, which may continue for up to one year. An Emergency Response Plan and Spill Management Plan will be implemented – both plans include responses to significant rainfall events. Evacuation and site readiness protocols are incorporated in standard operating procedures, including the evacuation of non-essential personnel. In the event of anomalous conditions (e.g. force majeure), the petroleum well can be immediately shut-in and safely secured and flow back and EPT halted for as long as required.

The EMP demonstrates a systematic identification and assessment of environmental impacts and risks associated with the regulated activity. The key potential environmental impacts and risks are:

- surface and groundwater quality - a reduction in surface and groundwater quality due to chemical spills or waste water releases during hydraulic fracturing and well testing activities
- groundwater quality - a reduction in groundwater quality may occur as a result of failure in well integrity during hydraulic fracturing activities
- groundwater quantity – a reduction in groundwater quantity due to groundwater extraction associated with the activities
- terrestrial environmental quality – localised contamination of soil due to release of wastewater

Mitigation measures for the management of wastewater are discussed under Section 3 above. The EMP demonstrates compliance with the Code and the potential impacts and risks to surface water quality from flowback fluids have been reduced to a level that is ALARP and acceptable.

4.1 Well integrity

The risks of well integrity failure in hydraulic fracturing operations are well understood and the Interest Holder has extensive experience in hydraulic fracturing in other jurisdictions. All required control measures for ensuring well integrity and aquifer isolation during hydraulic fracturing have been adopted. As an additional and precautionary measure during this early stage of exploration in the Beetaloo sub-basin, the Interest Holder will also implement passive seismic monitoring to provide real-time information regarding unlikely anomalous seismicity, above background baseline values, during hydraulic fracturing operations in compliance with traffic-light system for induced seismicity. Operations will cease if specified exceedance values established from baseline monitoring occur. The Interest Holder has identified and addressed the potential impacts and risks to other groundwater users.

For aquifers intersected by the well, there should be ‘no change’ to existing baseline groundwater quality, i.e. no change in the natural range of values as a result of the regulated activity. As discussed in section 1.10, the Interest Holder will be required to demonstrate ‘no change’ to existing groundwater quality at the Velkerri well site through a three year monitoring program.

Compliance with the ongoing groundwater monitoring at the well site, undertaken in accordance with the Code and Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin, must be submitted to the DENR every quarter for three years from the approval date of the EMP. The information provides important scientific information regarding spatial and temporal trends in 40 key water quality analytes, including metals, hydrocarbons and naturally occurring radionuclide materials (NORM) in the Cambrian Limestone Aquifer for the well site location. This is published on the DENR website. Impact monitoring bores situated 20 m down-gradient (downstream) of the petroleum wells will enable rapid detection of any anomalous water quality trends above established background values at the well sites. Water level monitoring data trends at both sites, as previously discussed, has been static. Any anomalous drawdown in water levels will also be detected.

The results of the groundwater monitoring will be published on the DENR website on a quarterly basis. The groundwater monitoring program includes ongoing groundwater level reporting at the well site.

4.2 Terrestrial environmental quality

The potential impacts and risks of contamination of soil, through inappropriate storage and handling of chemicals and wastewater has been identified by the Interest Holder. The EMP includes mitigation measures such as lease pad compaction to a predicted permeability of less than 1×10^{-7} m/s, bunding, use of spill mats /spill trays under drilling and hydraulic fracturing equipment, spill containment of chemicals and wastewater, and the implementation of the Wastewater Management Plan, Spill Management Plan and Emergency Response Plan, in accordance with the Code. The Interest Holder has not deviated from known industry codes and standards. The EMP documents how the Interest Holder will comply with the relevant mandatory requirements of the Code as a minimum best practice standard.

Drilling muds and cuttings will be dried out prior the wet season, and tested and analysed prior to disposal in accordance with the Table 10 of the Code. A suitably qualified third party will be engaged to determine whether the material can be disposed of on site. In the event that onsite disposal is appropriate, the Interest Holder will consult with DENR prior to disposal.

The NT EPA considers that all reasonably practicable measures will be used to control the environmental impacts and risks, considering the level of consequence and the resources needed to mitigate them. The NT EPA considers that the environmental impacts and risks will be reduced to an acceptable level, considering the principles of ecologically sustainable development as discussed above, the sensitivity of the local environment, relevant standards and compliance with the Code.

5. Other relevant matters

Schedule 1, clause 1 of the Regulations requires that an EMP provides a comprehensive description of the regulated activity, including provision of a proposed timetable for the activity. To meet this requirement, the NT EPA recommends that the Interest Holder be required to submit a detailed monthly timetable for the regulated activity to DENR. The timetable should address all aspects of the activity and include, but not be limited to dates for the implementation of commitments, the development of key documents (e.g. final rehabilitation strategy for the site) and associated hold points. The NT EPA recommends that the timetable be updated each month or as seasonal weather forecasts emerge.

CONCLUSION

The NT EPA has reviewed the public submissions as part of its decision-making and when making recommendations to the Minister. This NT EPA advice to the Minister for Environment and Natural Resources considers and provides a response to any relevant matters raised in public submissions.

The NT EPA considers that, subject to the recommended EMP approval conditions, the EMP:

- is appropriate for the nature and scale of the regulated activity
- demonstrates that the regulated activity can be carried out in a manner that potential environmental impacts and environmental risks of the activity will be reduced to a level that is as low as reasonably practicable and acceptable.

In providing this advice the NT EPA has considered the principles of ecologically sustainable development. The NT EPA has also taken into consideration that prior to commencing well activities (including drilling), a WOMP will be prepared by the Interest Holder and approved by the DPIR.

RECOMMENDATION

The NT EPA recommends that should the EMP for Origin Energy B2 Pty Ltd be approved, the following conditions be considered:

***Condition 1*:** The Interest Holder must submit to the DENR, an updated, monthly timetable for the regulated activity. The timetable must include dates for the implementation of commitments, the development of key documents (e.g. final rehabilitation strategy for the site) and associated hold points.

Condition 2: In addition to the minimum methane leak detection inspection frequencies required by the Code, the Interest Holder must undertake methane leak detection within seven (7) days of commissioning equipment that is in hydrocarbon service and under pressure and record to an auditable standard.

Condition 3: The Interest Holder must provide to DENR an analysis of offsite disposal and beneficial use options, other than flaring, for liquid hydrocarbons if the combustion of liquid hydrocarbons at the flare exceeds an average of 5,000 litres per day during the first month or in any of the following months of flaring.

Condition 4: In the event of any accidental release (overflow, failure, spill or leak), to ground of flowback fluid wastewater that exceeds 200 litres, the Interest Holder must provide a written report to DENR within 24 hours after the incident was detected.[20] The report must include:

i. details of the incident specifying material facts, actions taken to avoid or mitigate environmental harm;
ii. the corrective actions taken including the volume and depth of impacted soil removed for appropriate disposal if required; and
iii. any corrective actions proposed to be taken to prevent recurrence of an incident of a similar nature.

[20] Note this requirement applies in addition to the obligations of any relevant requirements of Part 3, Division 1 of the Petroleum (Environment) regulations 2016.

Condition 5: The Interest Holder must provide to DENR a fortnightly weather forecast for risk of onset of wet weather for the duration of the regulated activity.

Condition 6: The Interest Holder must provide to DENR a cementing report for the surface casing (13 3/8") through the aquifers, as soon as practicable but not more than fourteen (14) days after completion of the cementing job for the Velkerri exploration well EP76 S2-1.

DR PAUL VOGEL AM MAICD

CHAIRPERSON

NORTHERN TERRITORY ENVIRONMENT PROTECTION AUTHORITY

18 DECEMBER 2019