Northern Land Council Submission to Northern Territory Government Hydraulic Fracturing Inquiry

June 2014

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Hydraulic Fracturing Inquiry 30 June 2014

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1. About the Northern Land Council

The Northern Land Council (NLC) was established in 1973. Following the enactment of the *Aboriginal Land Rights (Northern Territory) Act* (the Land Rights Act), it became an independent statutory authority responsible for assisting Aboriginal people in the northern region of the Northern Territory to acquire and manage their traditional lands and seas.

The Land Rights Act combines concepts of traditional Aboriginal law and Australian property law. It creates a three way relationship between traditional Aboriginal owners, Land Trusts and Land Councils. The Land Rights Act requires the Land Councils to consult with traditional Aboriginal owners (and other Aboriginal people affected by proposals) before giving a direction to an Aboriginal Land Trust to enter into any agreement or take any action concerning Aboriginal land. Under the Land Rights Act, traditional owners must give their informed consent, as a group, to each proposal. Some of the most important functions of Land Councils include:

- Determining and expressing the wishes of Aboriginal people about the management of, and legislation in relation to, their land; and
- Negotiating on behalf of traditional owners with parties interested in using Aboriginal land or land the subject of a land claim.

The NLC has statutory responsibility for facilitating economic activity over more than 210,000 km^2 of the land mass of the Northern Territory, and over 80% of the coastline.

In 1994, the NLC became a Native Title Representative Body under the *Native Title Act 1993* (the Native Title Act). In this capacity, the NLC also represents the Aboriginal people of the Tiwi Islands and Groote Eylandt. The NLC's role and functions as a Native Title Representative Body are set out under Part 11, Division 3 of the Native Title Act.

The NLC assists the Aboriginal people of its region by providing services in its key output areas of land management, land acquisition, mining, land trust administration, native title services and advocacy, information and policy advice.

The vision of the NLC is a Territory in which the land rights of every traditional owner are legally recognised and in which Aboriginal people benefit economically and culturally from the secure possession of their lands and seas.

2. Executive Summary

Northern Land Council (NLC) is pleased to provide a submission in response to the NT Government's 2014 Inquiry into Hydraulic Fracturing. The NLC believes that a properly regulated extractive industry, based on worlds' best practice, is consistent with the 'sustainable livelihoods' approach first proposed by Aboriginal Peak Organisations NT (APONT) in 2011. APONT described the key qualities of a Sustainable Livelihoods Approach as:

- Empowerment of the disadvantaged individual or community to determine their own livelihood pathways;
- Long term and flexible programming;
- Responsive and participatory planning and implementation;
- Activity-focussed partnerships between disadvantaged people, their organisations, the public sector, the non-government sector and the private sector;
- Disaggregated strategies that address identifiable sub-groups (women, youth, the disabled); and
- Outcome-based monitoring and evaluation.

In considering the scope of this submission, it should be noted that the NLC makes the following submission on behalf of our Aboriginal constituents. As an organisation, it is not the role of the NLC to hold a subjective opinion on the merits (or otherwise) of hydraulic fracturing, and NLC seeks only to facilitate well informed decision making on proposals to develop petroleum projects on Aboriginal land and lands subject to the Native Title Act.

This submission provides information on the relevance of the Hydraulic Fracturing Inquiry to the NLC and NLC's constituents, addresses the Terms of Reference (TOR) generally, and goes on to provide information related to each of the TOR in turn. Attachment 1 lists the recommendations provided in and supported by the body of this submission. As well as being listed in their entirety, recommendations are inserted throughout the text of this submission where relevant.

3. Northern Land Council Interest

Approximately fifty percent (50%) of land in the Northern Territory (NT), and eighty percent (80%) of the coastline, is Aboriginal Land subject to the Land Rights Act. Dealings or works on Aboriginal land are governed by the Land Rights Act, which mandates processes in relation to the grant and conduct of any exploration or mining projects. Figure 1 illustrates the NLC region with respect to petroleum permits and permit applications. Importantly, the Land Rights Act provides that no exploration licence or exploration permit may be granted on Aboriginal land without the consent of traditional Aboriginal owners of that land, and that prior to any exploration licence or permit being granted on Aboriginal land an exploration agreement must be reached between the proponent and the relevant Land Council.

Pastoral leases cover the vast majority of land in the Northern Territory that is not Aboriginal land. The NLC represents and assists native title claimants and native title holders who hold native title interests over nearly all such land in the top end. The Native Title Act provides mechanisms, most commonly referred to as the 'Right to Negotiate', for native title parties and proponents to engage in substantive negotiations when the grant of a petroleum exploration permit is proposed on such land. Figure 2 illustrates the extent of Indigenous land interests in the NT and the relationship between Aboriginal land interests and regions prospective for petroleum and thus potentially subject to hydraulic fracturing.

The exploration and negotiation procedures under both the Native Title Act and the Land Rights Act have led to the NLC and relevant traditional owners or native title holders entering into a large number of agreements governing the conduct of petroleum exploration (the 'Exploration Agreements') in the top end. At the time of writing, the NLC is a party to Exploration Agreements governing 28 exploration permits, including two exploration permit applications on lands subject to the Land Rights Act . The vast majority of the land in our region remains under application for petroleum exploration. These applications will be processed by the NLC in accordance with the Native Title Act or Land Rights Act procedures in the coming years.

The Northern Land Council and traditional owners across our region are therefore increasingly familiar with oil and gas exploration, including the potential for large-scale unconventional exploration programs facilitated by the use of hydraulic fracturing techniques. Our comments are based on our experience from facilitating oil and gas exploration work programs throughout our region in accordance with our Exploration Agreements, and on industry specific research undertaken by NLC staff to inform our constituents throughout consultative processes. Our comments and recommendations aim to raise concerns and issues highlighted by traditional owners of the areas under permit.

Recommendation 1.1

The NLC believe that extractive activity on Aboriginal Land and where Native Title exists should be conducted with the free, prior and informed consent of Traditional Owners, consistent with the United Nations Declaration on the Rights of Indigenous People

In order to facilitate the dissemination of information on impacts and risks associated with hydraulic fracturing to Indigenous stakeholders and to enable NLC to properly administer free, prior and informed consideration of petroleum proposals, it is recommended that the following information is provided to the NLC in respect of petroleum developments on lands subject to the Native Title Act and to the Land Rights Act:

- *The total number of hydraulic fracturing events projected annually;*
- *The rate of growth in the number of hydraulic fracturing events projected annually;*
- *The anticipated density of wells and platforms, especially in relation to proximity to water sources and environmentally/culturally sensitive areas;*
- *The proposed minimum acceptable distance between wells;*
- *The projected longevity of each well or platform;*
- *How individual companies, the industry, and industry regulators will manage the sequential abandonment and drilling of new wells to that environmental risk remains well managed and mitigated, and*
- *The chemicals used in well drilling and reservior stimulation, and independent assessment of the risk such use of these chemicals may pose to environmental resources and human health. Such information should be provided prior to the use of these chemicals and for the specific purpose of consultations with affected peoples.*

Justification for NLC's interest in this specific information is provided throughout the following submission.

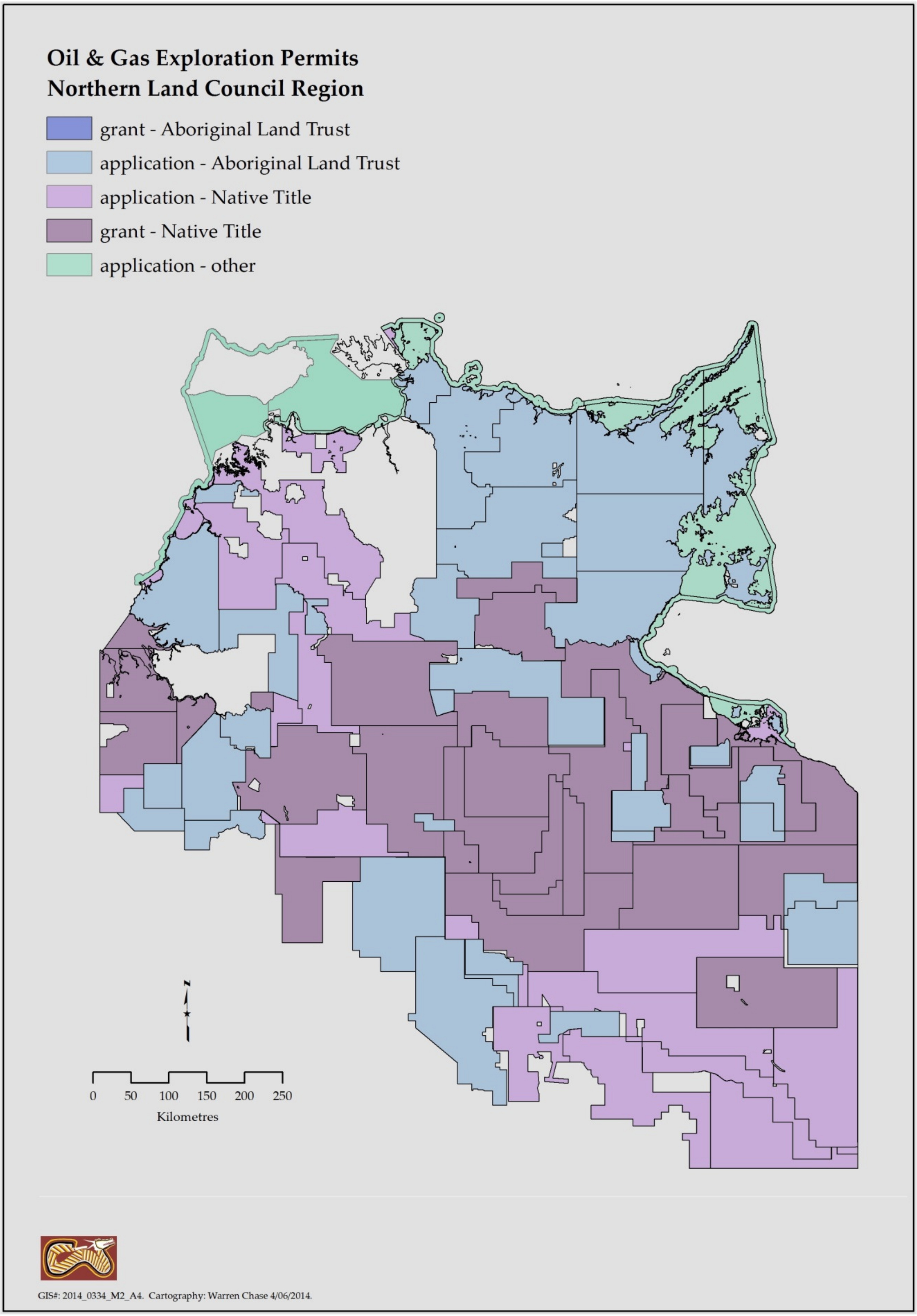


Figure 1: Map showing oil and gas exploration permits in the NLC region (Chase. W 2014)

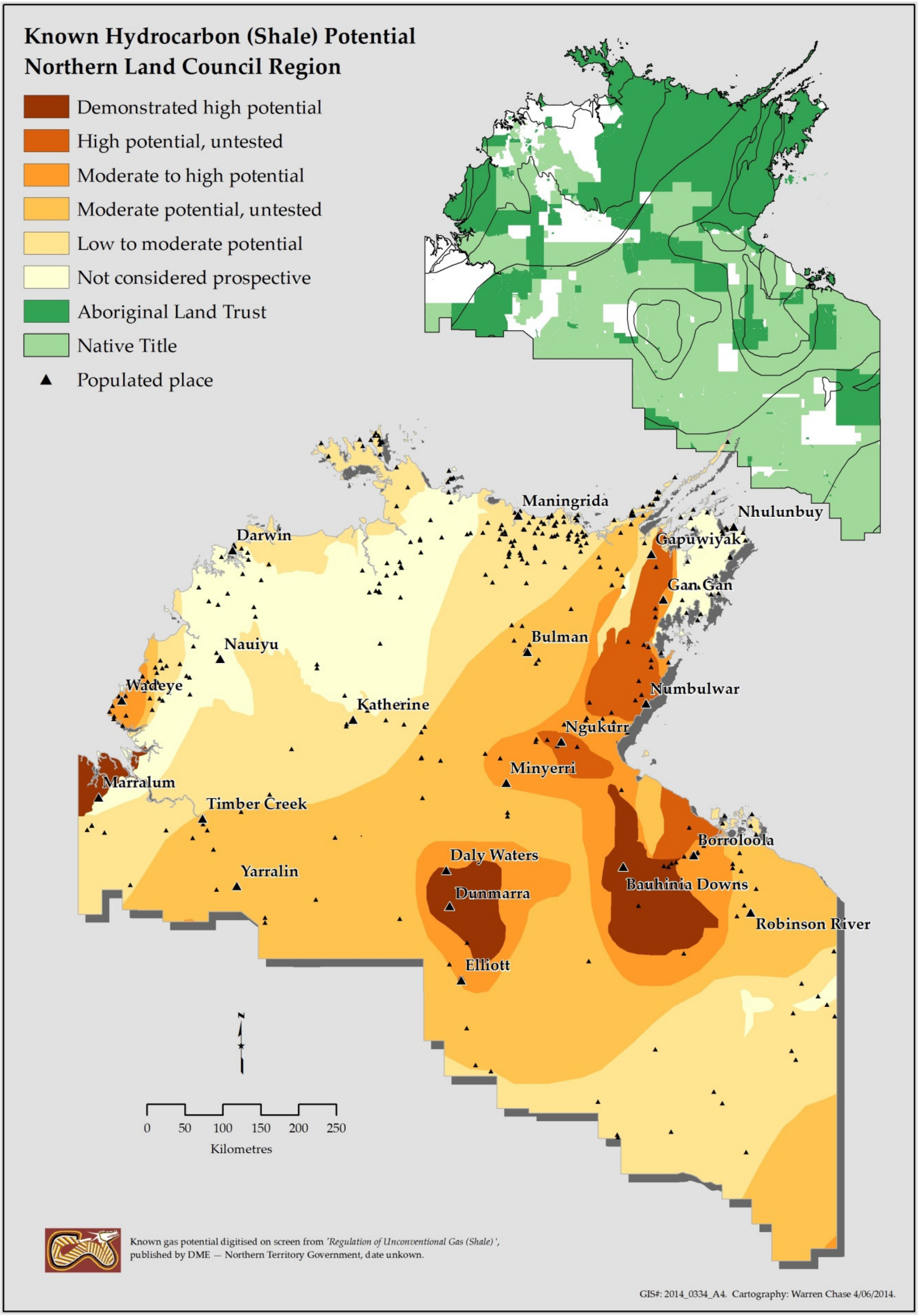


Figure 2: Map showing know hydrocarbon shale potential in the NLC region (Chase. W 2014)

Notwithstanding the specific points and recommendations raised in this submission, the Northern Land Council also support the following key recommendations of the ACOLA report (Cook et al, 2013);

"Collaboration between the states (and Territories) and Commonwealth is vital to developing a transparent and consistent regulatory framework for shale gas. Components of the framework include:

- *Developing guidelines on storage, reuse and disposal of fracking fluids across Australia. The goal being to reduce, reuse and recycle produced water where possible.*
- *Modifying existing CSG regulations where appropriate, or adopt best practice guidelines for the handling of produced water from other countries.*
- *Developing setback rules (minimum distance to other users) to protect other groundwater users (including groundwater dependent ecosystems) and surface water resources.*
- *Developing minimum values for vertical and horizontal separation of shale gas resources from potable aquifers based on best practice.*
- *Considering the banning chemicals that pose a risk to public health or the environment.*
- *Including the volume of water used for fracking within calculation of sustainable limits.*
- *Make transparent documentation and communication to the public and to regulatory agencies a priority.*

Communication, transparency and meeting community expectation will help to build community consent to operate. Suggested activities include:

- *Publicising action protocols and risk reduction plan in the event groundwater contamination is detected.*
- *Disclosing the makeup of fracking fluid via a fracking chemical database.*
- *Adding nontoxic environmental tracers to fracking fluid help to make cases of potential contamination more evident.*

4. Responses to the Terms Of Reference

The following section makes statements about the limitations of the Terms of Reference (TOR) and then goes on to address each of the TOR in turn. Not all of the TOR are given equal consideration in this submission as NLC chose to focus on issues we believe are of most significance to the interests of our constituents. The TOR are included and shaded grey to distinguish them from the submission's text and to aid readability as a singular document.

Matters not adequately considered in the Terms of Reference

To enable the provision of comment relevant to the TOR without limiting our capacity to advocate in the best interests of our constituents, NLC submits the following points on the limitations of the TOR provided the Commissioner for the purpose of this inquiry:

- The technique of hydraulic fracturing makes it possible to extract petroleum resources in the NT that would otherwise be inaccessible or uneconomic; the expansion of the industry would not occur at the same rate in the Northern Territory were hydraulic fracturing not used. Therefore it could be argued that any distinction between the rapid expansion of the petroleum industry in the NT and hydraulic fracturing as a technique to extract the resource is unnecessarily restrictive.
- It is not clear in the TOR whether the Inquiry will consider high-pressure horizontal drilling operations or both horizontal and vertical hydraulic fracturing operations. NLC understands that vertical fracturing has been commonplace in parts of the NT over the past two decades. More recently public interest has arisen in relation to hydraulic fracturing and may be a result of proposals that are likely to include horizontal fracturing, not simply to extend the life of existing wells, but as part of standard operations designed to access petroleum resources and improve well efficiency and profitability.
- There is no provision for detailed consideration of the probability and risk of low level radioactive contamination at the surface through transport and discharge of naturally occurring radioactive materials following flow-back of hydraulic fracturing fluids and waters from wells.
- Mechanisms to disseminate information about hydraulic fracturing and the outcomes of this inquiry to all residents of the Northern Territory are not discussed in the TOR. Many Aboriginal people do not have access to modern communications equipment or

have English as a second, third or fourth language. Failure to disseminate information arising from this inquiry in an appropriate manner will inhibit the NLC's capacity to facilitate free, prior and informed consideration of project proposals – which is a cornerstone of negotiation of Agreements with Aboriginal people under the Native Title Act and Land Rights Act.

Recommendation 1.2

The Commissioner should recommend specific pathways for the dissemination of information arising from the Inquiry.

In generating recommendations as a result of this inquiry the Commissioner may be mindful of the limitations listed above. Furthermore, recommendations may seek to address some of these limitations.

The Inquiry's stated objective is to investigate;

Hydraulic fracturing for hydrocarbon deposits in the Territory, including the assessment of the environmental risks and actual environmental impacts of hydraulic fracturing and the effectiveness of mitigation measures, and more particularly the matters mentioned in [clauses 1-7].

4.1 Historical and proposed use of hydraulic fracturing in the NT

1. Historical and proposed use of hydraulic fracturing (exploration, appraisal and production) of hydrocarbon deposits in the Northern Territory (number of wells; locations; timeline).

The NLC region is almost entirely covered by either petroleum Exploration Permit (EP) applications or granted EPs. As described in section 2 the NLC facilitates the granting of these EP tenements via either Land Rights Act or the Native Title Act. The NLC region is characterised by relatively pristine or near pristine natural environments with many population centres that are largely inhabited by Aboriginal people outside the metropolises of Darwin, Katherine and Nhulunbuy. Without conducting hydraulic fracturing it is widely accepted that it would not be economically viable to develop many of the hydrocarbon deposits present in the NLC region. Therefore the proposed use of hydraulic fracturing is likely to facilitate and expedite a range of environmental impacts such as:

a. Habitat fragmentation
b. Groundwater extraction
c. Pollution
d. Deterioration of cultural values
e. Social disruption
f. Increase in vehicular traffic
g. Economic
h. Altered fire regimes – and resultant impacts on habitat types and the life history of individual species and specifically of threatened, keystone and other vulnerable species.
i. Other potential impacts

Recommendations 2.1 and 2.2

It is recommended that the Commissioner provide the NT Government with specific and public advice on how to improve consideration of the cumulative and bioregional impacts of hydraulic fracturing into the Environmental Impact Statement (EIS) assessment process.

The outcomes of the Inquiry should be used to develop relevant and practical regulatory measures and standards that represent leading practice. This should include specific measures that become mandatory considerations in an Environmental Impact Assessment regime. Such a regime should include triggers for assessment not only of individual projects, but also at a landscape scale to enable analysis of cumulative impacts where petroleum development is proposed and enabled by the technique of hydraulic fracturing.

4.2 Environmental outcomes of hydraulic fracturing activity

2. Environmental outcomes of each hydraulic fracturing activity for hydrocarbon resources in the Northern Territory (number of wells; frequency of types of known environmental impacts).

Whilst this inquiry will assess the environmental outcomes of each hydraulic fracturing activity for hydrocarbon resources, and there are risks attendant to each, it is the cumulative environmental impacts that are of key concern to the NLC and which are likely to have a greater impact on the landscape at a bioregional scale, rather than the impacts of individual hydraulic fracturing activities to date.

Further information of relevance to this section is provided throughout Section 4.7.

4.3 Environmental impacts from hydraulic fracturing in the NT and globally

3. Frequency of types and causes of environmental impacts from hydraulic fracturing for hydrocarbon deposits in the Northern Territory and for similar deposits in other parts of the world.

Detailed studies have been conducted elsewhere in the world, but these studies do not analyse environments equivalent to those present within the NLC region (specifically our unique ecological and cultural landscapes). Australian examples primarily relate to coal seam gas projects, or in the case of shale hydrocarbon deposits, are from relatively unpopulated regions with natural environments quite different to those present in the NLC region (such as from the Cooper basin in South Australia).

It could be argued that there are no recorded cases of detrimental environmental impacts from hydraulic fracturing in the NT because it is a relatively new technique in the NT, and because the impacts that can occur (such as groundwater contamination) may not show up for many years following the cessation of hydraulic fracturing operations.

Whilst it is often suggested that groundwater contamination is more often associated with coal seam gas developments, Osborn et al. (2011) finds that groundwater contamination was caused by hydraulic fracturing of shale in Pennsylvania, USA. Osborn et al. (2011) found that near 75% of wells sampled within 1 kilometre of gas drilling in the Marcellus shale in Pennsylvania were contaminated with methane from the deep shale formations. Isotopic fingerprinting of the methane indicated that the deep shale was the source of contaminations, rather than biologically derived methane.

It is also relevant to note that well stimulation is not the only potential cause of groundwater contamination resulting from hydraulic fracturing operations. In a recent Australian case, groundwater was found to be contaminated due to leakage from a surface coal seam gas wastewater storage pond in northern NSW at the Bibblewindi Water Treatment Plant in the Pilliga. Routine groundwater sampling revealed elevated levels of naturally occurring elements including arsenic, lead, and uranium. Storage of wastewater will be an on-going management issue in the monsoonal environments of the NT. Large seasonal rainfalls and surface water flows increase the risks of contamination as a result of wastewater containment failures. Containment of contaminated or saline water in lined surface containment dams can carry increased levels of risk in tropical environments. Two well-known examples of water contamination associated with large seasonal surface flows in the NT are Ranger Mine and Mount Todd Gold Mine.

Interconnectivity of groundwater and surface water environments

It is not uncommon in the NT for the groundwater and surface water environments to exhibit high levels of interconnectivity. The groundwater-fed surface water systems of the NT are an important feature of the natural and cultural landscape (eg. Berry Springs, Mataranka Springs, and innumerable other sites scattered across the Territory). These springs form pockets of monsoonal rainforest and other unique biotic assemblages and are at times sites of cultural significance. This interconnectedness means that if groundwater is contaminated, then surface water and associated springs and ecosystems may also become contaminated.

Environmental fragmentation in the NLC region

The layout of platforms across the landscape may create a ‘patchwork’ of cleared areas, leading to fragmentation of local environments. Fragmentation not only poses a risk to the abundance and diversity of species, but will also have a flow-on cultural effect to Indigenous populations whose wellbeing stems from natural resource based spirituality and culture. Damage to key water systems or other parts of the environment will have impacts that extend well beyond the immediate area of work and may cause detriment to sacred sites and culturally and environmentally sensitive areas. Fragmentation has a spiritual dimension: In Indigenous traditions, many sites of significance are not isolated entities but are connected by ‘dreaming tracks’ that connect other Traditional Owner groups whose country may be separated by hundreds of kilometres. Thus the inability to visit a site of significance or a break in the chain connecting sites of the same tradition may cause significant distress to the wider Indigenous population.

Recommendation 5.1.

- *Traditional owners and Land Councils should have opportunity to provide input into well placement so as not to diminish traditional owners access to land for purposes of hunting, fishing and for recreational and spiritual purposes.*

4.4 Multiple well pads and environmental risk

4. The potential for multiple well pads to reduce or enhance the risks of environmental impacts.

Each well carries environmental impacts and presents a level of environmental risk. Environmental impacts will increase in proportion to the number of well platforms developed and some risks may increase in proportion the number of hydraulic fracturing events undertaken. In this sense, multiple wells (or developments proposing higher densities of well pads) represent increased likelihood and intensity of environmental impacts and risks. Should petroleum development progress, the question then becomes: What density of wells constitutes an unacceptable level of impact and risk, or a level that should trigger enhanced consideration and regulation?

In order to extract shale hydrocarbon resources significant ancillary infrastructure will be required such as access roads, processing plants, pipelines, export terminals, waste storage facilities, worker accommodation camps etc. Notwithstanding potential economic and other benefits to traditional owners of the roll out of such infrastructure, in relatively undisturbed landscapes (such as those within the NLC region) such infrastructure is likely to be a primary cause of habitat fragmentation and other environmental impacts. The application of particular technologies including hydraulic fracturing and multi-well platforms may reduce the number of wells required on a project, thus these technologies have the potential to reduce fragmentation of habitat associated with the exploitation of a deposit.

Water use should be a key environmental consideration in petroleum projects, and it may be argued that the application of hydraulic fracturing can increase the amount of water required to extract hydrocarbon resources. The discussion below expands on the issue of habitat fragmentation in particular; it is noted that while omitted here, equal and due consideration should be provided to the impacts and risks to water resources presented by multiple well pads.

Habitat fragmentation

According to Riiters et al. (2000) analysis of fragmentation is best done at landscape scale. Data obtained at 1km resolution suggests that fragmentation starts to become a major concern where forests are clumped into discrete areas occupying less than about $0.6km^2$ and separated by long corridors. At this point edge effects begin to dominate and impacts (including those on individual species) begin to be seen at lower scale. This suggests that a reduction in ground cover of less than 5% due to placement of well infrastructure will pose a low risk of environmental fragmentation. However, this is not a set value, as other variables, including presence of endemic species and physical qualities of the landscape (for example, susceptibility to erosion and soil nutrient capacity) must also be considered because these will impact on the landscape's ability to recover and maintain contiguity.

In the face of a rapidly advancing shale oil and gas industry, a number of land management studies and approaches have been applied directly to the question of what effect the industry has had on landscape contiguity. For example, Schneider et al. (2003) modelled cumulative impacts of land uses (including the oil and gas industry) in the Western Canadian Sedimentary Basin; Braun and Hanus (2005) examined the cumulative effects of logging and oil and gas activities on fragmentation of Alberta's forests; and Sloneker et al. (2012) have reviewed landscape impacts in Pennsylvania.

Three important and consistent conclusions were drawn from these works. First, a shift from old growth to new growth species can be expected; second, a decrease in species dependent on continuous habitats in favour of different species confined to smaller, fragmented areas will occur; and third, the number of exotic species will increase at the expense of natives. Although there is a cumulative fragmentation effect coming from many anthropogenic activities, the extreme impacts that may result from gas exploration and development activities in the NT (such as seismic exploration and infrastructure development – especially pipelines) need to be recognised.

Impact mitigation – multiple wellheads

Many companies are now implementing technologies that consist of a slowly mobile rig that can stay in "drill-ready" mode to construct multi-well platforms. Typically these rigs either move along a heavy duty, slow-moving track-conveyor system that serves as the base, or they sit on a hydraulic lift and walk system. These rigs are capable of drilling a well then moving 20 to 30 feet to drill another, thus providing a cost effective solution for drilling large numbers of wells within a short period of time. A typical layout (looking from above) of a multi-well pad is shown in Figure 3.

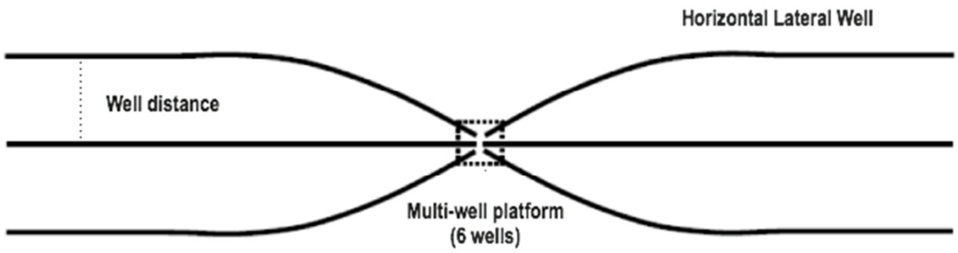


Figure 3: Typical schematic layout of a six well platform (Smith. H 2011)

The biggest advantages of multi-well pads are said to be the potential for cost reduction, shorter times to reach peak production and disturbance of smaller areas of the surface and a decrease in the risk of environmental fragmentation. Operators can drill multiple horizontal wells from a single surface location, thereby, reducing the cumulative surface impact of the operation. Co-locating wells and the centralising facilities such as storage tanks, liquid separators, and vapour recovery units requires less land disturbance, fewer roads and pipelines. The smaller footprint also reduces traffic for ongoing operations and maintenance activities.

The extent of impacts that might be encountered across a shale deposit depends upon a number of key factors including: the number of wells constructed (well density); the distance between wells or multi-well platforms (W); fracture spacing (F_s) and fracture half-length (X_f). W is generally defined by the maximum area of the resource reservoir that can be efficiently and economically drained by one well, which is equivalent to the distance between the centres of adjacent laterals; X_f is the radial distance from the wellbore to the outer tip of a fracture penetrated by the well or propagated from the well by hydraulic fracturing; and F_s is the distance between fractures (also equivalent to the distance between the perforations in the production tubing). The relationship between these variables is shown in Figures 4 and 5.

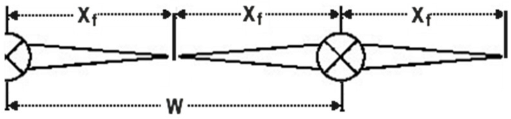


Figure 4: Fracture half-length (X_f) and well distance (W) (Smith. H 2011)

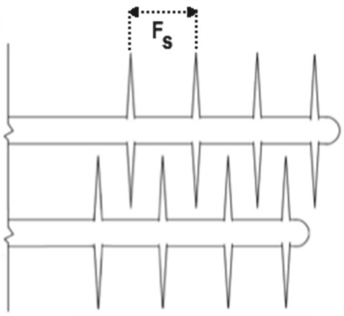


Figure 5: Fracture spacing (Fs) (Smith. H 2011)

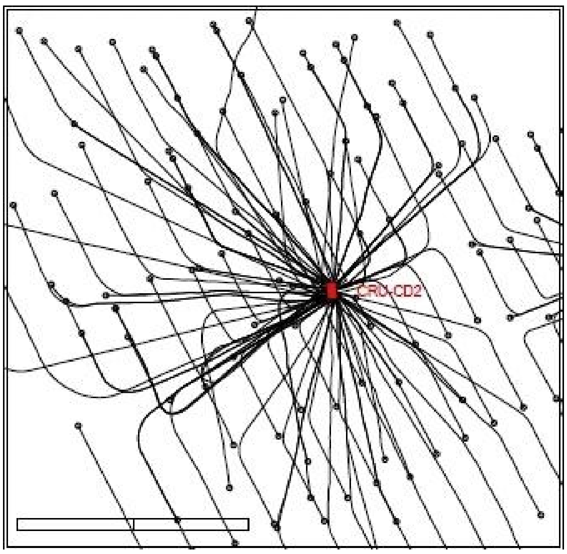
Although multi-well platforms may result in less surface disturbance compared to multiple single wells, it is the physical characteristics of the shale deposit that will ultimately define the full extent of disturbance. Porosity and permeability impact on how easily shale can be fractured and this, in turn, dictates the fracture half-length and distance horizontal laterals must be apart to ensure that interaction between fractures does not occur and well layout is optimised.

Keuengoua and Amorin (2011) and Yu and Sepehrnoori (2013) have modelled optimisation of well fields in economic terms, but to date there seems to have been little effort put into inferring the environmental impact of certain optimised parameters (e.g. average well density and distance between wells). To do this, the amount of land that needs to be disturbed to construct the well platform and its attendant infrastructure (e.g. access roads, pipes) must be calculated.

Yu and Sepehrnoori (2013) determined that the Barnett shale (which has porosity 0.06 and permeability 0.0001md) has optimal fracture half-length of 400ft (120m); optimal well distance (spacing) of 1000ft (305m) and optimal fracture spacing of 60ft (18m). Using an average horizontal well length of 1.5km, it is calculated that one well would be required for production every 46 hectares (0.46km^2) at an average well density of around 2.2 wells per km^2. The surface area of a single well pad and infrastructure is often as high as 20,000m^2, meaning that on average 4.4% of each square kilometre of the Barnett shale deposit will be cleared. Alternatively, if 6 wells were installed on a single platform, the optimal distance between platforms is around 1.65km (Cook et al. 2013), average well density is still 2.2 wells per km^2 but the percentage of disturbed area falls to <1% of each square kilometre.

The maximum number of wells that can be placed on a single site has still to be determined. Ladlee and Jacquet (2011) have identified a steady increase in both the number of multi-well pads and average number of wells per pad (from 1 to 2.15) since 2007. In some parts of Pennsylvania this cumulative statistic is now as high as 3.32 wells per pad with a maximum 12 wells having been completed on a single pad. However, there is capacity to increase these values further.

Hicks (2012) recently reported that energy company Encana completed 51 wells on a single 18,000m^2 site designed to extract gas from multiple layers below an entire canyon in Parachute, Colorado. Its construction allows the company to extract gas from an area of 2.6km^2, while disturbing <1% of the land surface and using average well density equivalent to 19.7 wells per km^2. The well pad's schematic is shown in Figure 6. One of the company's important selling points is that, with the exception of the drilling pad, the canyon will remain unfragmented.



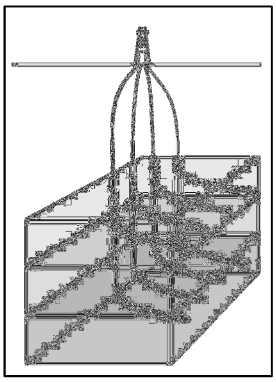


Figure 6: schematic layout of multi-well platform in Parachute, Colorado – plan view (left) and underground view (above). (Hicks. B 2012)

The case for construction of multi-well platforms over single wells appears quite well established in terms of minimising surface disturbance. However, the approach discussed here has been largely based around optimisation of production economics, rather than addressing cumulative impacts on the natural environment. It is equally important to understand what degree of clearance of the surface of a given area in a regular pattern will result in significant negative impacts in terms of habitat fragmentation and loss.

Implications for the Northern Territory

Evidence suggests that construction of multi-well platforms can reduce the risk of environmental fragmentation, but other factors that create unique environmental conditions must be considered. For example, while a 4.4% surface impact may be acceptable for a desert environment, it may not be acceptable for forests or permafrosts. This has implications for the NT, where environments tend to be harsher and drier and soils less capable of tolerating significant and long-term disturbance. The best way to determine the implications for the NT will be to provide careful consideration of local variations in a basin-by-basin approach. To demonstrate, the Beetaloo Basin will now be considered.

Ryder-Scott (2010) indicates that the Beetaloo Basin covers an area of about 35,260km^2. If its properties are similar to the Barnett shale (discussed above), a minimum of 77,000 high-pressure horizontal wells (or 12,900 multi-well platforms containing 6 wells) will be required over the full period of production. A total area between 240 km^2 (flowback20platforms) and 1550km^2 (single wells) will need to be cleared for the surface infrastructure required for hydraulic fracturing. In comparison with vertical wells, Cook et al. (2013) have indicated that if vertical wells replaced horizontal ones, the required well density would increase to an average close to 6.5 wells per km^2 and the area required for attendant infrastructure to just over 5%. Cumulative impacts, including approximately 3,000 km of seismic lines will increase the disturbed area by a further 0.2 – 0.3%. When weighed against the evidence presented, this suggests that the risk of environmental fragmentation of large areas of the Beetaloo Basin may be lower than anticipated provided project management is carefully planned and effectively regulated.

Should Beetaloo enter into production, increasing or optimising the number of wells constructed on a platform and reducing the area cleared for attendant infrastructure (including roads and pipelines) should mitigate some risk of fragmentation impacts. However, a more detailed analysis of the factors that affect this risk is required to ensure that environmental management remains effective across the life of the project. This analysis will need to include the locations of roads and pipeline corridors and assess the degree to which location will affect contiguity of surface hydrology, vegetation patterns and species.

Most of these impacts can be predicted through the Environmental and Social Impact Assessment (ESIA) process, based on the proposed activity and an understanding of the surrounding ecosystem. In the NT, these assessments have been performed on a project-by-project basis, which tends to restrict the degree to which cumulative impacts are assessed, particularly at landscape scale.

Recommendation 2.3

In addition to project-specific Environmental Impact Assessments, strategic regional assessments should be undertaken with specific consideration of habitat fragmentation. This may occur as part of this inquiry, a subsequent inquiry, or a Cumulative Impact Assessment process

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As discussed in section 3.3, habitat fragmentation and water management is of particular interest to NLC's constituents who rely on land and water resources for a variety of hunting and gathering, cultural, economic and recreational uses.

Recommendation 2.4

As stakeholders with key interests in potentially affected resources, Indigenous populations should be provided thorough consideration in cumulative impact assessment processes. The Inquiry should instigate further detailed consideration of broader socio-economic and cultural impacts of petroleum industry development in the NT, particularly those relevant to Aboriginal people.

4.5 Hydraulic fracturing with respect to geology, hydrogeology and hydrology

5. The relationship between environmental outcomes of hydraulic fracturing of shale petroleum deposits with geology, hydrogeology and hydrology

It is well known that within the NLC region shale deposits occur at various depths ranging from over 4,000m below ground to outcropping geological features. Where shale deposits exist in close proximity to groundwater resources – or where fault lines are present that connect the hydrocarbon resource to groundwater resources –hydraulic fracturing presents a level of risk to groundwater integrity.

Induced seismicity due to hydraulic fracturing

During the process of hydraulic fracturing water, sand and chemicals are pumped under intense pressure to crack the shale at depth (approximately 1km-4km). The sand acts as a "proppant" keeping the fractures open allowing the gas to flow more freely through the cracks. Reactivity of faults and resultant seismicity occurs due to a reduction in effective stress on fault planes (Bindley et al. 2013). Hydraulic fracturing can trigger seismicity due to an increase in fluid pressure in a fault zone (Bindley et al. 2013). Stimulated faults create new fractures in the rock creating possible pathways to groundwater and increasing the risk of intermixing causing contamination. Bindley et al. (2013) proposes the following pathways for possible fluid contamination:

a) directly from the wellbore;
b) through new stimulated fractures in rock;
c) through pre-existing fractures and minor faults; or
d) through the pore network of permeable beds or along bedding planes.

Recommendation 3.1 provides for subsurface mapping during the stage of well planning, and of quantifying and monitoring naturally occurring methane.

Hydrocarbons

In addition to the additive chemicals used in the hydraulic fracturing extraction process the mixture of flowback and produced water may also contain by-products of the hydrocarbons which potentially have dangerous levels of radiation and naturally occurring chemicals including benzene (carcinogenic), toluene, ethylbenzene and xylene– which can be released during the drilling process. Furthermore, there may be chemicals left as residue during these fracturing episodes which can potentially disperse and contaminate groundwater supplies.

Recommendation 3.2 includes a proposal for risk assessment pertaining to storage and disposal of potentially radioactive wastewater.

Hydrogeology

The hydrogeology of the NT is complex with groundwater resources ranging from small, limited fractured hard rock aquifers, to extensive, porous sandstone and karst aquifers. In addition, the groundwater systems of the NT are generally poorly understood due to the sparse number of well holes and paucity of data.

Although some generalisations can be made as to the correlation between the nature of an aquifer and the possible risks hydraulic fracturing presents to that type of system, these generalisations cannot replace detailed local and regional hydrogeological studies to assess potential groundwater impacts on a site-by-site basis.

There follows a few general geological, hydrogeological and hydrological factors that could affect the degree of risk hydraulic fracturing poses to the ground and surface water environments.

Distance between the aquifers and the underlying shale deposits.

The closer the shale deposit to the aquifer, the higher the risk that well stimulation might open a pathway for gas and fracking fluid migration directly into the aquifer. In the Beetaloo basin the aquifer-shale distance is approximately 1 km, compared to a > 2km distance for parts of the McArthur Basin. It is understood that the 1 km minimum hydraulic fracturing depth imposed by the NT Government via the Petroleum Act aims to address this issue.

Recommendation 3.2 suggests that NT government should review the 1km minimum hydraulic fracturing depth legislated in the Petroleum Act wherever deeper groundwater resources are found.

Ambient groundwater quality.

Some groundwaters in the NT are corrosive and can degrade cement and steel well casing. The groundwaters may be corrosive where:

- The pH is naturally low (often in the top end as they recharge regularly and rainfall is naturally mildly acidic);
- dissolved CO2 is high, or
- salinity is high.

Groundwater chemistry is spatially variable. Corrosive waters are known to be characteristic of Central Arnhem Land sandstone aquifers, and in some aquifers of the Great Artesian Basin (GAB). Abandoned oil wells drilled in the GAB in the 1960's (McDills, Dakota), are said to have significantly corroded after 50 years.

After unconventional shale gas has been extracted, wells are plugged, and left in the ground indefinitely. These wells may corrode (both the cement and the steel casing) and fail over time, potentially causing migration of gas and brine fluids into aquifers (Watson and Bachu, 2009). This risk increases in a corrosive environment. Further discussion of relevance to this discussion is provided in section 4.7a).

Recommendation 3.1 states that groundwater chemistry should be taken into account at well design phase, and well engineering responsive to the locally specific risks should be regulated by the appropriate agency.

Degree of vulnerability of aquifers

There is a risk of surface spills of contaminated 'produced' wastewater leaching into shallow water tables which supply water to Indigenous communities and outstations. Some aquifers are more vulnerable to contamination than others. The more vulnerable aquifers:

- Are shallow – in the Top End it is commonly <30m below the surface, and
- have porous substrate – Fractures, dissolution voids, sandy substrates all allow water and any leachate to rapidly percolate to the water table. These aquifers are also common in the NT, for example, in East Arnhem Land (major sandstone aquifer), Daly River Basin (karstic aquifers) and the Georgina Basin.

Water Resources

Apart from Darwin and Katherine, bore water supplies most NT towns, communities, pastoral stations, and outstations. Numerous enterprises, both indigenous and non-indigenous based, such as mining, tourism and horticulture, depend entirely on underlying aquifers for their operations. Groundwater-fed rivers, springs and streams may not only be of ecological importance, but of cultural significance.

The process of hydraulic fracturing may require significant quantities of water. This can have potential to manifest significant effects (drawdown) on local aquifers. The paucity of groundwater data in the Northern Territory does not allow for accurate risk assessment of drawdown on local aquifers and its possible effect on communities and ecosystems. It is recommended that baseline studies of groundwater be conducted and recharge rates be studied to evaluate the volume of water that can be sustainably utilised without detrimental effects on communities and ecosystems (*see recommendation 4.1*).

NLC believes that the protection of potable water resources (particularly in arid areas), including water based and water-dependent sacred sites, such as springs and waterholes should be of paramount importance. Despite water being a key part of the debate, the NLC highlight that the security and integrity of water supplies has yet to be adequately addressed either by the government or by industry. A number of factors contributing to our concerns are listed below:

- Drawdown from rivers and aquifers may be significant and highly localized where numerous wells are installed in proximity to each other.
- Migration of oil, gas and fracturing chemicals – faulty and unmaintained or abandoned wells generate a risk of groundwater and surface contamination (see comments below).
- Disposal of contaminated water – hydraulic fracturing generates significant volumes of contaminated wastewater that will require effective management. The methods by which this is achieved, and any risks presented to the integrity of potable water supplies should be considered in the Inquiry.
- The practice of injecting wastewater into abandoned wells under pressure generates a risk that contaminants and residual oil, gas and fracturing chemicals may migrate into aquifers or the surface via natural fault lines or abandoned wells or drill holes that intersect them.

Recommendation 3.2 provides for investigation into the specific risks and impacts posed by the injection of wastewater into abandoned wells under pressure.

Consideration should be given to risks and impacts incumbent on water quality, communities and groundwater dependant ecosystems.

Recommendation 4.1

To protect the interests of our constituents, NLC recommends:

- *Further baseline modelling of regional groundwater resources be undertaken in partnership with the Land Council and TO's*
- *A localised groundwater risk assessment be undertaken prior to each hydraulic fracturing activity being conducted, and*
- *That wells not be located near known aquifers and weak geological formations such as faults or fractures.*

4.6 Regional and local variability in relation to risks posed by hydraulic fracturing

6. The potential for regional and area variations of the risk of environmental impacts from hydraulic fracturing in the Northern Territory.

There is a high potential for variation in bioregional and local environmental risks arising from hydraulic fracturing within the NLC region. These risks are determined by various factors including the presence or absence of groundwater, regional landscape integrity (i.e. disturbed vs undisturbed or fragmented vs relatively intact environments), climate and habitat types (i.e. arid/semi-arid, tropical wetlands, open or closed woodlands, monsoon vine forests, alluvial floodplains, etc.), a diversity of which are present within the NLC region.

4.7 Mitigation methods of relevance to hydraulic fracturing

7. Effective methods for mitigating potential environment impacts before, during and after hydraulic fracturing with reference to:

7.a) the selection of sites for wells

Relevant points in relation to this issue are made elsewhere in this submission, specifically in Sections 4.3 and 4.5.

7.b) well design, construction, standards, control and operational safety and well integrity ratings

Well failure due to poor construction or age is one of the biggest risks associated with hydraulic fracturing to recover oil and gas from shale. The aim should therefore be to construct a well to a standard such that the seal between the pressurized production tubing and the external environment (aquifers and the atmosphere) is effective over an indefinite period of time. Failure of the structural integrity of any well is possible, so it is of benefit to understand the rate of failure, elements that may contribute to well failure, and how to best protect the environment from the risk of well failure.

This issue is of significant interest to NLC constituents, because where petroleum projects progress the protection of the environmental assets of Indigenous people is contingent on integrity of wells, both in the short and long term. This section analyses and summarises relevant information available in the public domain.

Well integrity and risk mitigation

One of the key environmental safeguards used by the oil and gas industry to reduce the risk of well failure is the use of multiple cemented cases (or barriers). This is standard industry practice, used irrespective of whether or not oil or gas is recovered by conventional means or through the more unconventional hydraulic fracturing.

The use of multiple cemented casings represents a risk mitigation strategy built around multiple redundancies – meaning that should one of these barriers fail, the others will still protect the environment (refer Figure 7).

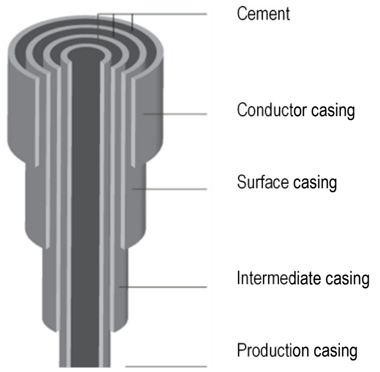

Figure 7: Internal structure of a typical oil and gas production well.

Of the four barriers, the surface casing is the most critical to environmental protection because it provides the main seal that isolates freshwater zones. It often extends tens of metres below the freshwater zone. Additional protection is provided by the other two casings; and by the production tubing, which runs through the innermost (production) casing. (Smith, 2011)

Consequently, a well is only considered to have failed when all of the barriers have failed and oil, gas, salt water or chemicals has the ability to migrate to the surface and/or subterranean environment.

To maximize the potential for creating a good seal and minimizing environmental risk, cementing must be done properly. During the cementing process, tubing is run into the well to the depth desired for the bottom of the cement plug. Cement is pumped down the tubing, passes out the bottom of the tubing and then flows back up the outside of the tubing. After the desired amount of cement is in place, water is pumped behind the cement to displace it to its predetermined depth. At that point the tubing is removed and when done correctly, the cement fills the space the tubing occupied in the well, leaving a solid section of cement.

There are several factors occurring during construction that may affect the overall effectiveness of the well and increase the risk of barrier failure. These include:

- The amount of cement fill;
- The properties of the set cement;
- Elimination of mud and gas channels within the cement, and
- How well the cement has bonded to the casing and the formation(s).

Should any of these factors be less than optimum the risk of environmental damage (through surface leaks, migration of gas or oil into rock strata or catastrophic blowout) will increase.

Where cementing problems occur during drilling squeezing additional cement in between the casings will usually rectify them. However there is a concern that other related factors may lead to failure once the wells are abandoned and maintenance has ceased for a long period of time. These include gradual decay of the cement and corrosion of casing and lead to circumstances where repair by squeeze infill of cement is difficult.

It should be understood that sealing a well may not resolve contamination issues where the cause of the contamination is the stimulated fractures in subterranean rock which act as preferential pathways for contaminated groundwater (i.e. not the original well).

Well integrity and gas migration

Each well presents a risk to groundwater integrity, albeit a low risk, given best practice construction and monitoring, but a risk nonetheless. However, the risks will increase in proportion to the number of wells constructed and the number of hydraulic fracturing events undertaken. Many wells are required for unconventional gas extraction as the amount of gas extracted in a fraction of that for a conventional gas well. Perhaps the most serious consequence related to loss of well integrity is gas migration. Uncontrolled migration of gas (also known as annular flow) indicates inadequate isolation of gas-bearing zones and creates a sustained casing pressure at the surface, which will continue to gradually increase after each bleed. The main cause is usually a fault in the cement between internal casings or between casings and the rock formations. Once the pressure in the formation has again built up following construction vertical migration of gas occurs. Bruffato et al. (2003) indicate this is a common problem for the offshore oil and gas industry where statistically, 60% of constructed wells show signs of leakage within a period of 30 years. Under these circumstances, the highly saline offshore conditions likely contributes to the high failure rate: The discussion in Section 4.5 on ambient groundwater qualities in the NT is of relevance to the analysis of the relevance of this point.

Statistics specific to instances of gas migration from on-shore wells are difficult to find. Anecdotally there are concerns that failure of well integrity may have been responsible for increased concentrations of thermogenic gas observed in a number of wells in Pennsylvania. The Department of Environmental Protection [2010] released a list of 55 incidents recorded between 2004 and 2009 that are probably the consequence of stray gas leakage. The majority of these involve migration of gas into drinking water, soil and/or explosion – each affecting multiple households. It was thought that over-pressurisation of newly constructed wells had resulted in failed cement bonding followed by direct release of gas from the well or migration of gas through a legacy well. Importantly, nearly all of these problems were successfully rectified upon repair of the well or installation of additional side vents to relieve the buildup of pressure.

Causes of barrier failure in wells.

Cement faults occur mainly because fluid loss from the slurry and hydration creates a porous gel-like structure causing the cement to lose its ability to spread fluid pressure. If the pressure drops to a value less than that of the gas pressure in the surrounding strata, gas will flow into the annulus and migrate upwards. Mavroudis (2001) has identified that where the cement bonds behind the casing have failed, the casing can corrode and zonal isolation will be lost. Continued inadequate zonal isolation may result in cross-flow between communicating formations and provides a means for migration of oil or gas into aquifers. However, there are a number of cement related causes of failure of barriers within a well. The principal ones are shown in Figure 8.

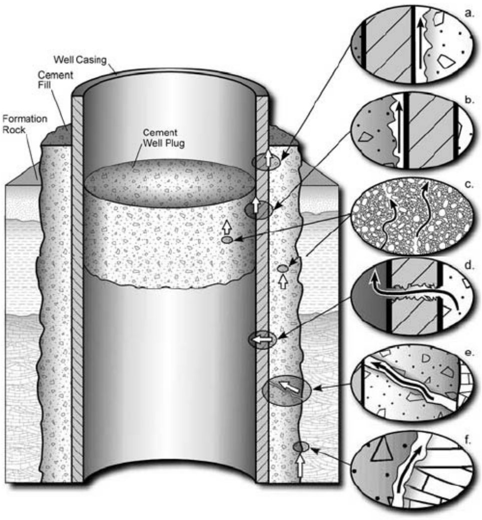

Figure 8: Possible pathways for oil/gas migration in an abandoned well. Similar pathways will be observed in a producing well, with the exception of (b) and (c) where the plug is not in place. (d) is also more likely to be predominant in an abandoned well, where casing has corroded. (Mavroudis, D 2001)

Modes of action

(a) between cement and the exterior of casing.
(b) between cement and the interior of casing.
(c) through the cement.
(d) through the casing.
(e) through fractures (channels) in the cement.
(f) between cement and the formation rock.

Channelling usually occurs where too much water is present in the cement mix. The excess water will separate, resulting in areas of weakness or fractures (channels) through which liquids under pressure may migrate. Channels may also be formed if cement is not properly set before being placed under pressure, leading to incomplete zonal isolation and allowing gas or liquids to be forced or bubble through the wet cement.

Cements can shrink during and after setting, during hardening (as a result of transfer of water into adjacent porous rock strata) or as a result of formation of hydration reaction products (which occupy a smaller volume than the original paste). Other processes that can lead to shrinkage include dissolved gas, higher than necessary curing temperatures and osmotic dewatering (where water is transported out of the drying cement) through contact with brines or salt beds. Voids within the cement will develop and similar to situations where insufficient cement has been poured during construction, bonding between parts of the casings or with the formations may not be adequate.

In many cases, cement will not bond well with salt, oil, sand and high porosity shale creating potential weak spots where the casing contacts formations. Cycling under high-pressure conditions typical of hydraulic fracturing well stimulation can heighten this problem and also lead to debonding and generation of multiple micro-fractures within the cemented systems. Dusseault et al. (2000) indicate that wells that have experienced several pressure or thermal cycles will almost always show loss of bonding – often over distances as large as 100m. Where there is inadequate bonding (or zonal isolation) between the outermost layer of cement and geological strata, or where the cements take on a porous nature as a result of shrinkage or microfracturing, leakage is likely to occur.

Plugging and abandonment

The information provided below is also of relevance to TOR 7.k).

Once production from a well becomes uneconomic, it is abandoned and plugged to prevent residual oil and gas reservoir fluids from migrating uphole over time. In the 1800's, wells were drilled without cemented casing and without the multiple redundancies provided now. On abandonment, plugging was aimed mainly at preventing water entering the hole and offered no real value for environmental protection. In many of the older fields, the wells were either left unplugged or 'plugged' with a bizarre range of objects from tree stumps and rocks to glass jugs. While these actions may have met the immediate goal, the application of newer high-pressure technologies to extract gas from the same fields has undoubtedly had detrimental effects on these wells.

Unplugged or poorly plugged wells have the potential to act as conduits, allowing fluids to bypass existing plugging materials and migrate uphole. If this occurs, it may cause problems with the fresh water aquifers in the area by allowing gas, oil or salt water to contaminate it.

Modern abandonment practices rely on cementation of the well's interior, meaning that the risk of it being ruptured in the future is greatly diminished. Modern plugging techniques require the placement of mechanical or cement plugs in the wellbore at specified intervals (usually above and below producing zones) to prevent any residual flow. Recently it has been recognised that mechanical plugs are prone to long-term corrosion so abandonment standards have been revised to include placement of additional cement on top of any mechanical plug used.

In addition, improved cement formulae, which are designed to reduce future maintenance requirement have been developed. The inclusion of silica flour (SiO_2) to create “thermal” cement is one advance, but is still not guaranteed to reduce shrinkage. Sophisticated life-of-well cement formulations that react to annular influx of hydrocarbon and expand to fill gaps in cement offering a better prospect for maintaining well integrity have been developed, but these have yet to have widespread application in the field.

Recommendation 5.2

The NLC recommends that the Commissioner provide specific and publicly available advice pertaining to the standardisation of well plugs that promotes long term well integrity. The Commissioner should investigate whether it is practicable and potentially beneficial to require as minimum standard in the NT the use of sophisticated life-of-well cement formulations that react to annular influx of hydrocarbon and expand to fill gaps in cement.

Assessing rates of barrier and well failure

There is significant information available on the mechanisms of well failure, however there are several variables affecting well integrity that are yet to be understood. The timeframes in which well casings and cement corrode (potentially resulting in environmental detriment) is a variable which has still not been projected. Other unknown variables include; the total number of wells which will enter into production, the percentage of wells likely to fail, the projected rate of contamination/seepage, and the projected extent of contamination and seepage. As a result of these knowledge gaps, it is impossible to adequately quantify the estimated net environmental impacts potentially caused by tens, or tens of thousands of wells over a significant period of time.

Davies et al. (2014) have provided some statistics related to well failure but advises that there is a lack of consistent definitions and the manner in which they are being interpreted by various agencies makes them difficult to clearly understand. There are several considerations regarding a number of variables, including the age and design of the well and surrounding formation geology; these factors dictate well construction and can lead to a significant spread in the statistical measures used. The problem is further compounded because in US states such as Texas and Pennsylvania (where gas was first produced in the 1800’s), thousands of wells were drilled but few records about their location or construction kept. This resulted in data which have not been included in the data pool and this may have led to an inherent bias in the outcomes.

Recommendation 5.3

The NT government should establish an enduring record of well locations in the NT, and this record should be shared with all Land Council's.

Davies et al. (2014) present data that indicates the rate of barrier failure of unconventional on-shore field wells tends to be around 3% significantly lower than for those on conventional fields. King and King (2013) report that the rate of well integrity failure may be even lower than 0.1%. Both of these studies are careful to acknowledge the range of variables involved, but draw essentially the same conclusion – that safety and environmental parameters associated with well construction are continually improving and there are very few modern wells where more than one barrier has failed to date. Should wells fail over time, the impact of several wells in an area will have a cumulative effect on the environment.

In analysing problems associated with well integrity, recognition of a number of fundamental differences between the shale oil industry in the NT and that of the United States assists in understanding how and why environmental impacts have occurred, the stakeholder concerns raised, and the relevance of these concerns to the NT.

Such differences include:

(a) The USA's longer history with the use of hydraulic fracturing to recover oil and gas from shale;
(b) The relative numbers of abandoned poorly plugged wells that might act as conduits for oil and gas;
(c) The considerably more robust construction of now abandoned wells in the NT, and
(d) The known location of abandoned oil and gas wells in the NT (where known wells are more easily avoided, managed or incorporated into a producing gas field)

Continual improvement of environmental performance in any industry is most often a response to effective governmental regulation. If the mistakes made elsewhere in respect of hydraulic fracturing are to be avoided in the NT, effective industry regulation is imperative.

Implications for the Northern Territory

The Northern Territory is in a position to learn from the problems encountered in other countries like the USA and develop leading practice standards for well construction, management, abandonment and regulation. Should hydraulic fracturing be deemed an acceptable means of producing oil and gas from shale, then further work determining the rate at which wells fail and developing better means of monitoring, maintaining and repairing them will be essential.

In trying to define these implications more fully, there are currently problems in obtaining definitive statistical outcomes to describe risk of well failure. However, it is reasonable to conclude that there is a risk that barrier failure will occur in a small number of wells in the NT. This small risk infers that there is a level of probability that well integrity will be compromised over time and may result in environmental contamination. Hypothesising the consequences of possible contamination generates a requirement to analyse the acceptability of such risk to remote communities and surrounding ecosystems that consequentially may endure lasting legacy effects.

Unfortunately the Northern Territory is in a position where important information regarding the projected rate of leakage initiated from abandoned wells and the possible time lapse before any significant environmental damage may occur remains unknown.

Recommendation 2.5

Until variables affecting well integrity over long time periods are determined or better understood, a cautious approach (application of the precautionary principle) to the regulation and assessment of projects proposing extraction of oil and gas by conventional and unconventional means is warranted.

The most cited guidelines for shale gas well construction and integrity are from the American Petroleum Institute (http://www.api.org/~/media/Files/Policy/Exploration/API_HF1.pdf).

Other jurisdictions in Australia have produced guidance on unconventional (CSG) gas bore construction include:

- Queensland: (Code of Practice for CSG Well Head Emissions, Detecting and Reporting Version 2 (2011); Code of Practice for Constructing and Abandoning CSG Wells in Queensland (2011));
- New South Wales (Code of Practice for CSG activities – Well Integrity; Code of Practice for CSG activities – Fracture Simulation Activities); and
- Western Australia gas industry: Hydraulic Fracturing Code of Practice.

7.c) water use

Robust and clear legislation will improve the management of environmental risks associated with hydraulic fracturing, and the management of water allocation in basins where hydraulic fracturing occurs. It is recognised that there are both gaps and duplication in Northern Territory legislation for the protection and use of water resources, and indeed the Northern Territory Government's Water Directorate is addressing this problem through legislative reform.

Most remote Indigenous communities in the NT have a high degree of dependence on groundwater resources for domestic water supplies. Protection and security of potable water supplies should be a primary consideration in the planning and decision making process.

Hydraulic fracturing operations should plan to avoid interfering with 'high value' aquifers, community borefields, and groundwater supplies for indigenous owned and operated enterprises wherever possible. Adequate assessment of groundwater resources prior to operations is essential to good management and protection of the resource.

Recommendation 4.2

Reform of existing NT legislation and regulations should be designed, in partnership with Land Councils and the Aboriginal Areas Protection Authority, to manage the potential impacts of unconventional gas development on the NT's water resources. This includes bringing water use for hydraulic fracturing and other extractive industry purposes into the water allocation planning framework, in line with the National Water Initiative framework (Recommendation 14c).

The water intensive nature of the hydraulic fracturing presents a level of risk to community livelihoods. A large volume of water (Frogtech 2013 estimates an average of 15 ML per well) is required to successfully fracture each well. A well-field may be comprised of hundreds and up to thousands of wells equating to a significant water requirement.

At present, petroleum activities are exempt from the need for licensing under the NT Water Act for extraction and use of surface water and groundwater. In areas of the NT where water is regulated and a water allocation plan has been produced, water is already fully allocated to primary producers, the environment and for domestic supply. There is potential for unregulated and poorly managed water take to cause drawdown in aquifers which may affect other groundwater users in the area, including Indigenous communities. This may lead to increasing pressure on the water supplies of indigenous populations in the areas affected. Underlying any development should be a commitment to protect and secure the water supplies of communities across the NT. Recommendation 3.1 provides for the monitoring of groundwater before, during and after hydraulic fracturing operations, and further suggests that data should be independently reviewed by appropriate experts.

Recommendation 4.3

Priority should be given to comprehensive groundwater assessment and management plans in any basin where water is extracted for unconventional gas operations in partnership and collaboration with the Northern Land Council.

7.d) chemical use

NLC is aware of and supports the NT government's ban on the use of BETEX chemicals, the requirement for disclosure of chemicals to the Department of Mines and Energy, and the department's publication of such information in the "chemicals disclosure list" on the internet.

Traditional Aboriginal owners of lands subject to the Native Title Act and the Land Rights Act have specifically raised questions pertaining to the risks associated with the use of chemicals during hydraulic fracturing. Recommendation 1.1 proposes that an independent risk assessment should be conducted in respect of the chemicals used in well drilling and well stimulation on a project-by-project basis, and that if such risk is deemed significant, that relevant information is presented to traditional owners for their consideration in the negotiation of agreements in respect of Aboriginal lands and land subject to the Native Title Act.

7.e) disposal and treatment of waste water and drilling muds

Flowback and Produced Water

Flowback and produced water are often used interchangeably however they are distinct. Flowback water is the process of the fluid flow reverse after a hydraulic fracturing event and defines the returned water. Produced water extracted from the subsurface with oil and gas. Both types constitute hazardous waste and require safe disposal. They contain salt, industrial chemicals, hydrocarbons and radioactive materials. The Institute of Medicine (2014) states that about 40% of the flowback water is recovered but varies from well to well highlighting that chemicals and residue from the process remain at a subsurface level. Flowback and produced water that may be contaminated with additive hydraulic fracturing fluid chemicals and low-level naturally occurring radiation needs to be stored and processed at the surface or reused in the hydraulic fracturing extraction process before being treated and removed from site. The storage and movement of contaminated water carries a risk of surface spills, which could result in contamination of surface and groundwater. To mitigate against risks of contamination due to surface spills, water treatment facilities should be built in proximity to extraction points to reduce risks associated with transportation. Best practice regulations and processes should be implemented governing the storage, processing and transport of chemicals and wastewater to prevent spillages and accidents.

Salts

Both flowback and produced water contain high concentrations of salt (brine) as they are both added to the hydraulic fracturing process and left as residue within the subsurface. Bracckish or brine water is stored or recycled back into the ground through wells. Brine wastewater is typically treated to remove any chemicals used during the fracturing process and returned back to the ground (recommendation 3.2 is of relevance here).

Where waste water management constitutes an environmental risk, near-surface geology, climate, operations management and effective regulation of operators are key risk mitigation considerations. Waste water will include brine, fracking fluids and water produced from each fracturing event (‘flowback’ and ‘produced’ water), as well as any additional elements naturally released from the deep formations which can include heavy metals and radionuclides. Some concerns pertaining to the management of fluid recovered from hydraulic fracturing include:

- Leakage from on-site storage ponds;
- Improper pit construction, maintenance and decommissioning;
- Incomplete treatment (including releasing into surface and groundwater resources);
- Spills on-site;
- Lack of activity monitoring at each well, and
- Waste water treatment accidents.

If not securely contained and treated, this water potentially poses a health risk to the local inhabitants as well as the groundwater and surface water resources in the area.

Recommendation 3.2 promotes high standard containment and treatment facilities for surface ‘produced’ water, preferably closed containment systems.

7.j) the use of single or multiple well pads

Section 3.4 contains further information of specific relevance to this issue.

7.k) rehabilitation and closure of wells (exploratory and production) including issues associated with corrosion and long term post closure

Well integrity

The fate of abandoned wells is one aspect of oil and gas recovery that does not seem to have received thorough analysis in other hydraulic fracturing reviews and which should therefore be considered in this inquiry. The NLC is concerned about ongoing management of abandoned wells because these present a risk of long-term chronic environmental impact through continuous leakage of oil or gas into the atmosphere, aquifers or both, and such wells will occur on lands subject to the Native Title Act and the Land Rights Act.

Modern wells are constructed with multiple cemented casings, but migration of gas through annuli becomes problematic once the cement begins to decay. We conclude that the probability of leakage will inevitably increase over time and especially in situations where the metal casings begin to rust or perforations have not been completely plugged. If an abandoned well is not monitored and maintained, it is reasonable to argue that leakage into the atmosphere or into groundwater aquifers will eventually occur should the well become re-pressurised.

History has shown us that once a mining company has left an area and their environmental bond returned, no further interest is shown, while government regulators only renew their interest if a problem is reported.

We therefore consider it unlikely that abandoned wells will be monitored and maintained in the long term because:

- Companies and regulators will no longer regard them as their responsibility;
- the overall high and cumulative cost of monitoring and maintaining large numbers of wells will increase over time and become a severe financial burden, and
- the number of abandoned wells may ultimately be so large that insufficient resources will be available to effectively undertake any management plans that have been developed.

Importantly, if workable systems of long-term management are not developed, failure to ensure that abandoned wells do not leak in perpetuity will eventually pose an undue financial burden on Aboriginal and other landowners who may not have the resources to manage them. Consequently, the quantum of future cost (which at this point does not appear to be limited in time) may ultimately outweigh any benefits received in the present.

Migration of oil/gas through corroded casings and cement will also occur when a new well is not properly constructed and cannot cope with the production pressures being applied. If regulatory and management systems are in place and implemented, immediate repair of faulty wells should be possible, and impacts limited to the short-term. However, the NLC remain concerned that if there is a high rate of well failure or if thousands of wells are constructed, the cumulative effect of small impacts (particularly in a localized area) may create an environmental risk as high as that related to long-term leakage from unmonitored, unmaintained abandoned wells.

Until these issues related to well integrity have been thoroughly investigated, doubt will remain about the oil and gas industry's ability to protect potable water supplies and prevent long-term environmental impacts. In addition, questions will remain about the regulatory body's ability to understand and effectively regulate the industry.

Recommendation 6.1

The Inquiry should make public the outcomes of investigations into the following matters associated with well integrity:

The rate of failure of new and abandoned wells including:

- *the variables contributing to those failures;*
- *the types of failures;*
- *the extent and types of environmental impacts caused by those failures;*
- *measures implemented to address those failures;*
- *the success of those measures;*

and, furthermore should instigate:

- *Ongoing-research into improving the safety and integrity of wells.*
- *Investigations into the ability of the Northern Territory's regulations and capacity of its regulators to effectively manage and regulate failure of wells in the short-term.*
- *Investigation of the ability of systems that have been put into place or are being developed by companies and government regulators to manage abandoned wells into the future.*

Recommendation 6.2

Abandonment plans from well operators should be made available to land holders. The NT government should provide consideration to options for the management of medium and long term liabilities associated with abandoned and failing wells, including the option of a levy and/or bond system.

5. Concluding remarks

Over the past decade there has been wide debate over the use of hydraulic fracturing (or reservoir stimulation) to recover tightly bound oil and gas from coal seams, tight sands and shale. As a result, numerous governments worldwide have undertaken inquiries into the matter and on the basis of those have generally chosen to accept it. Others have rejected hydraulic fracturing outright; it is noteworthy that elsewhere in the world (including Bulgaria and France), a moratorium has been placed on hydraulic fracturing due to the perceived environmental risks associated with hydraulic fracturing.

The NT's Aboriginal population has a profound interest in this discussion because of the high number of petroleum projects proposed on Aboriginal lands. In preparing this submission, the NLC is aware that there are diverse views amongst Aboriginal groups as to whether hydraulic fracturing poses an acceptable risk or not. The submission therefore seeks to express the full range of concerns of its Aboriginal constituents, to provide relevant information, and to invite ongoing dialogue and information sharing, thus to enable free, prior and informed consideration of projects developing on Aboriginal Lands. This NLC can achieve by taking the Inquiry's findings to our Aboriginal constituents and by incorporating them with research undertaken by officers of the NLC.

Arguments against hydraulic fracturing revolve around stakeholder concerns related to the risks incumbent on the natural environment and on the health of people. The counterbalance to the argument is largely economic – that the processing of the Northern Territory's shale oil and gas deposits has the potential to provide significant and positive economic benefits. It can also be argued that failure to take this opportunity may condemn sectors of the Northern Territory to ongoing reliance on already strained welfare systems and result in higher costs to all through a greater reliance on foreign controlled fuel supplies.

Being amongst the most socio-economically disadvantaged of people in the Northern Territory, it is only natural that Aboriginal people will wish to materially benefit from the potential economic growth that this industry offers, and understandable that they remain cautious where developments are said to pose a risk to their land, natural resources, spiritual attachments and culture. Many Indigenous people recognise gaps in knowledge about hydraulic fracturing need to be addressed before individuals are able to support (or oppose) an idustry that operates using this technique. Our submission is therefore not aimed towards arguing for or against hydraulic fracturing, but towards generating a better understanding of the process and its impacts so that Aboriginal landowners can make properly informed decisions about how they manage resource development on their land.

Many areas of Aboriginal freehold and Native Title lands are resource rich. The NT government (and some Aboriginal groups) are actively seeking to exploit the financial benefits these resources offer. This has created a potential for multiple resource and heavy industry based developments in close proximity to each other. With this comes the risk of overexploitation, an accumulation of negative impacts and systems that are inadequate to manage them.

Technical reports and financial assessments suggest that the economic impact of the shale oil industry on the Northern Territory will be immense, mainly because oil and gas bearing deposits are widespread and likely to be highly productive. Many overlap areas that are already under pressure from mining, townships and other industry. Although small now, once the shale oil and gas industry expands, the need for additional upstream and downstream infrastructure and capacity will increase. The soft and hard infrastructure needs of an expanding shale oil and gas industry and the ability of the Northern Territory to cope with rapid and burgeoning development of infrastructure, particularly in remote areas, need also to be carefully considered. Over time, cumulative impacts will increase. We have argued throughout this submission that there is a need for detailed and strategic assessment of cumulative impacts with consideration of:

- The impacts associated with numerous single or multiple wells located close to each other. Northern Territory legislation currently requires only production of an Environmental Management Plan for individual projects and does not consider the cumulative impacts of numerous wells either in close proximity, or across the wider landscape.
- The cumulative impacts of all industries at landscape and regional levels on key resources, such as water. Hydraulic fracturing events consume large volumes of water and are in competition with other users including other oil and gas companies, pastoralists, mining companies and communities. A balance is required to ensure that equitable allocation of water occurs.

The NLC will continue to advocate for the interests of traditional Aboriginal land owners in this important emerging industry.

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Figures

ATTACHMENT 1

Northern Land Council

Recommendations to Northern Territory Government's Hydraulic Fracturing Inquiry

June 2014

The NLC has made this submission on behalf of its Aboriginal constituents. It does not hold an opinion on the merits (or otherwise) of hydraulic fracturing and seeks only to ensure that its Aboriginal constituents are well informed when making decisions that affect their land. Consequently, we have made a number of suggestions throughout the submission. The submission also highlighted a number of issues that do not appear to have been considered in the Terms of Reference, but that should be carefully considered in the development of recommendations arising from this inquiry.

There follows a list of specific recommendations.

1. Communication

Recommendation 1.1

In order to facilitate the dissemination of information on impacts and risks associated with hydraulic fracturing to Indigenous stakeholders and to enable NLC to properly administer free, prior and informed consideration of petroleum proposals, it is recommended that the following information is provided to the NLC in respect of petroleum developments on lands subject to the Native Title and Land Rights Acts:

- The total number of hydraulic fracturing events projected annually;
- The rate of growth in the number of hydraulic fracturing events projected annually;

- The density of wells and platforms, especially in relation to their proximity to water sources and environmentally/culturally sensitive areas;
- The proposed minimum acceptable distance between wells;
- The anticipated longevity of each well or platform;
- How individual companies, the industry, and industry regulators will manage the sequential abandonment and drilling of new wells to ensure that the risk of environmental fragmentation (and other environmental impacts) remains well managed and minimised.
- The chemicals used in well drilling and reservoir stimulation, and independent assessment of the risk such use of these chemicals may pose to environmental resources and human health. Such information should be provided prior to the use of these chemicals and for the specific purpose of consultations with affected peoples.

(Section 3)

Recommendation 1.2

The Commissioner should recommend specific pathways for the dissemination of information arising from the Inquiry. (Section 4)

2. Project Assessment and Regulation

Note

It is of relevance that the method of hydraulic fracturing makes it possible to access petroleum resources in the NT that would otherwise be inaccessible or uneconomic; the expansion of the industry would not occur at the same rate in the NT if hydraulic fracturing was not possible. Therefore it could be argued that any distinction between the growth of the petroleum industry and hydraulic fracturing as a technique for extracting the resource is unnecessarily restrictive. As a result, some of the recommendations below on assessment and regulation relate to rapidly expanding petroleum developments which are enabled by hydraulic fracturing (see section 4).

Recommendation 2.1

It is recommended that the Commissioner provide the NT Government with specific and public advice on how to improve consideration of the cumulative and bioregional impacts of hydraulic fracturing into the Environmental Impact Statement (EIS) assessment process (section 4.1).

Recommendation 2.2

The outcomes of the Inquiry should be used to develop relevant and practical regulatory measures and standards that represent leading practice. This should include specific measures that become mandatory considerations in an Environmental Impact Assessment regime. Such a regime should include specific triggers for assessment not only of individual projects, but also assessment at a landscape scale to enable analysis of cumulative impacts where petroleum development is proposed and enabled by the technique of hydraulic fracturing (section 4.1).

Recommendation 2.3

Strategic regional assessments should be undertaken with specific consideration of habitat fragmentation. This may occur as part of this inquiry, a subsequent inquiry, or a Cumulative Impact Assessment process (section 4.4)

Recommendation 2.4

As stakeholders with key interests in potentially affected resources, Indigenous populations should be provided thorough consideration in Cumulative Impact Assessment processes. The Inquiry should instigate further detailed consideration of broader socio-economic and cultural impacts of petroleum industry development in the NT, particularly those relevant to Aboriginal people (section 4.4).

Recommendation 2.5

Until variables affecting well failure over long time periods are determined or better understood, a cautious approach (application of the precautionary principle) to the regulation and assessment of projects proposing extraction of oil and gas by conventional and unconventional means is warranted (section 4.7b).

3. Risk Assessment and Management

Recommendation 3.1

Noting that equivalent or similar requirements currently exist within the NT government's regulatory structure, the NLC raises the following risk management standards in the hope that they are preserved and/or enhanced as a result of the findings of this Inquiry:

- Subsurface mapping should be used in the initial stages of planning the well placement to identify possible faultlines or weaknesses within the geological formation. Avoidance of placing wells in high-risk areas will minimise the risk of fault stimulation resulting in new pathways for groundwater contamination (section 4.5).
- In order to effectively assess risks of contamination, baseline data of natural methane levels and signatures is required, as well as ongoing monitoring for additional contaminants entering the groundwater (section 4.5).
- Baseline studies are needed to characterise groundwater quality and water chemistry and should be taken into account in the well design phase. Well design should provide detailed consideration of local groundwater conditions and geology. Consideration of locally specific risks and robust and responsive engineering should be monitored in each case by the appropriate regulatory agency (section 4.5).
- Groundwater monitoring should be conducted before, during and after hydraulic fracturing operations. Data should be assessed by appropriate experts and independently reviewed (Section 4.7e).

Recommendation 3.2

In addition, NLC recommends that the following specific risk analysis and risk mitigation measures be implemented. Information arising should be made available to the NLC;

- Thorough risk assessment of the storage and disposal of potentially radioactive wastewater (section 4.5).

- Investigation into risks and impacts of injecting wastewater into abandoned wells under pressure poses to communities and water quality should be conducted (section 4.5).
- The surface 'produced' water containment and treatment facilities should be constructed to the highest standard possible, particularly in the wet tropics where large volumes of surface runoff occur in the monsoon season. Closed containment systems (eg tanks) are preferable to open pit-type systems (Section 4.7e).
- The 1km minimum hydraulic fracturing depth imposed by the NT Government via the Petroleum Act should be reviewed wherever deeper groundwater resources are found (section 4.5).

4. Water

Recommendation 4.1

To protect the interests of our constituents, NLC proposes:

- Further baseline modelling of regional groundwater resources be undertaken,
- A localised groundwater risk assessment be undertaken prior to each hydraulic fracturing activity being conducted, and
- That wells not be located near bore fields, known aquifers and weak geological formations such as faults or fractures.

(Section 4.5)

Recommendation 4.2

Reform of existing NT legislation and regulations should be designed to manage the potential impacts of unconventional gas development on the NT's water resources. This includes bringing water use for hydraulic fracturing into the water allocation planning framework, in line with the National Water Initiative framework (section 4.7c).

Recommendation 4.3

Priority should be given to comprehensive groundwater assessment and management planning in basins where water is extracted for unconventional gas operations (Section 4.7c).

5. Well Placement and Construction

Recommendation 5.1

Traditional owners and Land Councils should have opportunity to provide input into well placement, so as not to diminish traditional owners access to land for purposes of hunting, fishing and for recreational and spiritual purposes (Section 4.3).

Recommendation 5.2

The NLC recommends that the Commissioner provide specific advice pertaining to the standardisation of well plugs that promote long term well integrity. The Commissioner should investigate whether it is practicable and potentially beneficial to require as minimum standard in the NT the use of sophisticated life-of-well cement formulations that react to annular influx of hydrocarbon and expand to fill gaps in cement (Section 4.7b).

Recommendation 5.3

The NT government should establish an enduring record of well locations in the NT, and this record should be shared with the Land Council (Section 4.7b).

6. Well Closure and Abandonment

Recommendation 6.1

The Inquiry should make public the outcomes of investigations into the following matters associated with well integrity:

The rate of failure of new and abandoned onshore wells including:

- the variables contributing to those failures;
- the types of failures;
- the extent and types of environmental impacts caused by those failures;
- measures implemented to address those failures;
- the success of those measures;

and, furthermore, should instigate:

- Ongoing-research into improving the safety and integrity of wells.
- Investigation into the ability of the Northern Territory's regulations and capacity of its regulators to effectively manage and regulate failure of wells in the short-term.
- Investigation of the capacity of systems that have been put into place or are being developed by companies and government regulators to manage abandoned wells into the future.

(Section 4.7k)

Recommendation 6.2

- Abandonment plans from well operators should be made available to land holders. Any detected well failures should be reported and actions taken to remediate in a timely manner. The NT government should provide consideration to options for the management of medium and long term liabilities associated with abandoned and failing wells, including the option of a levy and/or a bond system (Section 4.7k).