IAH

NORTHERN TERRITORY BRANCH OF IAH AUSTRALIA

Submission to the Northern Territory Government's Hydraulic Fracturing Inquiry

McDills Oil Exploration Well 2001 - Drilled 1965

Northern Territory Branch of the International Association of Hydrogeologists

30 May 2014

Acronyms

ACOLA	Australian Council of Learned Academies
CSG	Coal seam gas
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
ESD	Ecologically Sustainable Development
IAH	International Association of Hydrogeologists
IAH(NT)	NT branch of the International Association of Hydrogeologists
IESC	Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development
NT	Northern Territory
NTG	Northern Territory Government

'Hydraulic fracturing' is commonly referred to by the term 'fracking'.

'Top End' refers to the monsoonal northern region of the NT.

Contents

Summary

Groundwater is often called the forgotten resource. It lies beneath our feet and supplies bores, springs and it maintains flows to our rivers. It is fundamental to human settlement and development in the Northern Territory.

The IAH(NT) is concerned about the impact of a burgeoning unconventional shale gas industry on the groundwater and surface water environment of the NT. This position paper outlines those concerns and submits a range of recommendations aimed at developing the best possible approach to groundwater impact management.

The IAH(NT) recognises that the unconventional gas industry has the potential to greatly benefit the economy of the NT and the Australian nation, and is a component of the developmental program of Government. The potential value of this resource can be illustrated by the preliminary profit prediction data from current exploration activities of Armour Energy, the company's mean prospective resource is estimated to be worth many billions of dollars *(Armour Energy, NT Trade Commission presentation 19/5/2014*).

It is clear that the unconventional shale gas industry and its activities within the NT will require careful management to prevent unintended consequences to natural resources, human health, and to mitigate the risk of long-term environmental damage. Should current profit predictions be realised, the NT government should become sufficiently resourced from the proceeds of unconventional shale gas extraction to fund the effective long term management of the impacts of this industry on the groundwater environment of the NT.

In the next 25 years, tens of thousands of new unconventional gas wells may be drilled in the NT. IAH(NT) believes the potential exists for contamination of aquifers and surface waters should well integrity be compromised, and/or 'produce' water surface storage facilities fail. We are concerned that the deterioration and failure of improperly decommissioned (also known as 'abandoned') wells could, over time; result in long-term release of oil and/or gas into the environment.

It is important to note that because groundwater flow is slow, it can take decades or longer for contamination to become a recognised problem. Therefore, considering the impacts on shale gas on groundwater must be framed in the context of decades or even centuries.

The cost of well remediation is potentially high. In one instance, the cost to NT and Commonwealth governments to plug a deteriorated, leaking oil well (McDills), (following the responsible company's insolvency) in the Simpson Desert, was around $500,000. Even more expensive well plugging examples have been incurred in the US.

It is the IAH(NT)s view that a funding requirement on the owner of a gas well at a level that matches reclamation costs would provide the best mechanism to ensure maintenance of well infrastructure, reduce environmental impacts, and protect the Northern Territory from costly liabilities stemming from the failure of some gas wells. Mitchell and Casman (2011) investigated a range of mechanisms for generating the funds required to minimise the risk of adverse economic, environmental, and human health effects of improperly decommissioned shale gas wells. They concluded that generating the funds required directly from the revenue stream during the most lucrative years of gas production had the lowest impact on an operator's internal rate of return. IAH(NT) members recommend that this funding approach is adopted in the Northern Territory.

At present the Territory budget is severely limited and groundwater monitoring and assessment programs are constrained by lack of resources. Generally, the

groundwater environment of the NT is poorly understood. In addition, we believe that the NTG does not currently have the local skill set to effectively predict and manage the impacts of fracking on water resources.

Skilled personnel with expertise in the earth and water sciences will be required to adequately assess and manage the fracking impacts and ensure protection of vital water resources. These technical experts would ideally be assembled in a single agency to collate and assess data pertaining to unconventional shale gas development and operations and generate advice to regulators and industry.

In recognition of the NT's social and economic dependency on groundwater, the NTG needs to invest in strengthening institutional provisions and building institutional capacity for its improved management before groundwater resources and consumers are adversely impacted. The onus is on the NTG to produce a robust regulatory framework to achieve environmental and water resource protection.

Recommendations

Section 2.2 Financial mechanisms to manage risk of well failure and other environmental impacts

> *2.2.1 Funds adequate to match reclamation should be generated directly from the revenue stream during the most lucrative years of gas production. These funds should be held by the NTG to assure against any long-term liabilities from unconventional shale gas extraction.*

Section 2.3 Groundwater contamination from surface storages

> *2.3.1 The proponent should aim to treat and re-use the flowback and produce water within the fracking process. Storage should be in lined ponds with a flood immunity of 1,000 years.*
>
> *2.3.2 The QLD Dam Safety Regulations should be applied until such time as NT Dam Safety Regulations are developed.*

Section 2.4 High water demand for fracking

> *2.4.1 'High-value' aquifers as defined in Sections 1.2 should be avoided as groundwater sources for unconventional gas shale fracking operations. In the arid parts of the NT the use of scarce low salinity water and aquifers used for drinking water supplies should be avoided.*
>
> *2.4.2 Extraction of water for shale gas operations should be managed within National Water Initiative Principles as they may have significant impacts on local groundwater systems (Cook et al. 2013).*
>
> *2.4.3 Re-use and re-cycling of produce water should be the first source of water used by fracking proponents before any additional water allocations from natural water resources will be considered.*

Section 2.5 Ground water management issues

> *2.5.1 The groundwater data paucity in shale gas basins should be addressed through an investigation program funded through royalties from shale gas production.*
>
> *2.5.2 The NTG must invest in a skilled labour force and capacity building to be able to adequately manage and review permit applications and data provided by*

proponents and the on-going environmental risks/ impacts of the fracking industry.

Section 3 NT Legislation and the Protection of Groundwater Resources

3.1 IAH(NT) recommends that the outcomes of the Inquiry are fed into the ongoing water resources legislative reform to:

- *Ensure that the roles and responsibilities of the regulator and industry under new or revised legislation are clear;*
- *Advise whether the provisions under the Petroleum Act adequately cover the activities associated with the relatively new (for the NT) phenomena of hydraulic fracking;*
- *Review the penalties associated with overuse or pollution of water resources through fracking activities, commensurate with the cost associated with that overuse or pollution;*
- *Provide transparent and effective regulations and companion codes of practise to guide both industry and Government;*
- *Include Dam Safety regulations;*
- *Employ qualified Hydrogeologists in these regulatory fields; and,*
- *Clarify roles and responsibilities in legislation, and precedence of legislation.*

Section 4 The NT EPA's Proposed EIS approach to Hydraulic Fracturing Projects

4.1 An agency whose major business is water should be established within the NTG. This agency should be resourced with relevantly skilled experts who can facilitate a coherent legislative framework.

4.2 A comprehensive assessment of local and regional groundwater resources be undertaken prior to use by the fracking industry.

4.3 Pre-fracking groundwater baseline studies should include <u>measurement of natural methane levels</u> in groundwater.

4.4 Drilling and groundwater data from gas fields should be made available to the NT Water Resources division (Department of Land Resource Management) to facilitate better understanding of the groundwater environment of the NT.

4.5 Funds for the NTG to engage resources (internal and external) for the assessment of permit applications, resource assessments and impact assessments should be provided by proponents as part of the application fee and licensing process.

1 Introduction

1.1 The International Association of Hydrogeologists

The International Association of Hydrogeologists (IAH) is a professional association encompassing those disciplines related to groundwater, its occurrence, utilization, testing and management.

IAH was established to foster closer ties, cooperation and information exchange related to the study of groundwater and operates as a truly international scientific and educational organisation. The IAH is a non-government and non-profit organisation and is supported by over 3,500 members internationally representing over 135 countries.

The IAH has the following objectives:

1. To promote international and national cooperation between involved scientists and engineers.
2. To sponsor international and national technical/management meetings and symposia on hydrogeology.
3. To publish hydrogeological reports, papers and maps.
4. To establish investigation commissions and working groups to report on special topics.
5. To encourage the international application of relevant approaches and techniques for the benefit of the hydrological and human environment.

This submission focuses on the challenges facing water resource management in relation to hydraulic fracking in the NT and has been drafted by the members of the Northern Territory (NT) branch of IAH Australia. All contributors work in a professional capacity across a range of industries in the NT related to groundwater and surface water management.

Recommendations have been provided on how these issues may be addressed.

1.2 Significance of Northern Territory's groundwater resources

The Northern Territory is underlain by numerous aquifers. Due to the ancient nature of NT geology, and the aridity of central and southern NT, high-yielding, freshwater aquifers are uncommon, and consequently of very high value.

The groundwater systems of the NT are generally poorly understood due to the vast terrain, sparse borehole distribution and lack of imperatives for groundwater exploration. There are undoubtedly aquifers which remain undiscovered and unexplored. Bearing this in mind, the following describes the *known* major features of the NT groundwater environment relevant to this inquiry.

The groundwater systems of the top end vary in some key features from those in the arid central and southern regions. The monsoonal climate ensures that most top end aquifers are recharged every year in the wet season, resulting in groundwater of very low salinity. Thus, top end groundwater and surface water systems can be considered to be some of the freshest, most pristine waters in Australia and may be regarded as being of national significance.

Top end hydrogeology also features numerous sites where groundwater and surface water are highly connected, primarily where rivers intersect porous rock aquifers such as sandstones. This is indicated where perennial creek or river flow occurs such as for the Daly, Roper and Flora rivers and numerous Arnhem Land and Gulf river systems. These rivers continue to flow long after the rains have ceased because they receive groundwater flow from adjacent aquifers.

The groundwater-fed surface water systems of the NT are an important feature of the landscape, these include Berry Springs, Mataranka Springs, Redbank Gorge waterhole, as well as other innumerable sites scattered across the Territory. They are generally fully intact and associated with highly significant biotic assemblages of national and international significance, as recognised by the World Heritage Listing of Kakadu National Park. These biotic assemblages are also known as 'groundwater dependent ecosystems' *(http://www.bom.gov.au/water/groundwater/gde/).*

An interesting and unique feature of the top end groundwater-fed rivers systems are the 'tufa' dams as shown in Figure 2. Features like these and the Mataranka Hot Springs are major tourism drawcards.

The southern two thirds of the NT are located in the arid-zone where surface water resources are virtually non-existent. Unlike in the humid tropics, few arid-zone groundwater systems receive modern recharge. The groundwater in these systems was received in wetter climatic periods thousands and millions of years ago. The main water supply for Alice Springs, the Mereenie Sandstone aquifer, receives minimal modern recharge and as such the water take essentially 'mines' the groundwater resource. Thus, for many arid-zone aquifers in the NT, there is no 'sustainable yield' since the resource, once removed, will not be replaced.

The lack of modern recharge also means that groundwater in the arid-zone is commonly of poor quality, brackish to saline, with high concentrations of ions such as fluoride and nitrate. Where fresh groundwaters occur it is not unusual for salinity to increase downward with freshwater aquifers overlying brackish or saline aquifers. Current water bore construction methods are directed at maintaining strict separation between the freshwater aquifers and the (generally) underlying saline aquifers.

The ancient rocks of central and southern NT are generally of low porosity therefore aquifers in these areas are of limited extent. The central region of the NT is dominated by the extensive Georgina and Wiso Basins. The hard limestone and dolomite formations of these basins form aquifers where fractures are found and/or dissolution processes have led to the formation of karst. On the Barkly Tableland and the Sturt Plateau hundreds of bores tap these aquifers for the pastoral industry.

Overlying these ancient rocks, a relict drainage system in central Australia, referred to as 'palaeovalleys', contains groundwater which is of variable quality. Major central and southern NT industries including the Yulara Tourist resort, Ti Tree horticulture, Granites-Tanami gold mining and numerous settlements in southern NT depend entirely on fresh-water occurrences in the palaeovalley aquifers. The palaeovalley systems remain largely untested and unexplored.

In summary, good quality aquifers are difficult to find in central and southern NT, highlighting the value of any fresh, moderate-high yielding aquifers that can be found. Figure 1 shows the more extensive aquifers of the NT extent in relation to the currently known prospective unconventional gas areas in the NT.

The groundwater resources underlying the NT are critical for modern human settlement and development with the exception of the Darwin and Katherine areas where surface water is the main water supply. Users of groundwater include the towns of Tennant Creek and Alice Springs, over 100 remote communities, the tourism industry (e.g. Yulara), the mining and petroleum industries, the horticultural industry, and pastoral industry. Irrigation developments around Darwin, Katherine and Mataranka and the Douglas/Daly region all rely on groundwater from major karstic aquifers of the Daly Basin. Ti Tree Basin provides the water resource for the horticultural industry. In addition, the recreational and commercial fishing industries in the top end depend on the groundwater-fed flows to the major river systems to maintain aquatic ecosystem health and therefore fish stocks.

The NT Water Act (1992) governs the investigation, allocation, use, protection, controls and management of groundwater. Under this Act, groundwater use is managed by the NT Government. To date, seven Water Control Districts have been declared in areas where increasing usage has necessitated the need for closer management.

A process of consultation with existing water users and other stakeholders supports the development of 'Water Allocation Plans'. These plans create rules for the distribution of water between the different users. The environment is given priority as a 'water user'. Sustainable water use and maintenance of the natural environment are two of the main goals of allocation plans. With the increasing pressure for development of the resource and recent changes in rainfall patterns, good management of groundwater is critical.

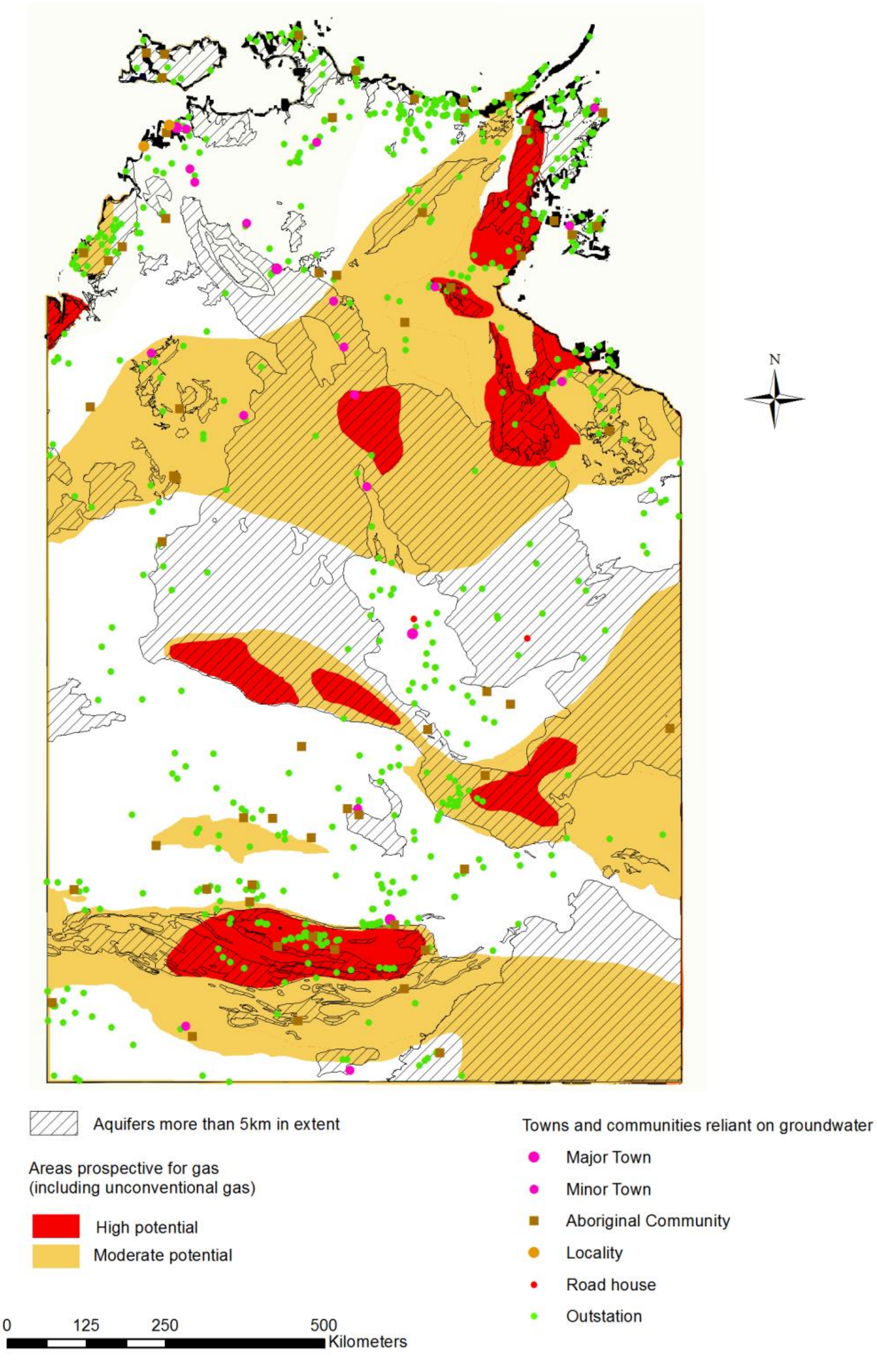

Figure 1: An overview of NT aquifers of >5km extent and prospective unconventional shale gas areas.

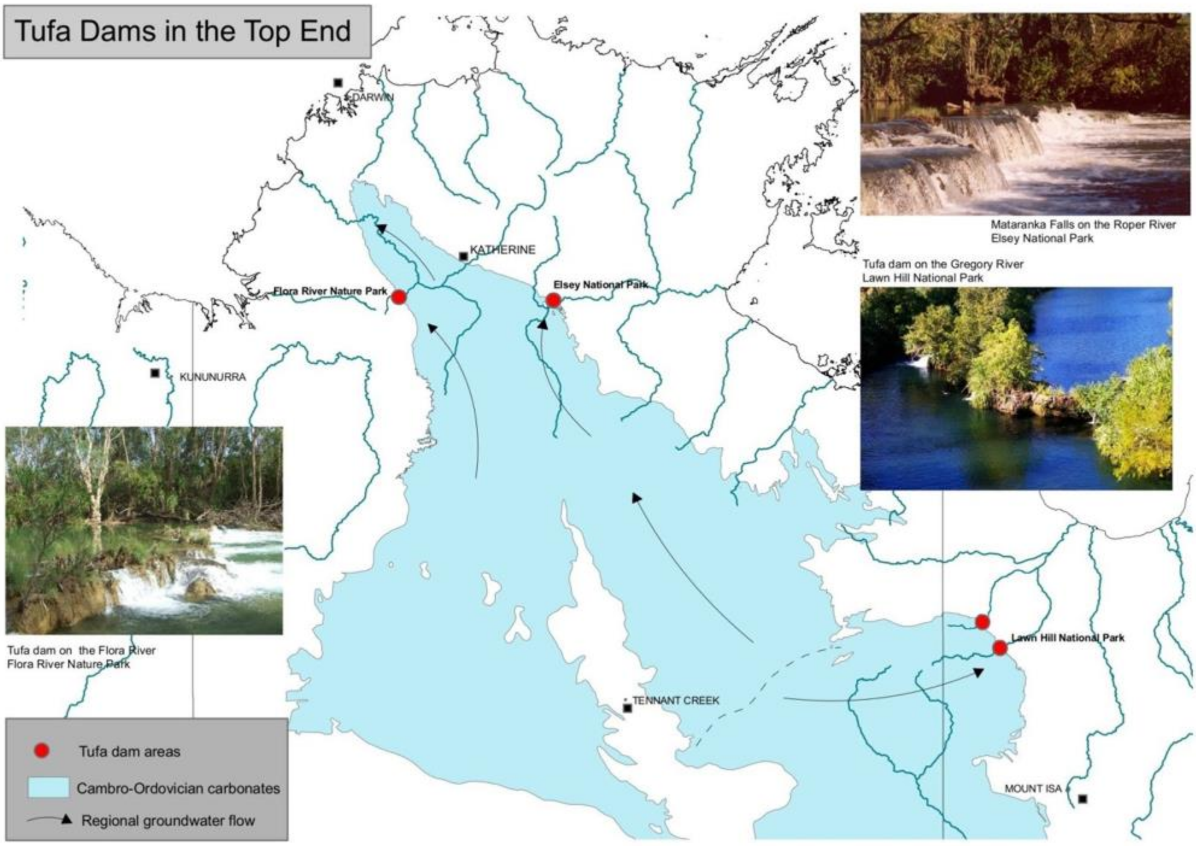

Figure 2.Major Cambro-Ordivician Aquifers, Regional Groundwater Flow Directions and the Location of Tufa Dams.

1.3 The Shale Gas Industry in the NT

Shale gas basins within the NT include the McArthur Basin, the Beetaloo Sub-basin, Wiso Basin, Georgina Basin, Amadeus Basin and Pedirka Basin (Figure 1). There may also be potential for coal seam gas within the Pedirka Basin (Munson, 2014).

Development of unconventional shale gas reserves in the Northern Territory is complicated by their remote locations, the great (>1000m) depth of the bores, the need for fracking due to the low permeability of the shale (as compared with coal seam gas) and the subsequent need for water to frack.

The potential demand on water resources for use in fracking operations in Australia has been estimated by the Canberra-based geoscience resource specialists 'Frogtech' (*FR*om *O*il to *G*roundwater) in its report *'The Potential Geological Risks Associated with Shale Gas Production in Australia'* commissioned by the ACOLA secretariat in 2013 as part of its report on the future of unconventional gas in Australia. Their water demand estimates, modified for the NT as some basins extend into other states, are presented in Table 1.

Basin	Basin Area (km^2)	No. Shale Gas wells	Total Water needed for fracking (GL)	Annual Fracking water demand (GL)	Ground-water Sustainable yield (GL/yr)	Ground-water extraction (GL/yr)
Amadeus	133,110	10,399	156	6.2	100	14
Georgina	228,120	17,849	268	10.7	171	9
McArthur	196,288	15,351	230	9.2	2,360	21
Wiso	154,310	12,126	182	7.3	116	4
All NT					**6,499**	**127**

Table 1: Estimated potential groundwater use per shale gas basin (Assuming well spacing of 800m, assuming 15 ML/well, 25 year well field life span) (from Frogtech, 2013) Table modified for the NT using Land and Water Audit 2001 data.

The economic potential for the use of hydraulic fracturing to develop hydrocarbon deposits in the Territory is very large. It is estimated that more than 67,000 shale gas wells may be drilled in these basins, with a combined water for fracking demand of more than 1,000 GL over the life of the bores (Frogtech, 2013). To put this in perspective, the annual groundwater extraction for the NT is estimated as being 127 GL.

The combined Best Estimate Recoverable Resource for the Amadeus, Beetaloo, Bonaparte, Georgina, McArthur and Pedirka Basins as summarised by Cook et al (2013) as totalling more than 140 tcf, and the combined Recoverable Resource to be more than 19 tcf. However, Cook et al. acknowledge that these resource estimates are constrained because (a) there has been little or no exploration or drilling in most basins, and, (b) the geology is not known in detail.

The NTG submission to the *Joint Select Committee's Inquiry into Development in Northern Australia* (February, 2014) recognises that land and water resources are critical to economic development. Indeed, the NTG submission acknowledges that there is a need to more fully understand earth (geology) and water resources through the NTG proposed partnership with COAG and other state governments to:

> '*invest in and accelerate the completion of investigations and research to fully understand Northern Australia's soil, vegetation, water and marine resources and development potential*' as well as '*…Northern Australia's minerals, oil and gas development potential*'.

The IAH(NT) supports this intent but in a modified form because it will not be possible to 'fully understand' water in the NT. More realistically, there will be an incremental increase in the understanding with an incremental decrease in the risk.

2 Hydraulic Fracturing and Groundwater in the NT

The following are considered by IAH(NT) to be the major groundwater-related concerns in regard to the proposed unconventional shale gas operations in the NT:

2.1 Decommissioned wells and 'well integrity' failure

Deterioration and failure of improperly decommissioned wells will, over time, result in long-term release of oil and/or gas into the environment. Pathways in the annulus may develop that would allow oil, gas, and brine to move vertically across geologic formations and contaminate groundwater. Substances dissolved in the brine may include those that occur naturally in the shale formations and others injected during the hydraulic fracturing process. Also upwardly migrating gas, known as stray gas, represents an explosion hazard if not properly vented away from buildings and drinking water wells.

The risk that annular pathways will develop increases over time as chemical, mechanical, and thermal stresses causes deterioration of well structures and components. Failure modes of improperly abandoned wells include the formation of cracks in the cement casing or packers, corrosion of steel production casing, faulty valves, and leaking temporary plugs or surface caps. A key paper on the causes of well failure (Dusseault et al, 2000) discusses cement shrinkage as the principle cause of well failure, particularly long after wells have been plugged and abandoned.

Estimates of well failure rates vary although the more conservative well failure rates found in the literature are between 4.6% and 8.9%. Further, a study from Alberta, Canada of more than 315,000 oil, gas and injection wells of various ages, (Watson and Bachu, 2009), shows that 'injection wells' into which liquids or gasses are pumped are 2-3 times more likely to leak than conventional 'production wells'.

The same study found that horizontal or inclined wells are observed to have significantly higher failure rates than vertical wells. It is universally acknowledged that problems with casing centralisation and cement slumping in horizontal or inclined wells may contribute to the increased incidence of leakage.(Council of Canadian Academies, 2014, Watson and Bachu, 2009).

A well-documented example of groundwater contamination caused by fracking operations from the USA occurred in Pennsylvania, USA (Osborn et al, 2011). It found that about 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. In addition, fracking-return fluids have also been known to contaminate drinking water, although the evidence is not as strong as for methane contamination (Horvath & Illgraffea, 2011).

Well integrity is of concern in the NT because some groundwater environments in the NT are naturally corrosive. An example of the effect of corrosive water on cementing and casing in the NT is provided by deep oil exploration wells (McDills and Dakota) drilled in the Perdika/Great Artesian Basin in the 1960s. (The Perdika Basin is one of the prospective unconventional shale gas areas of the NT). Now, some fifty years later, the steel casing has almost entirely corroded away, resulting in inter-aquifer contamination. This well required expensive rehabilitation works to stem artesian flow (Humphreys and Kunde, 2004). This single bore cost the Territory and Commonwealth Governments $500,000 to plug as the company responsible for the well was insolvent. This example highlights the issue of operator insolvency due to the boom and bust cycles of oil and gas development which complicate efforts to hold liable parties responsible and provide for timely environmental reclamation.

The McDills example could be considered to be an expensive example of what plugging a well can cost. The following example highlights that the McDills example is not unique. In Pennsylvania, in 2010, Cabot Oil & Gas Corporation estimated that it spent $2,190,000 to properly abandon three vertical Marcellus Shale gas wells.

2.2 Financial mechanisms to manage risk of well failure and other environmental impacts

Other Australian jurisdictions have considered financial mechanisms to address petroleum industry-related environmental impact concerns. For instance, one of the recommendations from the 2012 NSW Parliamentary Inquiry into coal seam gas operations:

> *'6.40 ...... They recommended that coal seam gas companies be required to pay 'high value (in dollar terms) and long term (50 years minimum)' security deposits, which would be refunded if long-term monitoring showed that there were no ill-effects of coal seam gas activities.'*

Commenting on the issue of how to hold coal seam gas companies to account for damage that may emerge many years, or decades, into the future, the National Water Commission called for the implementation of: *… 'bonds and sureties that deal with uncertainty and the timeframes associated with potential impacts'.* Given that these timeframes may extend for 100 or more years, current systems may need to be re-evaluated.

Events unfolding in relation to CSG in NSW demonstrate the imperative for the NT to plan for adequate time and money to be set aside to ensure ongoing well integrity to protect the NT environment.

The economic potential for the use of hydraulic fracturing to develop hydrocarbon deposits in the Territory is very large. Well head prices in the USA per thousand cubic feet of gas have varied between $2 and $6 over the last 15 years with occasional peaks over $8. While in Europe and Australia the price has varied between $3 and $10 over the last 15 years with occasional peaks over $10.A trillion cubic feet of gas equates to 1,000,000,000 thousand cubic feet. Armour Energy's 18.8 Trillion Cubic Feet of unconventional gas Mean Prospective Resource in the NT would have a wellhead value that over the past 15 years could have had a value of between $37.6 billion and $188 billion depending on the market the gas is exported to and the time the gas was sold.

In the Territory, petroleum royalties are 10% of the gross value at the wellhead of all petroleum products produced from a licence area as well as application fees and annual fees. The Territory government must ensure that some of the funding generated from these fees and the 10% royalty is used to develop a compliance program that effectively manages both the short and long term impacts on groundwater of development that utilises hydraulic fracturing to develop the Territory's hydrocarbon resources.

It needs to be highlighted that in the unconventional gas industry economics are dominated by high initial gas production rates. In some unconventional gas fields more than 80 % of the net present value of gross revenue may be realized in the first 10 years of a well with a projected life of 40 years, or more. The steep decline in production may drive divestment of assets by primary exploration and production companies well before the expected closure of an unconventional gas well. This may result in the transfer of marginally producing assets to a smaller independent operator who may not be able to fund the effective reclamation of a well.

It is the view of the IAH(NT) that a funding requirement on the owner of a gas well, at a level that matches reclamation costs, would provide the best mechanism to ensure maintenance of well infrastructure, reduce environmental impacts, and protect the Northern Territory from costly liabilities stemming from the failure of some gas wells. Mitchell and Casman (2011) investigated mechanisms for generating the funds required to minimise the risk of adverse economic, environmental, and human health effects of improperly abandoned shale gas wells. They concluded that generating the funds required directly from the revenue stream during the most lucrative years of gas production had the lowest impact on an operator's internal rate of return. IAH(NT) members recommend that this funding approach is adopted in the Northern Territory.

Recommendations:

> *2.2.1 Funds adequate to match reclamation should be generated directly from the revenue stream during the most lucrative years of gas production. These funds should be held by the NTG to assure against any long-term liabilities from unconventional shale gas extraction.*

2.3 Groundwater contamination from surface storages

'Flowback' is the excess fracking fluid, water and proppant that returns to the surface once the hydraulic fracturing event is complete and the pressure is released. 'Produce water' is that which returns to the surface in mixture with oil and gas. Approximately 30-70% of the fracking fluid injected into the shale is recovered and the gas is extracted from this fluid.

The recovered fluid is generally temporarily stored in sealed dams near the well (for evaporation and subsequent burial), or in above ground tanks for re-use in future hydraulic fracturing treatments. From there the water may be treated in a number of different ways including desalination, transport to another location, mixing with surface water or reinjection into decommissioned wells (common in the US) or saline aquifer.

In Australia, groundwater was found to be contaminated recently 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. The EPA fined Santos $1,500 for the pollution incident, however, the cost of cleaning up contaminated groundwater would far outweigh these sorts of fines. (http://www.miningaustralia.com.au/news/santos-csg-project-contaminates-groundwater)

Safe containment, treatment and disposal of wastewater at the surface is particularly difficult in the monsoonal north. There have been a number of mine sites in the top end where surface containment of waste water has failed (Ranger Uranium Mine, Redbank Copper Mine, Mt Todd Gold Mine).

One of the problems with trying to manage containment dams in high rainfall areas is that the NT currently has no dam safety regulations.

The key concerns of the recovered fluid are:

- unregulated release to surface and groundwater resources and subsequent impact on the aquatic environment
- leakage from on-site storage ponds leading to groundwater and surfacewater contamination
- improper pond construction, maintenance and decommissioning
- incomplete treatment
- spills on-site and
- waste water treatment accidents.

Recommendations:

2.3.1 The proponent should aim to treat and re-use the flowback and produce water within the fracking process. Storage should be in lined ponds with a flood immunity of 1,000 years.

2.3.2 The QLD Dam Safety Regulations should be applied until such time as NT Dam Safety Regulations are developed.

2.4 High water demand for fracking

Fracking is highly water intensive. An estimated average of 15 megalitres is required per well (Frogtech, 2013). A well field may consist of hundreds or thousands of wells each using this amount. Frogtech calculated the groundwater requirement for potential shale gas fields in the NT as shown in Table 1.

Unregulated pumping of large volumes of water from an aquifer may induce drawdowns which adversely affect other users and the surface water environment.

Over allocation due to fracking industry water demands may become deeply problematic in the NT, which, apart from parts of the Top End, is largely devoid of surface water resources. Most of the shale gas resources in Australia are located either wholly or partly within the arid and semi-arid zone. Groundwater will often be the sole water resource available for fracking. In these areas, natural groundwater recharge rates are particularly low. For instance, the water requirement for the proposed unconventional shale well field in the Beetaloo Sub-basin may impact other users, such as the pastoralists, who depend on water resources in the overlying limestone aquifers for stock watering.

Recommendations:

2.4.1 'High-value' aquifers as defined in Sections 1.2 should be avoided as groundwater sources for unconventional gas shale fracking operations. In the arid parts of the NT the use of scarce low salinity water and aquifers used for drinking water supplies should be avoided.

2.4.2 Extraction of water for shale gas operations should be managed within National Water Initiative Principles as they may have significant impacts on local groundwater systems (Cook et al. 2013).

2.4.3 Re-use and re-cycling of produce water should be the first source of water used by fracking proponents before any additional water allocations from natural water resources will be considered.

2.5 Groundwater management issues

The value of groundwater must reflect its true place in our society. In the NT there is virtually zero cost recovery for groundwater management. Fees and charges which reflect the level of groundwater management required to effectively manage the impacts on groundwater from hydraulic fracturing for hydrocarbon deposits are called for. This cost should be borne by both the industry using the technology and the NTG which benefits from the royalties obtained once production commences.

As outlined in section 2.2 above, with the high economic potential of shale gas development, it is necessary that funds acquired directly from the revenue stream be available to resource rectification of legacy issues, including well plugging, if required.

Most water bores in the NT are relatively shallow (<150 m). For this reason, any deep groundwater systems which gas wells may intersect, are largely unexplored. The few exceptions include the GAB and Amadeus Basin. Therefore the geology and the hydrogeology, particularly of deeper aquifers, is not well understood. It is evident that to determine potential impact of hydraulic fracking activities across these Basins, there needs to be much improved hydrogeological conceptualisation which requires investment in assessment.

Over the last few decades, the number of experienced NTG hydrogeologists has declined due to changing funding priorities. This has reduced the collective local knowledge base and experience. That knowledge base is needed to support the management and assessment of groundwater issues related to the approaching boom in unconventional gas extraction in the NT. This, coupled with the paucity of data and understanding of groundwater systems of the NT means that, at present, the NTG does not have the capacity to make well informed decision on these matters.

Examples from Queensland (Qld) and New South Wales (NSW) show how those jurisdictions have funded data gathering and investigations to develop baseline assessment plans (Qld), compliance plans (Queensland: CSG/LNG Compliance Plan) and strategic water resource management plans (Queensland: CSG Water Management Policy 2012; New South Wales: NSW Aquifer Interference Policy).

Recommendation:

2.5.1 The groundwater data paucity in shale gas basins should be addressed through an investigation program funded through royalties from shale gas production.

2.5.2 The NTG must invest in a skilled labour force and capacity building to be able to adequately manage and review permit applications and data provided by proponents and the on-going environmental risks/ impacts of the fracking industry.

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3 NT Legislation and the Protection of Groundwater Resources

Under the current legislative framework, the protection and use of water resources in the NT is administered by several agencies through a range of NT legislation. All aspects of water resource protection and use are covered under the Water Act but limitations are placed on its application to mining and petroleum activities. Water resource protection and use directly associated with mining and petroleum activities are covered under the Mining Management Act and the Petroleum Act.

It is well understood that unconventional gas extraction can be a water resource intensive activity. And yet, *petroleum activities are exempt from the need for licensing under the Water Act for extraction and use of surface water and groundwater*.

Pollution of water resources is prohibited under the Water Act unless licensed under this Act, but this conditional prohibition does not apply to wastes that are confined to a mining or petroleum site. Pollution of water resources is prohibited under the Waste Management and Pollution Control Act, but this prohibition does not apply to waste from an authorized petroleum pipeline or within 1km of the pipeline.

Petroleum activities must comply with permits and licences granted under the Petroleum Act. Permits and licences include conditions that the activities cause as little environmental disturbance as possible and the escape or release of petroleum must be approved. As defined in this Act, environment includes water and is not confined to the site of the activity.

Offences and penalties for unlawful pollution or waste disposal into water resources across the other Acts are consistent with the Environmental Offences and Penalties Act. Accordingly, penalties range from $5000 for causing environmental nuisance to up to $1,250,000 for intentionally causing serious harm to the environment. As outlined above, the cost of plugging for a single well could cost $500,000 although this figure is poorly constrained. The costs of remedying other impacts outlined above are also difficult to constrain.

The ability to protect the environment from pollution caused by hydraulic fracking, and to manage the allocation of potentially scant freshwater resources in basins where fracking occurs, is dependent on robust and clear legislation. It is recognised that there are both gaps and duplication in NT legislation for the protection and use of water resources, and indeed the NTG's Water Directorate is addressing this problem through legislative reform.

Recommendations:

3.1 IAH(NT) recommends that the outcomes of the Inquiry are fed into the ongoing water resources legislative reform to:

- *Ensure that the roles and responsibilities of the regulator and industry under new or revised legislation are clear;*
- *Advise whether the provisions under the Petroleum Act adequately cover the activities associated with the relatively new (for the NT) phenomena of hydraulic fracking;*
- *Review the penalties associated with overuse or pollution of water resources through fracking activities, commensurate with the cost associated with that overuse or pollution;*
- *Provide transparent and effective regulations and companion codes of practise to guide both industry and Government;*
- *Include Dam Safety regulations;*
- *Employ qualified Hydrogeologists in these regulatory fields; and,*
- *Clarify roles and responsibilities in legislation, and precedence of legislation.*

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4 The NT EPA's Proposed EIS approach to Hydraulic Fracturing Projects

It is understood that the NT EPA is depending on the hydraulic fracking inquiry to evaluate the potential for environmental impact from fracking in different parts of the NT by comparing the geological settings with areas elsewhere in Australia and internationally where shale gas has been explored. Due to basin geology variability and other factors, care should be taken when extrapolating hazard magnitude and frequency from the US experience and applying it to the Australian environment.

To be able to evaluate environmental impact risk, it is necessary to conceptualise the geology and hydrogeology just as is done for a mining application. The level of potential environmental impact may not be commensurate with the footprint of the development; i.e. the impact that a mine might have on ground water and surface water availability and quality is not necessarily always greater than that for an unconventional gas production well. This calls for a rigorous environmental assessment process that can consider the risks associated with individual wells in addition to cumulative impacts of a wellfield, rather than a blanket EIS for an entire basin. Understanding of the cumulative impacts of fracking project operations should be incorporated into the environmental impact assessment process.

The NTG is a signatory to the Intergovernmental Agreement on the Environment and has adopted the National Strategy for Ecologically Sustainable Development (ESD). The NT EPA take a lead role in ensuring the principles of ESD guide policy development and decision making in the development of the NT. The NT relies heavily on groundwater shallow and intermediate aquifers for community, potable water, horticulture, agriculture, industrial, cultural and stock and domestic water supplies. Investment in access to good quality groundwater made by those for these beneficial uses should not be undermined and put at risk.

Consistent with the principles of ESD, the onus and cost to demonstrate the potential level of environmental impact should remain with each proponent and not with the NTG and NT taxpayer.

It should be noted that the scope and effort needed to obtain the background data so that potential ground and surface water impacts of any development can be properly assessed are significant research undertakings in their own right. For instance the compilation and assessment of water data the IESC guidelines (IESC 2014) consider necessary to begin to evaluate coal seam gas developments is extensive and therefore likely to be a major financial outlay by the development proponents.

In recognition of the NT’s social and economic dependency on groundwater, the NTG needs to invest in strengthening institutional provisions and building institutional capacity for its improved management, before it is too late and groundwater resources and consumers are adversely impacted.

An agency whose major responsibility is water management should be established by the NTG. This agency must work flexibly with local stakeholders as partners in resource administration, protection and monitoring, whilst also acting on broader water resource planning and management strategy. Such an agency might also be expected to take responsibility of review of development proposals from a water perspective.

For instance, one crucial part of the whole fracking process is the assessment of environmental impacts of proposed developments. The NSW (2012) parliamentary enquiry discussed the potential for perceived bias by the public if environmental impact assessment is conducted and paid for by the proponent gas companies. The committee, however, believed it was not feasible due to a lack of resources for the NSW Government to undertake the research to assess environmental impacts of coal seam gas projects. Instead the NSW parliamentary committee took the view that

> *'6.89 The Committee considers the central issue to be not who does the research, but whether the NSW Government has sufficient officers with the necessary skills to effectively peer review environmental assessments, and therefore supports transparent Government review of environmental assessments of coal seam gas proposals.'*

This consideration illustrates the need for adequate groundwater expertise to be set up within a NT Government Agency.

Other jurisdictions have created and built up specific technical expertise in such agencies, for example the Office of Groundwater Impact Assessment in Queensland, or the Office of Water in New South Wales. It is noted here that the Department of Mines and Energy in the NT, the regulatory body for unconventional gas projects, has no in-house groundwater technical expertise, neither does the NT EPA which is responsible for assessing environmental impacts as described above.

Reform of existing NT legislation and regulations is required to address the lack of a robust framework to assess and manage the potential impacts of unconventional gas development on the NT’s water resources. This includes bringing water use for fracking into the water allocation planning framework, in line with the National Water Initiative framework. It may also include aligning the guidelines around shale gas bores and water bores to reduce bureaucracy whilst ensuring robust guidance for the drilling, testing, construction, rehabilitation and decommissioning of all wells that intersect aquifers.

It is noted that, in other jurisdictions where fracking and unconventional gas exploration and production is more developed and there is more data to assess fracking environmental impact, legislation and regulation has become more stringent with time (Hoare and Finn, 2014). This presumably indicates that the impacts of CSG and fracking are greater than expected, whether because of the process or because of the cumulative effect.

The notion of commercial-in-confidence should not apply to any ground and surface water data generated by the petroleum industry in the NT. These data should be reported and made accessible to the public as a matter of course.

Given the more advanced position of other states, this is an opportunity for the NT to develop its own legislation and regulation, with advice from other jurisdictions, whilst also recognising the NT situation where the variables are shale gas rather than CSG; data paucity; and semi-arid to arid to sub-tropical environments etc. The IESC guidelines which outlines the scope and extent of background surface and groundwater data needed to assess coal seam gas, should serve as a guide to the rigour required by frack gas proponents in the NT.

Furthermore, other relevant data from interstate should also be reviewed for guidance. The NSW Chief Scientist background papers commissioned for CSG review are also relevant to the NT as they deal with most factors that should be considered in fracking hydrocarbons and developing CSG. No doubt other reviews from Australia and overseas are also likely to be relevant to the NT.

Recommendations:

4.1 An agency whose major business is water should be established within the NTG. This agency should be resourced with relevantly skilled experts who can facilitate a coherent legislative framework.

4.2 A comprehensive assessment of local and regional groundwater resources be undertaken prior to use by the fracking industry.

4.3 Pre-fracking groundwater baseline studies should include measurement of natural methane levels in groundwater.

4.4 Drilling and groundwater data from gas fields should be made available to the NT Water Resources division (Department of Land Resource Management) to facilitate better understanding of the groundwater environment of the NT.

4.5 Funds for the NTG to engage resources (internal and external) for the assessment of permit applications, resource assessments and impact assessments should be provided by proponents as part of the application fee and licensing process.

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