Presentation to
2017 NT Fracking Inquiry

Dr Errol Lawson

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Curriculum Vitae

1960-1987: Engineer with the Defence Science & Technology Organisation -final appointment Chief of Communications & Electronic Engineering Division

1987-1991: Director Defence & Aerospace Industry Development SA Government-Major projects were Collins submarine, ANZAC ships, JORN

1991-2001: Consultancy practice to Defence, DSTO & Defence Industry.

2001-2005: Research into Social Systems of novel & complex socio/technical engineering projects. PhD awarded in 2005

2005-2013: Develop and deliver course in novel & complex socio/technical systems. Adjunct Associate Professor with Systems Engineering Institute of University of South Australia

NOTE*
This submission updates and extends the Presentation made by Dr Errol Lawson to the Scientific Inquiry into Hydraulic Fracturing at Katherine on 8th March 2017.
The submission includes new material but follows the same sequence of sections as the earlier presentation.
Note also that the format has changed from Power Point to Word

PURPOSE OF PRESENTATION

- To discuss potential sources of contamination of the Tindal aquifer occasioned by a shale gas industry through all stages from Exploration to Completion and beyond
- To position potential sources of contamination on a Risk analysis matrix
- Primarily of relevance to Terms of Reference 1.

The Tindal aquifer is part of the Cambrian Limestone Aquifer system. The Katherine community is accustomed to refer to the Tindal aquifer rather than the Cambrian Limestone aquifer system. The Katherine Region supports aboriginal communities, townships, and a number of industries; some are sustainable for example tourism, pastoral, agriculture and horticulture, some, for example mining, have a limited life. All are dependent on the aquifer system for water during the 6 to 8 month Dry season. In meeting after meeting concern at the prospect of a production gas industry focuses on the risk to the aquifer system. This presentation concentrates on the potential sources of contamination of the aquifer. I leave the issue of over allocation and depletion of the aquifer to others, noting that the greater aquifer system is not baselined neither in sustainable discharge nor interconnections.

To date much of the interaction between interested parties and the gas industry has been confined to the Exploration phase. This presentation looks into the far future when the gas resource is depleted and no longer commercial, the gas industry has left, but the existing social, economic and environmental eco-system, dependent as it is on the aquifer for water during the DRY season, remains. The gas industry may have departed the Region but any contamination as a consequence of their activities remains.

This presentation follows the Risk Matrix approach as described in section 7 of the Background and Issues Paper of 20 February 2017.

ToR 1: assess the scientific evidence to determine the nature and extent of the environmental impacts and risks, including the cumulative impacts and risks , associated with hydraulic fracturing of unconventional reservoirs and the Associated Activities in the Northern Territory

Ref: Regional groundwater modelling of the Cambrian Limestone aquifer system of the Wiso Basin, Georgina Basin and Daly Basin. Report No. 29/2006A Anthony Knapton, Land and Water Division. Alice Springs.

Potential risks of hydraulic fracturing Unconventional Gas:

Presentation by Damien Barrett CSIRO to Community Meetings Darwin & Katherine 21/22 November 2013

- Surface transportation spills
- Well casing leaks
- Connectivity through rock fractures
- Drill site discharge
- Wastewater disposal
- Retention pond release

Largest risk:

- Wastewater disposal
- High epistemic uncertainty
- High flow back volumes
- Large number of wells

Rozzell and Reaven (2012) Water Pollution Risk Associated with Natural Gas Extraction from the Marcellus Shale. Risk Analysis, 32, 1382-1393

This list is extracted from a presentation by the then Dr (now professor) Damien Barrett of the CSIRO to a community meeting in Katherine on 22 November 2013.

This presentation analyses three of the potential risks to aquifers identified by Dr Barrett;

Well casing leaks-contamination from below

Wastewater disposal and **Retention pond release**-contamination from above

For this submission, an EVENT is defined as either migration to the aquifer of gas, fluids or solid matter from the fracked shale bed or spillage at the surface works.

The LIKELIHOOD (horizontal axis) is usually expressed as the Probability of the events occurring, where in this case, and for the purposes of Risk Analysis, the probability of the EVENT is the probability of a single well casing leakage multiplied by the number of wells.

The IMPACT (vertical axis) is contamination of the aquifer so as to render it unsuitable for any of human consumption, stock watering, agriculture and horticulture, fisheries, and tourist activities.

The time frame for the potential of the risk is set at 100 years as that is well after the gas companies have left but the sustainable industries and the associated communities intend to remain.

Amendment to page 4 of Presentation Version 4 (Revised 19 March 2017) to 2017 NT Fracking Inquiry (Dr Errol Lawson)

Well Casing Leaks

For a gas industry to have no lasting effect on the several sustainable industries and permanent communities that rely on the Tindal aquifer, inter alia, the wells to extract the gas must maintain integrity into the distant future, ideally in perpetuity.

- Gas Industry fracking processes require drilling down to the shale bed through the Tindal aquifer and establishing well integrity by the application of cement to seal the space between the casing and the surrounding geological structure.
- In order to place the EVENT (as defined previously) on the LIKELIHOOD Axis it is necessary to know, or have an estimate of, the number of wells in a production gas field, as well as the long term failure rate.
- The most recent figure available is the estimate by Dr Close in the Origin Energy presentation of 10 March of 50 well pads on 500sqkms as typical well pad density to access the Betaloo sub basin.
- The Betaloo sub-basin is part of the larger Middle Velkerri B basin.
- The notes below derive a figure for the maximum number of multi-pad wells in the Middle Velkerri B basin as between 19,800 and 33,000.

Estimate of the potential number of wells in the Middle Velkerri B Basin:

Dr Close's presentation to the Inquiry on 10 March included a figure of 50 well pads in a 500sqkm area as representative of well pad density for a production gas field over the Betaloo sub-basin.

Average Area per well pad (500/50)	10 sqkm/well pad
Well pads spacing	3.2km
Well pads per square kilometre (50/500)	0.2
At 6-10 wells/pad, fracked wells on 500sqkms	300 to 500
Area of Middle Velkerri B shale	16145sqkm
Potential number of wells pads over Middle Velkerri B	(16145 X 0.2) = 3300

At 6-10 wells per pad, the number of fracked wells could be between 19,800 and 33,000. This is the order of the number of fracked wells penetrating the aquifer and ultimately abandoned by the gas industry. Well pads spaced on the surface at 3.2km present an industrial scale development spreading uniformly across the Basin.

NOTE: In the absence of any information on "sweet spots" an assumption in the analysis above is that gas concentration is uniform throughout the shale deposit. The Falcon Oil and Gas Pty Ltd report **"Beetaloo Basin Drilling Results Indicate Material Gas Resource-Results of the 2016 Exploration Drilling and Testing Program"** mentions "sweet spots" but gives no quantitative information.

Failure Rate

Risk is directly related to rate of failure of well integrity. Dr Anthony Ingraffea (ref 2) states US failure rates of 5% initially, 60% over 20 years and eventually most fail. My difficulty with Ingraffea's presentation is that the 5% rate of loss of well integrity "soon" and 60% rate of loss of integrity with age apply to data on offshore wells extracted from reference 5 (dated 2003) and no time line is attached to "eventually."

The US EPA reports could be expected to be rigorous and impartial. They may be the closest to that ideal available. In the December 2016 report "Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States." (Ref 3), Table 10.1 gives rates of integrity failure for four onshore locations using data mainly from the 2008 to 2013 timeframe. The time lag in publication demonstrates the problems of long delays in provision of data to the EPA and/or delays in analysis, publication, peer review, amendments and final publication. The final Key Finding is:

In an estimated 0.5% of the approximately 28,500 hydraulic fracturing jobs surveyed, a failure occurred during hydraulic fracturing such that there was no additional barrier between the annular space with fluid and the protected drinking water resource.

The figure of 28, 500 is derived in the EPA 2016 Report (ref 4), "Review of Well Operator Files for Hydraulically Fractured Oil and Gas Production Wells: Hydraulic Fracturing Operations. Office of Research and Development, Washington, DC. EPA/601/R-14/004.

The Summary in the Review of Well Operator Files includes the following on Well Integrity:

Well integrity failures during hydraulic fracturing [0.5 (0.1-2) percent of the hydraulic fracturing jobs]. In these cases, well components (e.g., casing, cement, or packers) failed during hydraulic fracturing, and no additional casing or cement barriers separated the well components that failed from the operator-reported protected ground water resources.

There is consistency between the two EPA reports of 0.5% failures during fracturing, with the additional refinement in the "Review of Well Operator Files" of 95% confidence levels.

Failure rate figures such as these must be treated cautiously as they seem to be derived over a number of plays in the US and also over a number of years, during which the industry, driven by cost and pressure to maximise the success rate and increase productivity, could be expected to improve its performance. The EPA failure rate figures are derived from cumulative statistics with no filtering or adjustment for location, age of wells or maturity of the fracking process and apply only to the hydraulic fracturing stage.

However it seems safe to say:

- During fracturing some well components (e.g., casing, cement, or packers) will fail.
- Well casing leaks will show progressively in 5% of wells during early production
- A higher percentage will fail over 20 years
- Figures beyond 20 years are not available

There are a number of factors which can cause loss of integrity which make the effort nugatory to seek a set of failure rates for; during fracturing, during production, and beyond abandonment.

The assessments of Risk are polarised between the industry which has a time horizon of the commercial life of the gas measured in a few decades, and the communities and industries in and around the gas field, whose interests, especially the issue of aquifer contamination, are permanent.

There can be no doubt that wells do loose integrity and contamination can occur to overlying aquifers. Failures occur so frequently that they have their own acronym, SCVF/GM short for Sustained Casing Vent Flow/Gas Migration

In the following sections to relate failures to causes I turn to first principles and examine the environment to which a gas well is exposed.

References:

1. Natural Resources Exploration FINAL REPORT NUTWOOD DOWNS (EL 27877) NUTWOOD DOWNS EL27905 – FINAL REPORT | 27/07/2010 to 18/07/2013
2. Shale Gas Development: Leaks and Vents A. R. Ingraffea Dwight C. Baum Professor Cornell University and Physicians, Scientists, and Engineers for Healthy Energy, Inc. Northwestern University April 18, 2013
3. U.S. EPA (U.S. Environmental Protection Agency). 2016. Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States. Office of Research and Development, Washington, DC. EPA/600/R-16/236Fa.
4. U.S. Environmental Protection Agency. 2016. Review of Well Operator Files for Hydraulically Fractured Oil and Gas Production Wells: Hydraulic Fracturing Operations. Office of Research and Development, Washington, DC. EPA/601/R-14/004.
5. Brufatto *et al*., *Oilfield Review*, Schlumberger, Autumn, 2003

The Environment

The seal is exposed to an environment characterised by:

- MECHANICAL SHOCK and VIBRATION
- HIGH TEMPERATURE
- THERMAL SHOCK
- MOISTURE
- SALT/CORROSIVE ENVIRONMENT
- PRESSURE DIFFERENTIAL
- TEMPERATURE DIFFERENTIAL
- EARTH MOVEMENTS
- AQUIFER(S)

Throughout my experience in engineering for Defence I encountered all of these environmental factors, except Earth Movements. This is without doubt a very severe environment and my first thoughts as an engineer/designer are;

1. Design and proving a project operating in that environment is at the high risk end of the engineering spectrum,
2. what are the consequences of failure,
3. a “recovery from failure” sub-system may be needed to be built in,
4. real time monitoring may be necessary,
5. is in situ maintenance/repair required,
6. how will the design be proven,
7. how long is the system expected to work for, days, months decades?

The answer to the last question will determine the total system cost and development time scale and bear heavily on the commercial decisions of the client. It will also determine if the “mays” in items 3 and 4 become “shoulds”.

Life Cycle/Failure Mechanisms

After a well is drilled it is cased with concentric hollow steel tubes. All gaps between successive tubes and the final gap to the surrounding rock/earth is progressively filled with cement extruded from the bottom up to re-establish a barrier between any mobile gas, liquids or solids released by the bore well and other strata and the surface. The following outlines the life cycle of a gas well and the conditions to which the critical metal to cement seal is exposed Points of potential failure are discussed. The sequential stages in the life cycle of a producing well are:

- Inject the cement
- Perforate the horizontal casing
- Frack the shale in stages
- Gas flow
- Plug the casing

Cement injection

In workshop conditions, cleanliness and metal surface priming is essential for good uniform bonding between two different materials. This ideal is not possible where a steel casing is inserted some 1000s of metres into the earth; complete metal-cement contact over entire casings length is essential but difficult, maybe impossible. It is possible for the cement to pick up debris from the bottom of the bore eg, drilling mud, grease, loose rock and earth. It is highly unlikely that the bonding between the steel and the cement would be uniform and at full strength. Voids above a certain size can be detected by suitable instrumentation. But areas of contact where the bonds are weak or there is no bonding would be hard to detect. The annular gap is typically 2.5cm (1 inch), which requires the casing to be placed concentrically in the bore otherwise some sections of the cement sheath will be too thin to achieve structural strength. Depending on the absorptive characteristics of the bore hole, water may be drawn out of the cement mix resulting in weakening of the cement.

The conclusion is that the process cannot be guaranteed to achieve 100% bonding between the steel casing and the cement. Nor can cement of uniform strength and nominal thickness be guaranteed. This is based on the characteristics of the cement described in industry presentations to the general public of the NT. Other cement preparations are available.

The mining services companies of Halliburton and Schlumberger both have developed Self-Healing cement and Thermally Responsive cement. The three references below show that the companies have been aware for some years of the propensity of the cement-to-casing and the cement-to-rock seals to fail and provide a path for gas migration as the following extract from reference 3 (2009) shows:

> *Cement sheath is a critical piece when constructing a well for long-term competence. The ability of the cement to block annular fluid flow has both economical and environmental implications. Examples of uncontrolled movement of formation fluids through a leaking cement sheath include unwanted water migrating to the perforations, hydrocarbons escaping to a lower-pressure reservoir, and hydrocarbon-based fluids flowing to environmentally sensitive water zones or to the surface.*

As the extract below from reference 1 shows, FUTUR self-healing cement is promoted on the basis of its ability to perform “into abandonment”.

> , *FUTUR cement self-heals from the time it is placed until the end of the well’s operational life and into abandonment*

This is an example of the different timeframes of the gas industry and that of the communities; the former short term, the latter long term.

References:

1. FUTUR Self-Healing Cement System (Schlumberger)
2. Thermastone Thermally responsive cement system (Schlumberger)
3. Dynamic Test Evaluates the Effectiveness of Self-Healing Cement Systems in the Downhole Environment. Authors; Robert Phillip Darbe (Halliburton Energy Services) | Jeffery Karcher (Halliburton) | Keith Pewitt (Halliburton): Society of Petroleum Engineers Middle East Drilling Technology Conference & Exhibition, 26-28 October, Manama, Bahrain Publication Date 2009

Perforation

Perforation is achieved when an explosive device administers a shaped pressure pulse rising to tens of thousands of psi within microseconds to stages of the production casing in the horizontal leg. The object is to punch holes in the casing through which gas from the formation will escape to the surface. Just as a hammer on a railway line can be heard some distance away, this shock would be propagated along the casing. There are as many explosive shocks as there are stages causing stress of the boundary layer and relative movement between the two rigid materials, steel and cement. In practice the perforation channels penetrate the shale 6-18 inches. During the fracking process the induced fractures spread out from these channels

The material presented to the NT communities is devoid of any information on Perforation. It is conflated with the subsequent stage of fracturing the formation. It as if Perforation is a straightforward operation with the technical details settled and stable long ago and of no great significance to the success or failure of the well. A literature search reveals that as a process Perforation is neither settled nor stable but has been subject to continuous development and is critical to the subsequent yield of gas from the target formation.

References 1 and 2 below, (the first dated 1999 and the second 2011), indicate the perforation process is experiencing continuous evolutionary development.

Reference 3 has a comprehensive review on the history of fracturing up to 2006. Of particular interest is the discussion of under and over pressure, that is the pressure differential between the casing and the formation. Some Perforation instruments are designed such that immediately after the initial shaped charge explosion punctures the casing and cement sheath opening a channel into the formation, the pressure in the casing, the underpressure, drops in less than a second. The reversal of pressure cleans out the channel from the products of the explosion which if not removed increase the resistance to gas flow and reduce the productivity of the well.

Ref 1 Apparatus and method for orienting a down hole tool in horizontal or deviated well. US Patent US 5964294 A Schlumberger Technology Corporation. Publication date 12 Oct 1999

Ref 2 Perforating Gun Assembly and Method for Controlling Wellbore Pressure Regimes During Perforation. US Patent 20110000699 A1; Halliburton Energy Services. Publication date Jan 6, 2011

Ref 3. The Search for Perfect Perforations. Middle East & Asia Reservoir Review Number 7 2006

Frack the shale in stages

Except for an initial plug of hydrochloric acid to clear the residue of the Perforations, the Fracking fluid is mostly water plus sand, injected from the surface into the horizontal leg by stages. The temperature of the fluid as enters the casing is the ambient at the surface, say less than 50 degrees. As it enters the horizontal leg it encounters much higher formation temperatures, inducing a thermal gradient across the cross section of the casing/cement combination resulting in differential thermal expansion at the casing to cement boundary. The fracking fluid is applied at 10,000psi leading to mechanical expansion of the casing and stress on the steel/cement bond. The rate of build up to 10,000 psi is surely controlled to avoid mechanical shock and in the extreme hydraulic hammer.

Reference 4 (dated Februrary 2013) provides an analysis of the stress on the bond between the outer surface of the steel well bore and the cement sheath as a function of pressure and temperature differentials, and the development of a laboratory test model which validates the model. Two extracts are pertinent to this submission on Well Integrity.

The aim of this paper is to present the development of a possible sample design that allow to investigate the mechanical failure of cement due to cyclic loading which is not yet fully recognised among petroleum engineering research facilities.

Note the phrase “not yet fully recognised” and

Debonding between cement and casing: If internal pressure occurs, the casing might deform in a way that the contact between cement and casing is lost and a micro-annulus is created.

Reference 4; International Journal of Engineering and Applied Sciences. February 2013. Vol 2 No 2 ISSN 2305-8269
WELLBORE INTEGRITY AND CEMENT FAILURE AT HPHT CONDITIONS
Catalin Teodoriu1, Christian Kosinowski2, Mahmood Amani3, Jerome Schubert4 ,
Arash Shadravan5, Clausthal University of Technology, Germany1,2, Texas A&M University, Qatar3, Texas A&M University, USA4, 5

Gas flow

Fracking fluid, including acid to clear the perforation debris, is expelled with the initial gas flow; some fluid escapes into capillaries between casing and cement; as flow proceeds the proportion of fluid associated with the shale increases as does the salinity and content which may include radio nuclides, heavy metals and the products of the perforation explosions. The gas flows at high velocity in a long comparatively small-diameter tube and could be expected to have a characteristic sound effectively transferring small displacements to the outer surface of the casing. Since the gas is expanding from a high pressure environment in the shale to a low pressure environment at well head it would be cooling the inside of the casing. This would result in both axial and transverse temperature differentials in the bore casing.

Plug the casing

At some juncture in the life cycle of the well the gas flow is assessed as not commercial. The well is plugged ie cement is injected into the production casing and the shale bed sealed off.

With the addition of seismic movements, there are a number of environmental factors contributing to relative movement between the outer surface of the casing and the inner surface of the cement. These will lead to breakdown of the bond and the formation of migration paths for both gas and the residual salty water brew in the now depleted shale reservoir. Over time gas continues to be released in the abandoned well and pressure builds up. The gas pressure or capillary action will force gas and formation fluids along the weakened or failed cement/steel bonds.

Discussion on Loss of Well Integrity

The preceding section examined the separate stages in the life cycle of a fracked horizontal gas well from drilling the bore hole, through the sequential processes of casing, cementing, perforation fracking, production to abandonment. The examination was not in the abstract;

it focuses on the region in the Northern Territory in which the Betaloo sub-basin lies below the Tindal aquifer. My aim was:

- Undertake an analysis of the life cycle processes, sourcing engineering and operational information and cumulative statistics from the US.
- Develop a qualitative estimate of probability of occurrence of a single Event, namely a Well Failure
- Estimate the number of multi-pad well heads of a production gas field in the study region
- Estimate the probability of Well Failures over the production field expressed more directly as number of failures over a given period of time.
- Position Well Failures on the Risk Matrix horizontal axis in the range of Low to High.
- Position the Consequences of Well Failures on the vertical axis of the Risk Matrix.
- Two “consequences” can be identified.
- The community of the Region is deeply concerned about contamination of the Aquifer and all that would mean to the established industries and the environment.
- The industry concern is for loss of production and schedule.

My examination leads me to the following:

- Wells are at constant risk of failure from the earliest stage of cement injection. One obvious mechanism is failure of the bond between the well bore casing and the cement sheath. The bond is subjected to an extremely severe environment resulting in increasing failure rate over time until eventually all wells fail.
- The time horizon of the industry is indicated by the choice of the descriptor “abandonment” to denote the end of useful life of a given well.
- The time horizon of the communities is well beyond end of life of a production field.
- The revolutionary technologies which have facilitated staged hydraulic fracturing of horizontal wells on shale formations have been the cause of increased intrinsic stress on the steel/cement bond.
- The industry approach to overcoming problems is characterised by the “trial and error” paradigm, in parallel with, but overshadowed by the drive for increased productivity from each well.
- Trial and Error is a legitimate form of engineering, as long as the error is detected in a controlled trial, rather than in the field.
- There is insufficient failure data analysis available to an outsider, but I suggest that the drive for productivity and speed is leading to developments which acerbate the problem of cement bond failure.
- As is often the case where a complex system is managed in so called “silos”, at the sub-system level, developments in one sub-system aimed at improving the performance of that sub-system, cause new problems in other sub-systems. If there is no overarching management of system integration which coordinates changes and

resolves conflicts between the various sub-systems a circular pattern of faults and blame shifting can erupt.

- The current state of the Australian Electricity system illustrates this systemic dysfunction.

Failure of the bond and formation of migration paths allows gas and other materials from the gas reservoir to migrate to the aquifer above and beyond the aquifer to the atmosphere. The regional communities are already alerted to contamination by the existence in the NT of several legacy mines. This has been raised to a higher level of concern by the presence of fire fighting foam and other contaminants in the Tindal aquifer.

This analysis indicates that the probability of well failure over the communities' time frame is 100%. At a multi-pad well spacing of 1.5km well contamination is a certainty. The consequences of contamination are already being felt from the fire fighting foam. The prospect of the advent of a further source of contamination is one of the principle reasons for community opposition to the gas industry and associated hydraulic fracking.

Waste Water Disposal -Retention Pond Release

Waste water is returned to the surface after a fracking operation. As well as the initial fracking additives it is highly saline and may contain heavy metals and radionuclides.

Since 13th November 2013 industry responses to questions on methods for the management of produced water have included:

- Retention/Evaporation ponds--Risk of inundation and overflowing during a Wet season downpour
- Road transport to a disposal facility-- A producing gas field of many thousands of wells implies 25 million/10,000 equals 2500 tanks per fracked well in transit along the Stuart Highway.
- Deep Well injection—US experience not encouraging; Incomplete knowledge of aquifers, particularly connectivity between aquifers, indicates precautionary principle
- Reverse Osmosis—Expensive, power hungry, centralised, residue disposal

The other risks identified by Dr Barrett are Waste Water disposal and Retention Pond release. Over the course of several discussions with the gas industry a number of methods for the management of waste water, usually referred to as produced water, have been canvassed-and rejected by community groups as unsuitable for the top end of the Northern Territory.

Retention Ponds

Not for nothing is this time of the year called the WET. We have constantly spoken about the risk to retention/evaporation ponds or tanks from very heavy downpours which could easily fill the pond to overflowing, labelled by Dr Barrett “high epistemic uncertainty.”

Road Transport

Road transport is subject to human error and the volumes of water to be transported in a development phase of a production gas field with a large number of wells, is so great as to virtually guarantee a finite accident/spillage rate. The simple rule is “if it falls on the ground, either by forces of nature or by human error, it will end up in the river or the aquifer. The presence of PFAS and glyphosate in the Tindal aquifer illustrates that rule.

Deep Well Injection

Deep well injection, given the incomplete state of knowledge about the aquifer structure and interconnectivity, has to be regarded as High Risk.

Reverse Osmosis

Reverse osmosis has been raised on occasions in discussion with industry. It is known to be expensive to construct, operate and maintain. Is power hungry and there is some concern that the process may not remove all the materials in the produced water. There are the problems of transport of the fluid to be treated to the facility and disposal of the residual wet sludge, also requiring transport.

SUMMARY

Of the number of Potential risks of hydraulic fracturing unconventional gas identified by Dr Barrett, this submission has analysed three in some depth. The conclusions positioning each on the Risk Matrix are:

Well Casing Leaks

There is a high probability that at any time during the development and production phases of an unconventional gas industry accessing shale deposits below the Tindal aquifer, well casing leaks will occur.

There is a certainty that over an extended period of time, say 100 years, after the residual gas reservoir cannot be extracted commercially and all wells are abandoned using methods currently described, extensive casing leaks will occur. In both cases the consequences of casing leaks for the communities and industries dependent on the aquifer for water are catastrophic.

Waste Water Disposal -Retention Pond Release

When considered in the context of the development and production stages of a gas field and given that human error is a factor, the methods briefly discussed attract "risk ratings" of highly probable. As with well casing leaks, the consequences should be rated as catastrophic.

CONCLUSION

The gas industry has proposed to exploit methane bearing shale deposits which are overlaid by a social, economic and environmental eco-system which is both established and sustainable.

This submission demonstrates that such a project being of relatively short duration and exploiting a non-renewable resource would entail an unacceptable risk to the existing and future communities and enterprises the majority are sustainable and environmentally benign.

I would be pleased to address any questions the Panel may have.

Errol Lawson

19 March 2017

Readings

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

U.S. Environmental Protection Agency. 2016. Review of Well Operator Files for Hydraulically Fractured Oil and Gas Production Wells: Hydraulic Fracturing Operations. Office of Research and Development, Washington, DC. EPA/601/R-14/004.

The integrity of oil and gas wells. Robert B. Jacksona,b,1aDepartment of Environmental Earth System Science, School of Earth Sciences, Woods Institute for the Environment, and Precourt Institute for Energy, Stanford University, Stanford, CA 94305; and Division of Earth and Ocean Sciences and Center on Global Change, Nicholas School of the Environment, Duke University, Durham, NC 27708

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WELLBORE INTEGRITY AND CEMENT FAILURE AT HPHT CONDITIONS
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Arash Shadravan5 Clausthal University of Technology, Germany1,2, Texas A&M University, Qatar3, Texas A&M University, USA4, 5

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Economic Impact of shale and tight gas development in the NT Deloitte access economics 14 July 2015

Potential Geological Risks Associated with Shale Gas Production in Australia
January 2013 Project Code: AAS801 The Frogtech Report. © Australian Council of Learned Academies (ACOLA) This report is available at www.acola.org.au

Report of the Independent Inquiry into Hydraulic Fracturing in the Northern Territory 28 November 2014 (The Hawke Report)

All hydraulic fracturing is equal, but some is more equal than others: an overview of the types of hydraulic fracturing and the environmental impacts. *Dr Tina Hunter CENTRE FOR INTERNATIONAL MINERALS AND ENERGY LAW, UNIVERSITY OF QUEENSLAND* australian environment review April 2014

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