

From: [Christine Anderson](#)
To: [DPC:Engineering](#)
Subject: Leigh Creek In Situ Gas comment
Date: Tuesday, 27 February 2018 1:58:08 PM

Hi Jarrod

I oppose both the proposed Leigh Creek ISG demonstration plant and the proposed SAPEX PEL 122& 123 fracture stimulation activities.

Regardless of how good your Statement of Environmental objectives, there will always be risks from the proposals, particularly of chamber collapse, and groundwater disturbance and contamination, and gas leakage, and loss of local biodiversity and almost certainly some form of disturbance of aboriginal cultural sites.

All these risks will occur at a time when water resources are under more and more stress, and more erratic climate and loss of habitat are accelerating loss of biodiversity. It is abundantly clear that the world and South Australia needs to dramatically reduce its carbon emissions now, in order to reduce the damage done.

We have the technology now to do this at reasonable cost - SA is already producing about 50% of its stationary energy from renewables now, and is in the middle of an election campaign where the Labor government is promising 75% in 5 years, and would easily be able to produce 100% renewable electricity within that time. Extending the tram line and completing the electrification of the Gawler train would be a great start to reducing fossil fuel usage for transport.

In these circumstances, it is irresponsible to consider any new or expanded exploration or exploitation of any fossil fuel resources. Taking any risks for fossil fuel resources is completely unacceptable.

Chris Anderson

27 Feb 2018

Mr Jarrod Spencer
Senior Environmental Officer,
Regulation and Assessment
Engineering and Operations Branch
Department of the Premier and Cabinet.

Dear Jarrod,

In response to the proposed SAPEX application for fracture and stimulation activities associated with PEL's 122 and 123 in the Arckaringa Basin, I oppose this application on the grounds that it will not equally satisfy sustainable business triple bottom line requirements. First of all I draw an analogy for easy interpretation and then will follow up with my reasoning.

I see triple bottom line outcomes as essentially the foundations of a three legged bbq, the legs being social, environmental and economical outcomes. If the legs are not equally represented the sausages roll of the bbq until eventually the bbq becomes so unstable it falls completely over and everyone except the vegetarians go hungry. So in this scenario the vegetarians are the mining company and the social (regional communities) and environment are irreparably damaged.

Environmental concerns:

Section 4.3.1 (SAPEX EIR A6-13)

First of all, " the GAB springs of SA are complex and relatively unique ecosystems " (DEWNR 2015), and all springs in SA are protected under the EPBC Act 1999. The DEWNR Technical Report (2015 p26) identifies the many current knowledge gaps associated with the connectivity between the aquifers and springs, spring sensitivity to drawdown, limited species distribution information, mobilisation and accumulation of sulphides, heavy metals and metalloids not to mention the degree to which spring ecosystems have already been degraded post- European influences. The report further identifies human activities as the most significant risk of aquifer drawdown.

The effects of aquifer drawdown on springs associated with the GAB include: habitat fragmentation and reduction, biodiversity loss, increased risk of endemic extinctions, increased salinity and acid sulfate hazard, damage to spring structure, changes in community ecology. (DEWNR 2015)

Whilst the EIR identifies that "not all springs are mound springs and some springs maybe sourced from deeper aquifers other than the GAB," it is significant here to acknowledge that we just don't have the objective science to confirm that there is absolutely no risk to these unique, endangered and fragile wetland ecosystems (National Water Commission 2013 p1) . These wetland ecosystems have survived more than one million years in the landscape (NWC 2013 p1) and as custodians of the landscape we cannot afford any additional risk no matter how small for selfish short term limited financial gain. We must manage our natural resources sustainably to ensure their healthy existence for at least another million years.

The EIR fails to list all springs located within close proximity and within the PEL areas in question. The EIR only refers to the major tourist mound springs outside the PEL's and the Francis Swamp Complex. Who will be monitoring the additional springs not listed in the EIR for example the Lake

Cadibarrawirracanna Complex and The Peake Creek Group including Weedina Springs and Warrangarrana Spring, Billa Kalina or Lethbridge Springs? Are these springs deemed not important enough even though they have EPBC Act protection? A line on map delineating an exploration lease area above ground does not ecologically delineate all connected processes below the soil surface. Water sourced from local aquifers are already sustaining the regional communities of Coober Pedy and William Creek and more extensively the pastoral industry; unnecessary additional ecological pressures from drilling activities maybe enough to cause the further extinction of Springs. In the EIR (pages 44 and 47) it is stated that “the majority of bores in the target area have been abandoned” due to the geological formation of the cretaceous sediments and possibly historical pastoral activities. Therefore I advise that nonessential, opportunistic activities would merely be wasting the most precious resource we have in central arid Australia, that is our water.

To reiterate and highlight the importance of interconnectedness of vital water in an arid landscape I refer to Allan Savory's (p 68. 1988) explanation of effective and non-effective water cycles. Simplistically in an effective water cycle, after one inch of rain the surface water infiltrates the soil. If during the next month there is no rainfall, then half an inch of that rain is utilised by plants and there is little run-off. Half an inch of that water remains in the subsoil. With the second fall of rain a month later, water molecules are easily absorbed into the already moist soil penetrating deeper than the first inch of rain. After the third fall of rain, water molecules finally reach and replenish the underground aquifers.

Whereas in a non effective water cycle water is continually lost from the environment through evaporation, surface run-off and very little infiltration. Let me explain, after one inch of rain poorly plants utilise some water and hard, compacted exposed surface soil expels water across the landscape leaving only a minimal amount to infiltrate the soil. Any infiltration is used by the poorly plants before the next rainfall event. One month later after another inch of rainfall the same scenario occurs only there is no soil moisture to enhance infiltration and the majority of water is lost from the immediate area.

This scenario is obviously focussing on surface water and aquifer recharge, however with water being sourced from local aquifers this surely must have a longer term effect on the localised vegetation given perennial vegetation has significant deep roots to access underground water to survive prolonged periods of drought. For the protection of native vegetation in the longer term, localised aquifer extraction activities should be triggering additional native vegetation clearance requirements. In addition if extremely valuable ground water is being extracted for short term mining exploration and drilling activities it is highly likely these non essential activities are having a detrimental impact on already stressed and fragile arid vegetation and potentially the springs mentioned earlier.

Social Concerns:

Working in the rangelands for 15 years and residing in Coober Pedy for the last 10 years I have travelled the world multiple times undertaking volunteer activities and am currently working in the environmental and tourism industries. During this time I have met many thousands of people through my work and travel and every time I meet a new person the second question they ask is “Do

you live underground?” My point being is Coober Pedy is internationally renowned for its underground living. Much of the Coober Pedy business industry focusses on the underground component with underground accommodation and tourism ventures.

My concern being that I am not convinced Tri Star has given due consideration to the wider implications of the perceived impact fracking in the Arkaringa basin may have on Coober Pedy's significant industries and wider community. I appreciate the drill site/s are not in the immediate vicinity of the town, whether they directly physically impact the town or not is irrelevant if tourists perceive they may not be safe staying underground. This is something which needs serious consideration given how easily hysteria drives a mob mentality just remember 9/11 and how the airlines were impacted. More closely the affect the movie Wolf creek had on outback travellers and tourism. This may seem a frivolous analogy but when peoples livelihoods, investment opportunities and communities may so easily be damaged this is a genuine concern which requires further investigation and most certainly does not deserve to be ignored for one company's short term gain.

In summing up we know we don't know enough about aquifer connectedness to be 100 percent sure drilling and fracking in one area will not detrimentally affect another area over time or initiate geological fractures beyond the scope of the models. As an concerned environmental citizen, underground dweller, owner of an underground dwelling and developing underground business in Coober Pedy I have significant reservations regarding the Fracture Stimulation Activities proposed for PEL 122 1nd 123.

Postscript: Finally I draw your attention to the following comment on page 44 of the EIR which states ,” weather conditions are too hot for cropping as discussed in section 4”, is this just a generic cut and paste comment or does it show complete disrespect for the people, industries and legislation applicable to the area? For your information the area in question is pastoral country, largely sustained by accessing underground water, under the Pastoral Land Management and Conservation Act 1989, cropping in this region is prohibited. I suggest the company need to undertake some more homework with respect to the environment and the people who live out here
24/7

Yours Sincerely
Janet Walton
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Coober Pedy
SA 5723
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References:

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Department of Environment, Water and Natural Resources (DEWNR) February, 2015. A *hydrogeological characterisation of the Arkaringa Basin*. Technical report 2015/03.

National Water Commission 2013, Allocating Water and Maintaining Springs in the Great Artesian Basin, *Volume VII: Summary of findings for Natural Resource Management of the Western Great Artesian Basin*. NWC, Canberra.

Submission regarding SAPEX fracture stimulation proposal -PEL122 & PEL123

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Summary

Scientific evidence supports the view that fracture stimulation in the Arckaringa Basin represents an unreasonable risk to the environment, especially the Great Artesian Basin and the ecosystems it supports. I strongly advise for the SAPEX/Tri-Star fracture stimulation proposal not to be authorised. The principal arguments are:

- The Arckaringa Basin presents a unique geological and hydrogeological setting.
- Within and around the project area are many artesian springs that support fragile and unique ecosystems.
- The various aquifers in the Arckaringa Basin are interconnected through various pathways including faults, fractures, juxtaposition of permeable beds and numerous boreholes in the region.
- Fracture stimulation will further increase the interconnectivity between aquifers.
- Fracture stimulation has the potential to release natural hydrocarbons and chemical additives into the interconnected pathways leading to pollution of the GAB aquifers and associated springs and unique ecosystems.
- Drawdown of the GAB is also a likely consequence of fracture stimulation activities in the Arckaringa Basin.
- Fracture stimulation activities in the Arckaringa Basin should be considered as having a high impact under the Development Act 1993 and should require an approval under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999.

1. Introduction

This document is a submission regarding SAPEX proposal for a fracture stimulation oil and gas recovery program in the Arckaringa Basin. In the EIR, SAPEX presents only very general geological data, omits important environmental aspects, overlooks the interconnectivity between various aquifers, and dangerously minimises the risks associated with fracture stimulation. This document highlights some of those issues, focussing on the geological aspect. A more detailed study of the proposal and its potential geological and environmental consequences is required. This document is thus not exhaustive and the various regulatory authorities are encouraged to look further into the issues presented here.

2. Existing environment

2.1. GAB springs

The SAPEX EIR only mentions Artesian condition in the North of PEL 122 and East of PEL 123. The EIR mentions only three groups of GAB springs, namely the Francis Swamp, Strangways and Wabma Kabardu spring complexes. It conveniently omits many more GAB springs within the project area, including the spring complex around Lake Cadibarrawirracanna and several springs from the Peake Creek West complex within PEL 122, and the Lethbridge and Billa Kalina spring complexes in PEL 123. A more accurate map showing GAB springs is presented here (Figure 1). All those springs support fragile and unique ecosystems with endemic flora and fauna (see Walton, 2018).

2.2. Geology, aquifers and connectivity

The geological setting of the Arckaringa Basin has been presented in sufficient details in other documents. I hereby only highlight important information omitted from the EIR.

The suspected interconnectivity of the different aquifers in the Arckaringa Basin (J-K aquifers/GAB, Mount Toondina Formation aquifers, and Boorthanna Formation aquifers) has been recently verified within PEL 123 (Priestley et al., 2017). This contradicts the EIR which states that connectivity between the Boorthanna Formation and overlying aquifers only exists in areas where the Mount Toondina and Stuart Range Formation are absent.

Beside diffuse leakage through the pore space within the aquitard (Stuart Range Formation), Priestley et al. (2017) have highlighted the existence of preferential pathways enhancing inter-aquifer leakage. Such preferential pathways can be faults, intercalations of higher permeability sediments, or thinner aquitard sections (Cherry and Parker, 2004). Zones of enhanced inter-aquifer leakage can have a disproportional contribution to the water balance relative to their size.

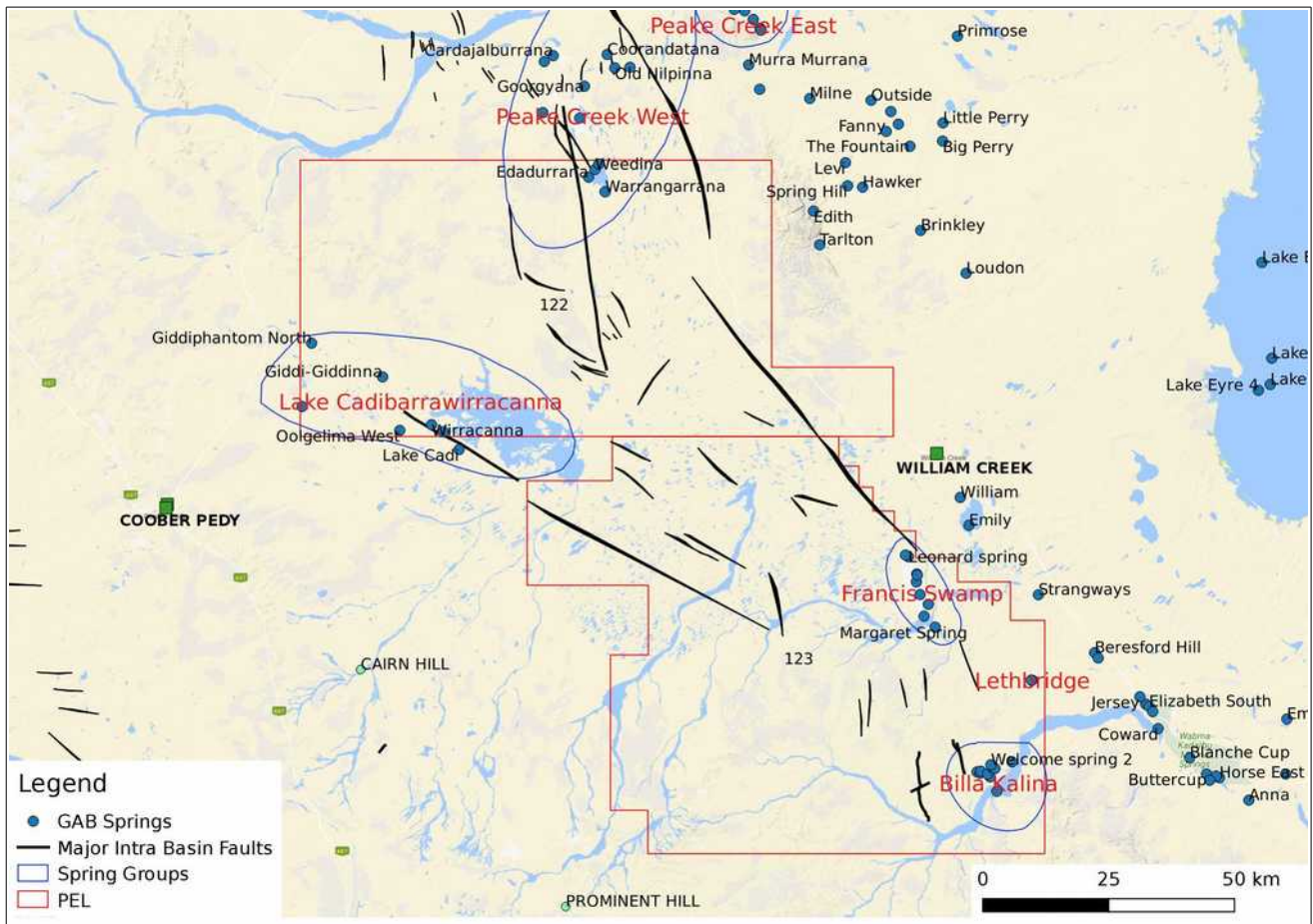


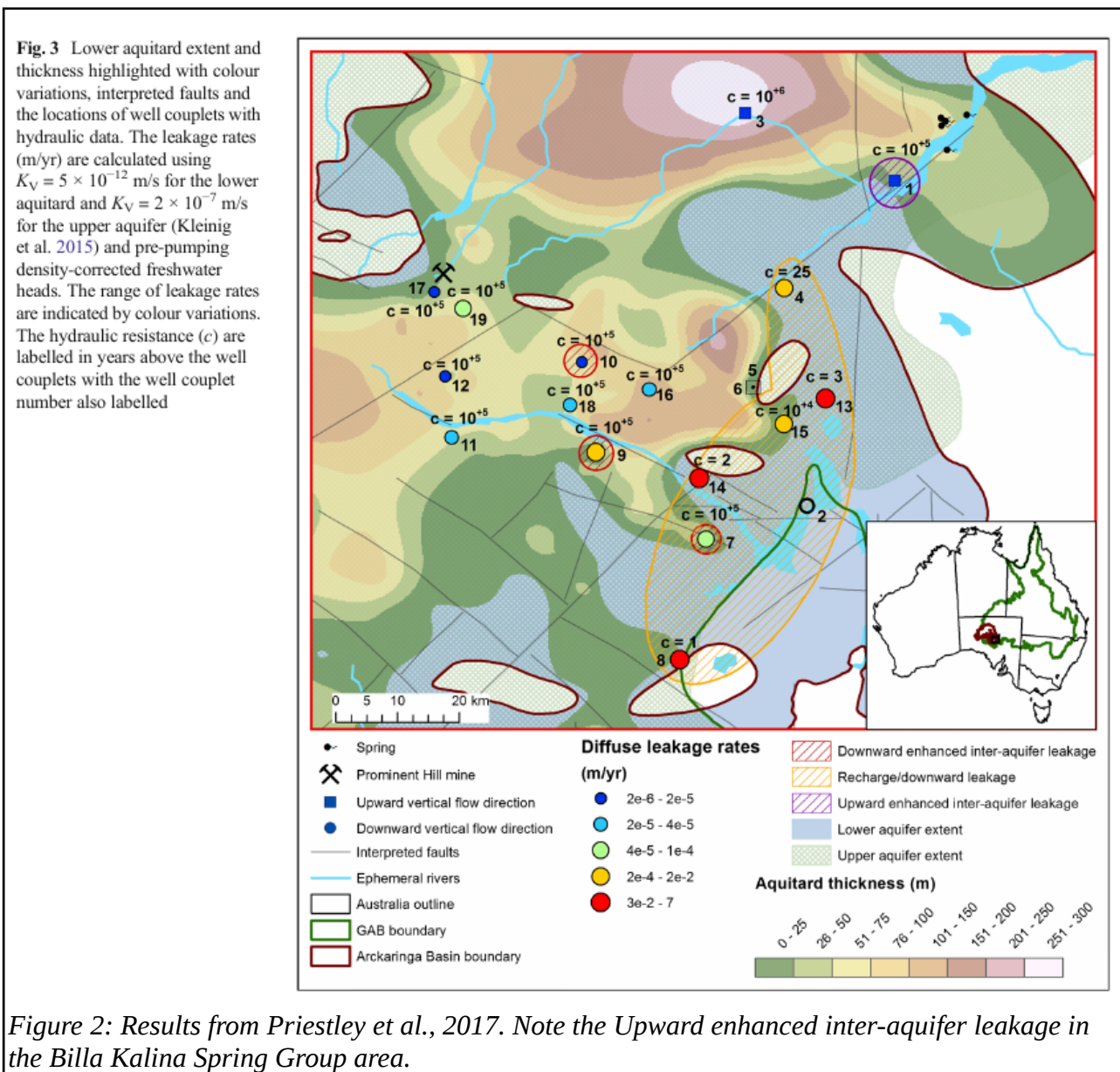
Figure 1: Map showing artesian springs and major faults in the project area.

Priestley et al. (2017) also mention upward inter-aquifer leakage in the spring discharge area (in this case the Billa Kalina spring complex, within PEL 123), where the hydraulic gradient brings water from the Boorthanna Formation to the surface (Figure 2). This study confirms previous work realised by DEWNR (2015b) indicating that “connectivity between the Boorthanna Formation and J-K aquifer does occur due to secondary permeability in the Stuart Range Formation”. DEWNR (2015a) also states that “conditions similar to those described for the south-east corner of the Arckaringa Basin occur to the west of the Peake and Denison Inlier”, i.e. in PEL 122. Aquaterra REM (2005) and SKM (2009) also indicate that upward leakage from the Boorthanna Formation aquifer into the overlying J-K aquifer, salt pan and saline environments near the eastern margin of the Arckaringa Basin is possible on the basis of hydraulic gradient data. This type of study will hopefully be realised in other parts of the Arckaringa basin in the future. In any case a direct consequence of this study is that the Stuart Range Formation cannot be considered an aquitard at the regional scale.

This is also a direct consequence of the very structure of the basin, which is significantly cross-cut by faults with sufficient vertical displacement to place in direct contact different lithologies (Howe et al., 2008). In a similar way, the different lithological units present major lateral thickness variations, with lithologies such as the Stuart Range Formation being absent in places. This comes

as a direct consequence of alternate episodes of erosion and deposition during the geological history of the basin (Drexel and Preiss, 1995).

Figure 1 presents known major faults within the project area. Those faults are a compilation of datasets available from SARIG and the Bioregional Assessment website. There are many more faults described in articles dealing with the Arckaringa Basin, but as the datasets were not readily available I have not incorporated them here. More structural features could certainly be delineated in target areas had SAPEX provided rigorous structural interpretations based on drill holes, interpretation of seismic data, and any other source they might have.



In the EIR, SAPEX states that silt units within the Lower Mount Toondina Formation constitute an additional aquitard separating the aquifers around the Stuart Range Formation and the GAB. The Lower Mount Toondina Formation comprises fluvio-lacustrine units (Figure 3). It is thus expected to present important cross bedding and lateral lithological variations. This implies that silt units in neighbouring drill holes are not necessarily continuous. Furthermore, the continuity of thin silt units would be significantly disrupted by even minor faults with little vertical play, and faults and fractures within the unit will constitute preferential pathways for fluid circulation. It is thus important to note that silt lenses within the Lower Mount Toondina Formation do not constitute an aquitard. In any case, as stated in the Bio-Regional Assessment website, “given these uncertainties regarding the distribution and lithological composition of the Lower Mount Toondina Formation, little can be implied regarding the hydrogeological characteristics” (Bioregional Assessments, 2017). Stating that silt units within the Lower Mount Toondina Formation would prevent pollution related to the fracturing activities from reaching the GAB is thus misleading.

I refer the reader to the documents cited in this chapter for a better understanding of the Arckaringa Basin structure and hydrogeology, especially the work realised by Priestley et al., 2017; DEWNR, 2015a and 2015b; and Howe et al., 2008.

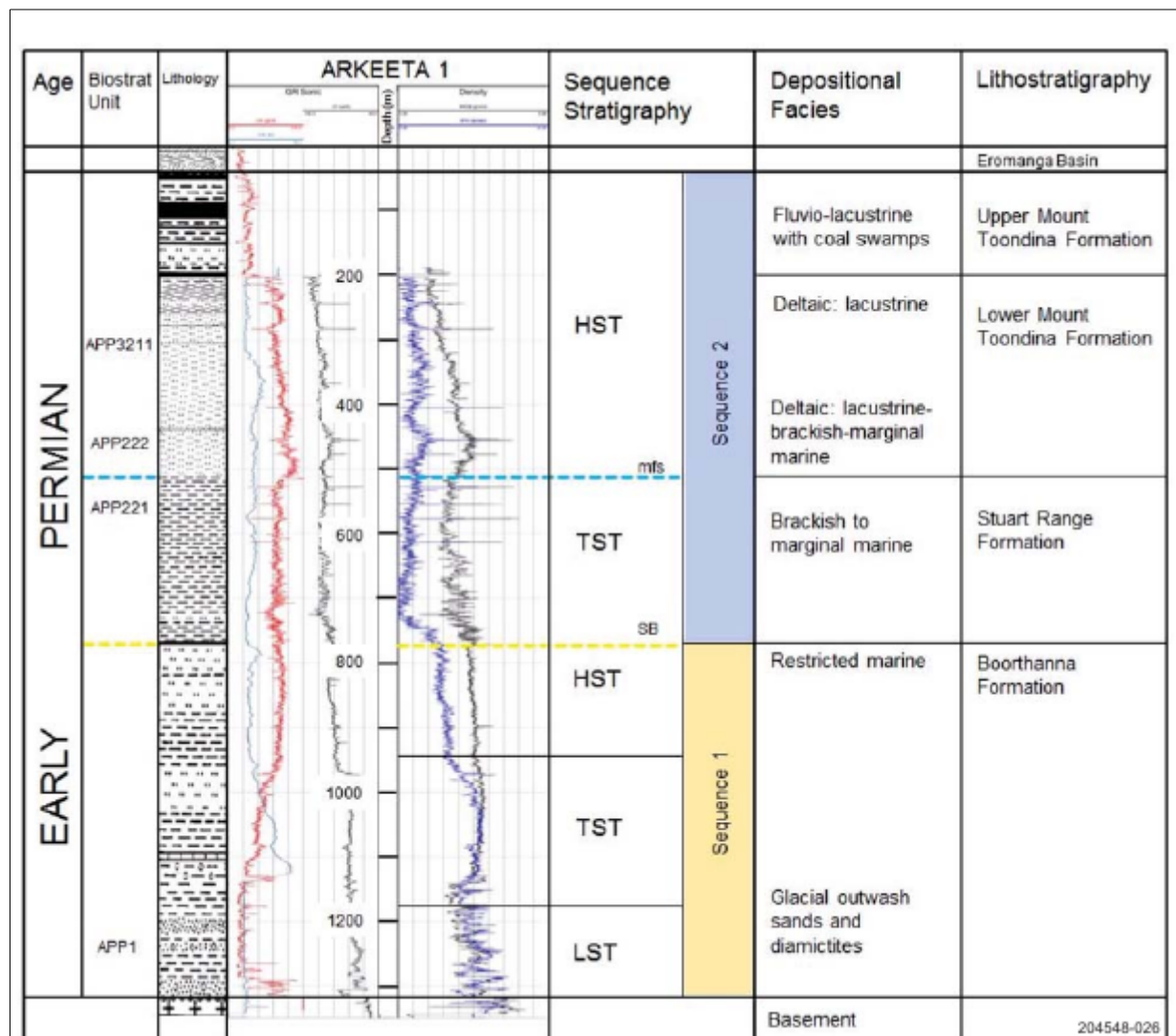


Figure 3: Arckaringa Basin Stratigraphy - from <http://petroleum.statedevelopment.sa.gov.au/>

3. Fracture propagation

Hydraulic fractures propagate when fluid pressure exceeds the least principal stress and the tensile strength of the host sediment (Hubbert and Willis, 1957). They continue to propagate until the stress-intensity at the fracture tip is lower than the critical stress-intensity of the rock being fractured (e.g. Savalli and Engelder, 2005). Pre-existing fractures require a lesser pressure to be opened and as thus constitute preferential pathways for fluid movements, so that hydraulic fracture fluid can move greater distances in pre-existing fracture systems (Lacazette and Geiser, 2013).

SAPEX presented data from Eagleford Shale as an analogy to the Stuart Range formation. Data in the Eagleford shale show that fractures of up to 556m have been measured using microseismicity (Davies et al., 2012). This study also determines that roughly 1% of fractures will extend more than 350m. In light of the high number of fractures created by a single fracture stimulation event, this implies that fractures of that size will be created with every stimulation episode. Fracture stimulation within the Stuart Range Formation (up to 250m thick in the project area) would thus create a significant amount of fractures cutting the unit from top to bottom, necessarily connecting Boorthanna aquifers and Mount Toondina aquifers.

As a side note, the choice of the Eagleford Shale as an analogy to the Stuart Range Formation seems not so much constrained by the actual lithology (the Eagleford Shale is much more a carbonate than a shale *sensus stricto*) than the fact it is the known example in which hydraulic fracturing generated the smaller number of large fractures (as stated in Davies et al., 2012). This seems thus to be the “best case scenario” rather than a relevant analogy.

Using microseismicity to monitor fracture propagation is however limited and does not accurately identify pre-existing fractures that might be opened or reactivated by the fracture stimulation process, due to the very weak seismicity associated with this phenomenon. More recent studies using newer methods indicate that fracturing fluids can move at much greater distances in pre-existing fractures (Lacazette and Geiser, 2013), with documented distances of the order of 1000m. Pre-existing fluid paths zones such as faults will inherently facilitate the movement of fracturing fluids or freed hydrocarbons. In a situation like that of the Arckaringa Basin, where water from various aquifers supports all human presence and activities as well as fragile endemic ecosystems, this would have catastrophic consequences.

SAPEX offers to realise numerical simulations before actual fracturing episodes, in order to assess the potential impact of fracture stimulation. It is extremely important to keep in mind that fracture propagation in anisotropic geological units, especially containing pre-existing discontinuities, is very poorly understood. To date, numerical models fail to correctly predict fracture propagation (Hattori et al., 2017). As was explained in an earlier study: “We cannot yet accurately predict fracture propagation behaviour in detail, so to date much of what we know of how fractures will behave in situ conditions comes from operational experience” (King et al., 2008).

4. Fracking activities: potential consequences

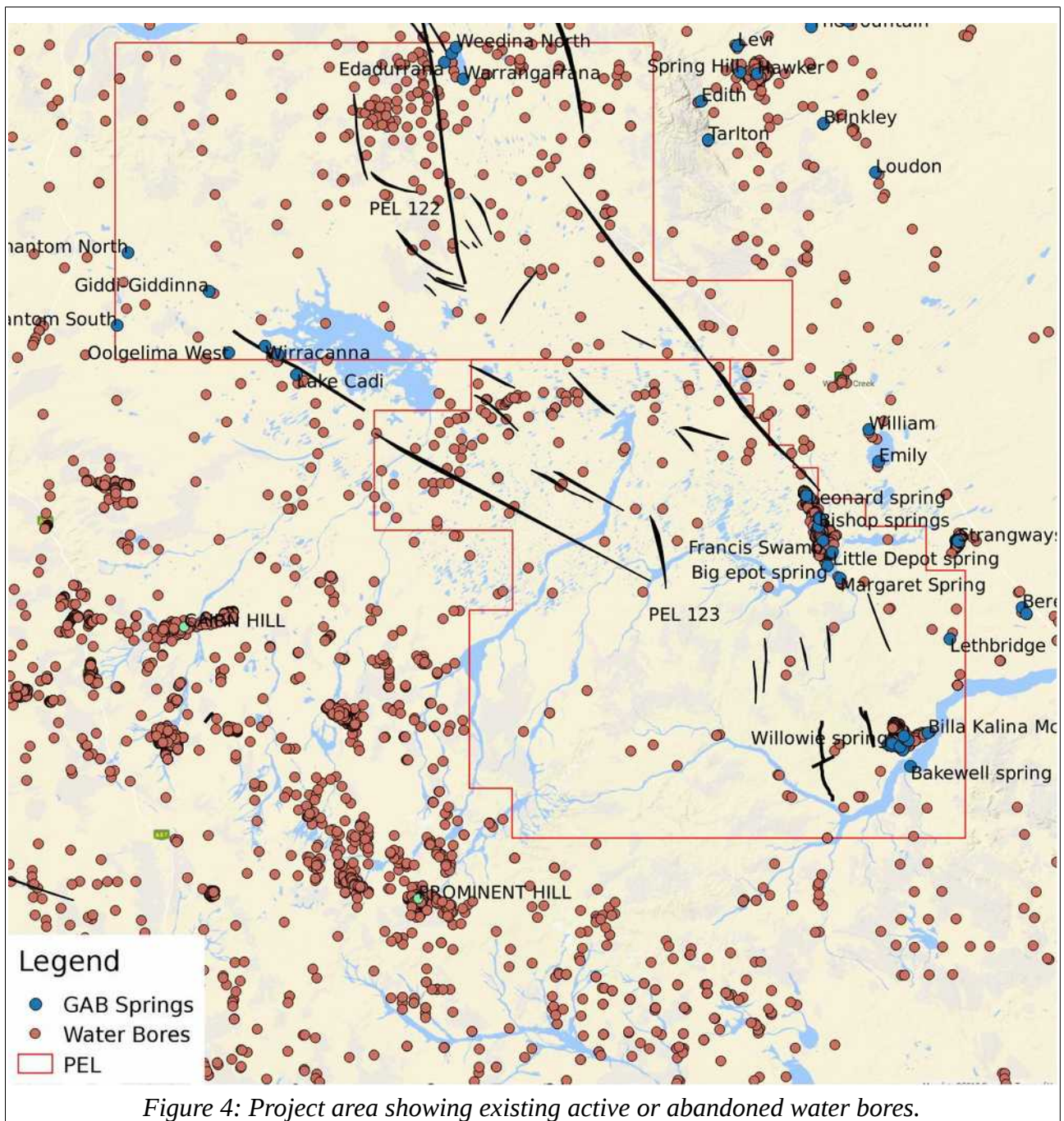
4.1. Water contamination

As stated above, fracturing fluids or freed hydrocarbons can find their way along newly created fractures or pre-existing discontinuities. Due to the interconnectivity of the various aquifers in the Arckaringa Basin, those pollutants will find their way to the GAB. This can have dramatic consequences on GAB spring ecosystems, wiping out entire species. This could also have dramatic consequences on the cattle industry, other mining activities, tourism or the water supply for human consumption. (*note: the risk assessment table in the EIR states that contamination of the GAB or drawdown of the GAB would have “minor” consequences*).

It is also important to note that fracture stimulation uses proppant to keep the fractures open. This means that once a fracture has been created, it will stay open and enable the flow of any fluid, water, hydrocarbon or chemical additives used in the fracture stimulation process.

The fluid flow in the various aquifers can be fairly slow. In the GAB it is estimated to be about 5mm/y. This also implies that pollutants could appear in an artesian spring or water bore well after the end of the hydrocarbon production, and a significant distance away from the production area.

Poorly cased water holes or de-commissioned bore holes that have not properly been sealed are also a known conduit for fracking-related pollutants (United States Environmental Protection Agency, 2016). There are numerous used or abandoned bore holes in the area (Figure 4). Those bore holes present a serious risk if fracture stimulation were to be conducted in the Arckaringa Basin.



It is also known that unconventional wells are six times more likely to have problems affecting cement and/or casing than conventional wells (Ingraffea et al., 2014). Those integrity problems can induce aquifer contamination around the well at any given level (Figure 5). This itself should constitute a high enough risk for the sustainability of the Arckaringa Basin environment to justify a ban on fracture stimulation in this area.

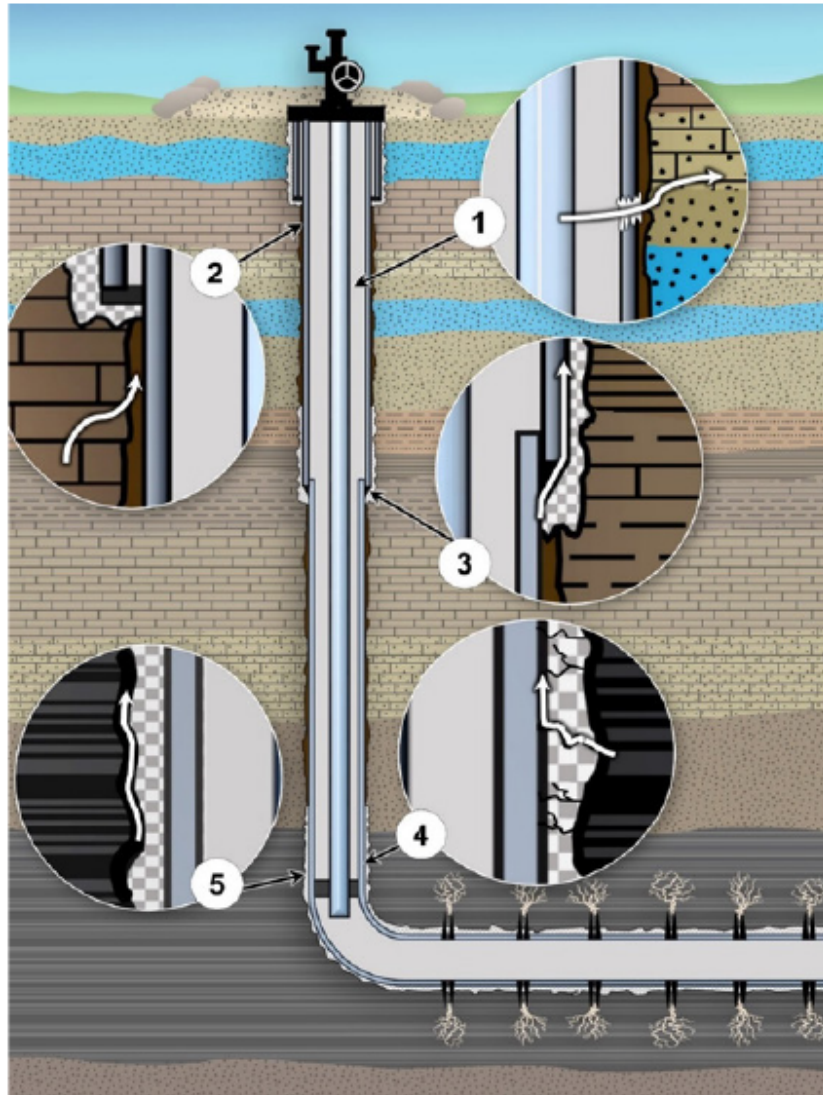


Figure ES-6. Potential pathways for fluid movement in a cemented well.

These pathways (represented by the white arrows) include: (1) a casing and tubing leak into the surrounding rock, (2) an uncemented annulus (i.e., the space behind the casing), (3) microannuli between the casing and cement, (4) gaps in cement due to poor cement quality, and (5) microannuli between the cement and the surrounding rock. This figure is intended to provide a conceptual illustration of pathways that can be present in a well and is not to scale.

Figure 5: Potential pathways for fluid movement in a cemented well. Source: United States Environmental Protection Agency.

4.2. Change of water level

Another likely consequence of fracture stimulation in the Arckaringa Basin would be the lowering of the water table in areas where the hydraulic gradient would drain GAB waters into deeper aquifers. Once again, the creation of propped fractures would make this phenomenon irreversible once started. This could lead to the drying out of GAB springs and water bores.

5. Conclusion

This submission clearly states, in brief, the geological reasons I believe fracture stimulation activities should not be approved in the Arckaringa Basin. The interconnectivity of the different aquifers implies a significant risk of contamination of the GAB by natural hydrocarbons or by chemical additives used in fracture stimulation. This interconnectivity can be enhanced by fracture stimulation itself, through newly created fractures or opening of pre-existing discontinuities. The process of fracturing is impossible to predict. I believe there is sufficient scientific evidence to demonstrate that fracture stimulation in the Arckaringa Basin presents unreasonable risks to the GAB and associated springs, unique ecosystems, and the human lives and activities of those dependent on the GAB.

If it were to proceed, I believe fracture stimulation in the Arckaringa Basin should be considered as a high impact activity under the Development Act 1993. I also believe fracture stimulation activity in the Arckaringa Basin should require an approval under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999, due to the high sensitivity of endemic ecosystems in the area.

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Walton, J., 2018. Submission regarding SAPEX fracture stimulation proposal -PEL122 & PEL123.

From: [DPC:Engineering](#)
To: [Pepicelli, Dominic \(DPC\)](#); [Spencer, Jarrod \(DPC\)](#); [Malavazos, Michael \(DPC\)](#)
Subject: FW: NO FRACKING IN OR NEAR COOBER PEDY
Date: Friday, 4 May 2018 11:15:24 AM

See below.

-----Original Message-----

From: Sandy K <sk@spinecorp.com.au>
Sent: Friday, 4 May 2018 3:23 AM
To: DPC:Engineering <DPC.Engineering@sa.gov.au>
Cc: Sandy K <sk@spinecorp.com.au>
Subject: NO FRACKING IN OR NEAR COOBER PEDY

Good morning,

I am a long-time resident and homeowner in Coober Pedy and I wish to express that I am **STRONGLY OPPOSED** to fracking in general, let alone in any proposed areas that have the potential to disrupt or impact on our precious lands.

Regards,
Sandy K Friend
0418 888 864
PO BOX 888
Coober Pedy
SA 5723

Sent from my iPhone



Colin Harris
President, Friends of Mound Springs
4 Angove Court
ROSSLYN PARK SA 5072

Attention: Jarrod Spencer
Department of the Premier and Cabinet
Energy Resources Division
GPO Box 320, Adelaide 5001

Re: Application by SAPEX Limited for Exploration and Appraisal Fracture Stimulation Activities in PEL 122 & 123 of the Arckaringa Basin.

The South Australian - Friends of Mound Springs group would like to comment on the proposal and the associated Environmental Impact Report prepared by SAPEX Ltd for exploration and fracture stimulation activities in the Arckaringa Basin - PEL 122 & 123 Fracture Stimulation Activities – Environmental Impact Report December 2017.

Introduction

The Friends of Mound Springs group (FOMS) was established in 2006, under the umbrella of the South Australian organisation Friends of Parks Inc, to support the conservation and management of the Great Artesian Basin mound springs of Far North South Australia. The Friends group has a widely based membership, both local and interstate, from researchers, government personnel and others with a general interest or involvement in artesian (mound) springs issues. The group has a strong core of professional experience relating to the ecology, hydrology and cultural values of mound springs.

The group provides support for the South Australian Department of Environment and Water in the management of springs within the Parks network (such as Wabma Kadarbu Mound Springs Conservation Park). The group also has a role in promoting and supporting research of mound springs in general, and in the protection of mound springs outside the Parks network in collaboration with pastoral lessees and other interest groups. The group provides a forum for disseminating information and research findings regarding the springs and promotes increased public awareness about the conservation values of the springs.

Mound springs are natural outlets for the groundwaters of the Great Artesian Basin (GAB), where artesian pressure forces water to the ground surface. Most springs occur through fractures and geological faults near the margins of the Basin in the Far North of South Australia, north-western New South Wales and eastern and south-western Queensland. There are other springs further into the GAB, such as Dalhousie Springs in Far North South Australia, where groundwater rises to the surface through geological faults.

It is estimated that there are approximately 5000 individual (mound) springs in Far North SA, mostly concentrated in several groups. These are of international importance because of their outstanding natural and cultural features. As virtual oases in the desert, the springs were, and still are, of vital importance to Indigenous people. The springs also support a range of endemic plant and animal species of enormous conservation significance. They provided essential water supplies for early European explorers and settlers and were instrumental in guiding the routes of the Overland Telegraph line and Ghan railway in the late nineteenth century. Reflecting their importance, the native species associated with mound springs are listed as threatened ecological communities under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*.

Since bores were first sunk into the GAB in the 1880s it is estimated that natural flows from these springs have declined by up to 40 percent because of the impacts of flowing and pumped waterbores. There have also been impacts from introduced livestock and pest plants and animals. A number of programs are now in place to address such impacts, and the Friends of Mound Springs group is playing its part in this process.

Comments on SAPEX Proposal and Environmental Impact Report

There are many (mound) springs within the area proposed by SAPEX for exploration and fracture stimulation activities. These include springs near Lake Cadibarrawirracanna, springs at Frances Swamp on Anna Creek Station and springs on Billa Kalina and Nilpinna Stations. These springs are of high conservation significance and many provide habitat for endemic flora and fauna. As noted above, spring flows generally have already been significantly reduced through groundwater extraction associated with artesian bores for pastoral purposes and mining activities and it is most important that further hydrological disturbance of the Great Artesian Basin be minimised.

FOMS is fortunate to have, as one of its members, an internationally recognised hydrogeologist who has conducted hydrogeological research relating to the Great Artesian Basin and its associated (mound) springs for more than four decades and has provided the following comments on the Environmental Impact Report prepared by SAPEX.

Much of the report contains rather general information, without providing detail or useful information. An example is the referral to the hydrogeology data and detailed descriptions in a Coffey (2007) – unpublished report by a consultant (for the company). The EIR does not appear to provide a summary or details of this report. Many of the figures in the EIR are similar, generalised, without providing useful details.

An example is Fig. 15, which looks impressive, with so many waterbores shown. The figure should be showing the depths of the individual bores, which would provide information about which bores have depths of only several 10s m, and which bores are several 100s m or more in depth. This would be more useful. The bore locations should also indicate which aquifers are tapped by these bores, and thus provide an understanding of the geometry of the aquifers. It further would allow an interpretation of the origin of the groundwater (i.e. aquifer), as well as the details and differences in groundwater hydrochemistry and quality.

Several schematic cross-sections of lithostratigraphic units provide a general understanding of the geology, but no detailed cross-sections are provided using drill-holes and waterbores with geophysical logs. No maps of lineaments and/or geological faults interpreted from air

photos or satellite imagery, or from geophysical surveys (e.g. seismic) have been provided or structure contour maps of various stratigraphic units.

Fracking targets are predominantly in the Stuart Range Formation and Boorthanna Formation (Arckaringa Basin units) at 700 – 1800 m depth. If separations of at least 500 m (of low permeable or impermeable rocks) between the Upper Stuart Range and Lower Mt Toondina Formation and the Great Artesian Basin sandstone aquifers (Eromanga Basin units) can be maintained, and no fluid flow paths by the way of geological faults or other interconnectivity can be shown to be present, then the Great Artesian Basin aquifers might possibly be safeguarded from the effects of fracking in the deeper lithological units in the Arckaringa Basin sequence.

The determination of faults would require air photos or satellite imagery interpretation, and/or geophysical surveys (seismic) and the determination of the origin of the groundwater. The determination of possible connection(s) between groundwater originating from specific aquifers with any artesian spring(s) requires more detailed potentiometric data and hydrochemical data and possibly isotope hydrology data.

The SAPEX – PEL 122 & PEL 123 Fracture Stimulation Activities Environmental Impact Report (EIR) addresses the application of fracture stimulation to the exploration and appraisal of shale oil and gas in the Permian sediments of the ARCKARINGA Basin.

The EIR suggests that fracture propagation and potential contamination of the GAB aquifers is not likely to occur due to stress barriers and the separation between the targets and the GAB aquifers. The main targets for fracture stimulation are the Stuart Range Formation and the Boorthanna Formation. The Mt Toondina Formation is a source seal. The EIR states that fracture propagation and stress induced fractures are unlikely to propagate beyond the Mt Toondina Formation and that the impermeable Stuart Range Formation shale and the Mt Toondina Formation provide excellent geological barriers, with minimal 500 m between the target formations and the Jurassic GAB aquifers. The Boorthanna Formation is mature for oil generation and the Stuart Range Formation contains excellent source rocks, with potential for oil generation and shale being the primary target.

Although a separation of at least 500 m would provide a guarantee according to the EIR, and it suggests that fracture propagation into the overlying GAB aquifers is considered improbable, recent studies indicate that groundwater is present in the Stuart Range Formation and the Boorthanna Formation, and that groundwater movement occurs and interconnectivity between the various geological units exists (DEWNR, 2013, 2015-03, Priestley et al., 2017).

Direct contacts exist between the Eromanga Basin (GAB) sedimentary sequence and the Mt Toondina Formation and Stuart Range Formation in some areas, in particular where palaeochannels are present at the unconformity between the Eromanga Basin and the Arckaringa Basin. Although the Stuart Range Formation acts as a regional aquitard in some areas, it also is a leaky aquitard in some areas, with possible interconnectivity and cross-formational flow, however, detailed data is lacking.

Any fracture propagation into the Stuart Range Formation and Mt Toondina Formation would increase the possibility of improved interconnectivity of the Arckaringa Basin and the Eromanga Basin (Great Artesian Basin) aquifers. This could lead to changes in the hydrochemistry (including any chemical additives from the fracture stimulation) of the GAB aquifers and the artesian groundwater feeding the GAB springs. The high conservation value ecosystems - flora and fauna dependent on the groundwater of the GAB springs could then be affected.

In addition, the GAB groundwater resources, the only water resources for human activity and the pastoral industry in this part of South Australia could be affected.

[References

DEWNR, 2013 – Australian Government Initiative on Coal Seam Gas and Large Coal Mining. Arckaringa Basin and Pedirka Basin Groundwater Assessment Projects. SA

DEWNR, 2015-03 - A hydrogeological characterisation of the Arckaringa Basin. SA Department of Environment, Water and Natural Resources.

*Priestley S. C., et al., 2017 - Detecting inter-aquifer leakage in areas with limited data using hydraulics and multiple environmental tracers, including ^4He , $^{36}\text{Cl}/\text{Cl}$, ^{14}C and $^{87}\text{Sr}/^{86}\text{Sr}$. *Hydrogeology Journal*, 25, p. 2031-2047.]*

In summary, the Friends of Mound Springs submits that mound springs of international importance are potentially at risk through the activities proposed by SAPEX, but the information provided in the Environmental Impact Report is not specific or detailed enough to enable a proper, measured assessment of that risk. In this situation, the Friends of Mound Springs contend that the precautionary principle should be applied and the SAPEX proposal should not be approved on the basis of the general information provided. That decision could be reviewed at a later date pending the provision of more detailed information.

If more information is required about the mound springs in the subject area, FOMS would be happy to provide it.

Yours sincerely

Colin Harris *per [signature]*

Colin Harris
President, Friends of Mound Springs

Attention: Jarrod Spencer
Department of the Premier and Cabinet
Energy Resources Division
GPO Box 320, Adelaide 5001

Or via email to DPC.Engineering@sa.gov.au

SAPEX Limited PEL 122 & 123 Fracture Stimulation Activities

Submission from Michele Madigan

26 Trevena Rd Taillem Bend South Australia

michelemadigan@internode.on.net

Introduction

Thank you for the opportunity to make a submission in the matter of the SAPEX (Tristar)'s proposal of Fracture Stimulation Activities in South Australia's Arckaringa Basin.

I take this opportunity as a South Australian citizen concerned about the environment and particularly that of the desert regions of our state of South Australia. Also one concerned with the serious issue of keeping safe and clean our limited SA water resources.

For most of the 1990s I lived in Coober Pedy and had occasion to visit areas under consideration on a number of occasions accompanying the Senior Aboriginal Women of Coober Pedy – the *Kupa Piti Kungka Tjuta*. Already with a strong geographic basis and interest, I learned much from these women's all encompassing appreciation for, knowledge of and interest in, the well being of country, particularly in their overriding concern for its groundwaters.

Since 2001 I have kept up connections with the Coober Pedy area, returning two or three times a year till the present. It is therefore a grave concern that the fragile environment of the nearby Arckaringa Basin is being threatened by becoming a potential gas fracking target: shale gas.

SUBMISSION.

In this current proposed project, “*SAPEX intends to evaluate the size and commerciality of the oil and gas resources within target shale formations including the Stuart Range and Boorthanna Formation*”. I note in particular that “*Shale targets are expected to range between 700-1800m deep in both licences.*”

In Response:

The very nature of the fracking procedure particularly in the delicate desert region of the Arckaringa Basin with its essential connection to the ancient waters of the Great Artesian Basin, means that there will be irreversible damage done by such an invasive, damaging procedure. Because of its totally intrusive nature, any attempt simply ‘*to evaluate*’ immediately causes irretrievable damage – so should in no way be permitted.

Within and around the area of the proposed project there are many artesian springs that support fragile and unique ecosystems. The various aquifers of the area are interconnected by a number of factors, including the many boreholes of the area. The present connections will, of course, be further connected by the proposed fracture stimulation. It is more than probable that this stimulation will release natural hydrocarbons and chemical additives into these connections **leading to the disastrous pollution of the waters of the Great Artesian Basin and its springs and the whole ecosystem of the area.**

SAPEX seems to make no acknowledgment of the fault lines that exist within the designated area and thus the obvious additional danger of further disturbance of the grounds and groundwaters by this entirely intrusive method of extracting gas by unconventional fracking.

As a consequence, it seems obvious that it would be completely unreasonable for the project to be given permission to go ahead.

Any of us who has anything to do with mining and other resources companies and their procedures has learned to treat with prudent scepticism, bland company assurances of *careful procedures* which will have *minimal impact* on lands and the groundwaters (supporting the animal and plant life of the area) that they have

designated desires to exploit. The effects on human health and other human activity such as animal husbandry and tourism are, as a matter of course, also gravely minimised by such companies in their EIS statements.

It's noted that in their Environmental Impact Statement, SAPEX have adopted this characteristic stance, as described above. There are only general environmental impacts mentioned. There is – very surprisingly – simply no mention of the interconnectivity of the aquifers. Strangely, only three springs systems throughout the entire Arckaringa Region are named, omitting many.

Warning signals should surely emerge at the dismissive tone of a SAPEXTristar's summary of risk: In assessing the impact of one of the most invasive and destructive interventions (unconventional fracking) on one of the most fragile systems in the nation, their summary of December 2017 is an incredible 'low risk.' Namely; *'The body of this EIR reviews the potential of the activities to impact on public safety, cultural heritage, stock, native fauna and flora or result in significant noise and air emissions, radioactivity and seismic events. **Each of these has been assessed to be a low risk.** SAPEX is confident that with the implementation of the management measures outlined in the EIR, the proposed activities **do not present a significant level of environmental risk.**'* (My emphasis).

Learning from National and International Experiences.

I submit it would be entirely irresponsible for the South Australian Government and its Energy Resources Division to refuse to learn from the mistakes of the past, including the recent past, concerning similar projects in other areas, - in Australia and overseas. It is in fact, only recently that within our own country, the state of Queensland has been forced, in the aftermath of disastrous destruction to country, to ban fracking throughout the state.

In 2015 (4/12/15) the Parliament of South Australia's Natural Resources Committee in their videoed interview with Professor Tony Ingraffea learned much about the experiences of various regions in the United States. The US experience has shown, for example, that much deeper drilling may be necessary as original estimates prove too optimistic.

As an international expert, Professor Ingraffea advising at the time of the South East of SA proposal, that drilling may have to extend to 2000 or 3000 metres down. Moreover, as well as depth drilling, the same vast distance of drilling will be required in lateral connection.

His other warnings were many, including the contrast with traditional fracking: It seems that many Australians have little idea of the disturbing differences between conventional and unconventional fracking.

"The fracking that has occurred in the north-east part of your state is traditional

fracking. It uses perhaps a few hundred thousand litres of fracking fluid. To get gas out of shale you will need 20 million litres of fracking fluid per well. You will also need pressures three or four times higher than are currently being used for frack jobs in your state.'

Questions raised can be summarised in the Arckaringa context: What is the accuracy of an estimate put forward by SAPEX of the amount of contaminated fluid which will result from the process? What will be done with the large amounts of contaminated fluid from each well?; What will be done with the larger amounts of methane? How will the fragile ecosystem be affected by the large and constant amount of heavy vehicular traffic?

It is obvious that if the SAFEXTristar proposed project is permitted to go ahead, the delicate ecosystems which make up the Arckaringa Basin will be destroyed - and to what end?

As Professor Irene Watson (*Tanganekald, Meintangk*) Traditional Owner from the southeast of SA summarises the short lived nature of any unconventional gas project – and its disastrous aftermath: *It is our understanding that in general, unconventional gas projects have a short term life of up to 30 years. Such short term gain cannot be offset by the high probability of long-term risk to our lands and waters. First Nations Peoples know that without the sustainability of the land to provide food and water, the future of humanity, along with other species, is threatened*

Unsustainable competition for finite water resources must be disallowed. In this time of unprecedented environmental disasters potential for release of greenhouse gases as fugitive emissions which increases climate change must be avoided at all costs.'

Conclusion

We need our South Australian government systems and our Parliamentary members of both Houses to stand up for our State of South Australia. Of all the states of Australia, South Australia must treasure and conserve its already very limited water resources. The desert areas with their ancient waters of the Great Artesian Basin must be protected.

SAPLEX's unsustainable and crucially destructive project of certain damage in these multiple manifestations must, under no circumstances be permitted to go ahead in the Arckaringa Basin.

Thank you for receiving my submission.

Michele Madigan

23rd May, 2018

From: [Merv Renton](#)
To: [DPC:Engineering](#)
Subject: AGAINST the SAPEX/Tri-Star fracture stimulation (fracking) proposal
Date: Thursday, 31 May 2018 10:38:28 PM

Attention: Jarrod Spencer
Department of the Premier and Cabinet
Energy Resources Division,

I believe that that the SAPEX/Tri-Star fracture stimulation (fracking) proposal **should NOT be approved.**

I believe there is no general approval for this activity in this region either from a majority of local residents or the broader South Australian community.

I believe:

- Fracking represents an unacceptable risk to the Great Artesian Basin aquifers which this proposed activity would drill and frack.
- These aquifers are unique and important and support a number of fragile and unique ecosystems such as mound springs which must be protected from threatening processes including fracking.
- Fracking brings the risk of cross contamination. The subsequent release of hydrocarbons and chemicals into these aquifers threatens not only the natural environment but also the community and industry in the region which rely on this precious water source for drinking and other water uses.
- The use of water associated with this activity is not an appropriate use of this limited, crucial and irreplaceable water source of the Great Artesian Basin.

Concerns about the process that have been expressed include:

- The unknown number and status of faults and fractures between the water of the Great Artesian Basin and the deeper Arckaringa Basin and the impact of high pressure fracking through these basins with chemicals.
- The effect of fracking on seismic activity, risking water resources and underground housing in Coober Pedy.
- That the widespread gas field work will affect the reputation of the region and impact tourism and other business in the region.
- Impacts on Indigenous cultural sites and activities.
- The above and below ground pollution effects of released gases, chemicals, radioactive materials and noise.

This proposal should NOT be approved so we can protect South Australia's precious inland water supplies and regional communities.

Thanks for doing what you do,

Merv Renton
Royal Park, SA 5014

From: [Mark Adams](#)
To: [DPC:Engineering](#)
Subject: Arckaringa Basin
Date: Thursday, 31 May 2018 10:40:42 AM

To whom it may concern, please rule out the possibility of fracking in the Arckaringa Basin, because of concerns about:

- The unknown faults and fractures between the water of the Great Artesian Basin and the deeper Arckaringa Basin and the impact of high pressure fracking through these basins with chemicals.
- The impacts of fracking on seismic activity, risking water resources and underground housing in Coober Pedy.
- The reputational impacts on tourism and other business in the region potentially caused by expansive gasfield impacts.
- Impacts on Indigenous cultural sites and activities.
- The above and below ground pollution impacts from released gases, chemicals, radioactive materials and noise.

From: [anna.weiss](#)
To: [DPC:Engineering](#)
Subject: Fracking in Arckaringa Basin
Date: Thursday, 31 May 2018 2:57:55 PM

To whom it concerns,

You must not even contemplate fracking in this area.

It risks contaminating the Great Artesian Basin and the town and area of Coober Pedy.

Fracking is polluting with the use of the chemicals used the technique itself has implications for the stability of the structure of the soil and its substructures.

Once the Artesian Basin is contaminated it will render it unusable for those that rely on it.

Be wise and think of the greater implications for the sustainability of such endeavours.

Sincerely

Anna Weiss

From: [Marcia](#)
To: [DPC:Engineering](#)
Subject: Fracking in Coober Pedy
Date: Thursday, 31 May 2018 12:25:03 PM

Fracking is dangerous, there is no other form of mining that is as dangerous as fracking. Don't let this company put shale gas into our Great Artesian Basin, it's not worth the money they or you will get from fracking. Once our Artesian Basin is polluted with gas it is no longer a water source for millions of Australians.

Regards

Marcia Herbst

From: [Anne-Maree Taranto](#)
To: [DPC:Engineering](#)
Subject: Fracking near Coober Pedy is unacceptable
Date: Thursday, 31 May 2018 12:01:01 PM

I am writing to urge you to not approve SAPEX/Tri-Star fracking in the Great Artesian Basin and Arckaringa Basin. This aquifer contains a precious water source for sustaining life in the outback.

What is your 50 year vision for this area?

What is your 100, 300, 1000 year vision?

Surely we can plan a future that is free of contamination by supporting sustainable energy sources and ceasing endorsement of dangerous technologies such as Underground Coal gasification and fracking.

Anne-Maree Taranto

From: [Jill Golden](#)
To: [DPC:Engineering](#)
Subject: Fracking near Coober Pedy
Date: Thursday, 31 May 2018 12:28:37 PM

I wish to convey my opposition to fracking near Coober Pedy for the following reasons:

- The unknown faults and fractures between the water of the Great Artesian Basin and the deeper Arckaringa Basin and the impact of high pressure fracking through these basins with chemicals.
- The impacts of fracking on seismic activity, risking water resources and underground housing in Coober Pedy.
- The reputational impacts on tourism and other business in the region potentially caused by expansive gasfield impacts.
- Impacts on Indigenous cultural sites and activities.
- The above and below ground pollution impacts from released gases, chemicals, radioactive materials and noise.
- Fracking represents an unacceptable risk the Great Artesian Basin aquifers through and around which this proposed activity would drill and frack. These aquifers are unique and important and support a number of fragile and unique ecosystems such as mound springs which deserve and require protection from threatening processes including fracking.
- Fracking poses the risk of cross contamination and the release of hydrocarbons and chemicals into these aquifers threatens not only the natural environment but also the community and industry in the region which rely on this water source for drinking and other water uses.
- The draw-down of water associated with this activity is not an appropriate use of this limited, crucial and irreplaceable water source of the Great Artesian Basin.

Sincerely,
Jill Golden

From: [no name](#)
To: [DPC:Engineering](#)
Subject: Fracking our Desert
Date: Thursday, 31 May 2018 10:38:01 AM

As has been stated ,Water is more valuable than gas , we have better cleaner sauces of gas that require far less money !

From: [Gregory Fitzgerald](#)
To: [DPC:Engineering](#)
Subject: No fracking in s.a
Date: Thursday, 31 May 2018 10:55:52 AM

Enough proof is around now,that fracking is not good for the environment or for people,i
DONT want fracking anywhere in my home state of south australia, if politicians cant do
what the people want,dont become a bludging sit on your ass poli

From: [Hannah Woolhouse](#)
To: [DPC:Engineering](#)
Subject: Fracking. Coober Pedy
Date: Thursday, 31 May 2018 5:55:07 PM

To whom it may concern:-

Australia should be the world leader in renewable power alternatives and fracking has no place on the Australian continent.

The need for social licence should not be underestimated by government and big business. Therefore as fracking is being considered in the Coober Pedy region the following points should be taken into account.

- * Geologically the area is maladapted to the process of fracking; unknown faults and fractures in the rock between the Great Artesian Basin and the Arckaringa Basin (which is deeper underground) mean that use of high-pressure fracking, of chemicals and release of hydrocarbons, all represent very real dangers for underground water in the area which will negatively impact the natural environment, the local community and regional industry. Therefore use of fracking processes is totally irresponsible and undesirable. It is not wanted by the local community at large.
- * The local community is quite rightly concerned about seismic activity caused by fracking, the risks to their water supply and to underground housing.
- * The above and below ground impacts of pollution, released gases, chemicals, radio-active substances and noise will without doubt be unacceptable.
- * There will also be negative effects on indigenous cultural sites and activities.
- * Tourism and other businesses in the region will suffer from reduced income linked to loss of good reputation, and physically from harm caused by expansive gas-field impacts.
- * Ecologically this area, like so many in Australia, will not be able to support fracking activity which will destroy vital aquifers supporting ***fragile and unique ecosystems*** (e.g. mound springs).
- * Water in the area is a very scarce and irreplaceable, vital resource. Its use for fracking activity is inappropriate.

Development money would be better spent on improving and establishing renewable energy installations in the region and in putting Australia in the position it should occupy as the world leader in sustainable energy systems.

From: [Donovan Moseley](#)
To: [DPC:Engineering](#)
Subject: RE SAPEX/TRI-STAR FRACTURE STIMULATION PROPOSAL
Date: Thursday, 31 May 2018 10:59:15 AM

- Fracking represents an unacceptable risk the Great Artesian Basin aquifers through and around which this proposed activity would drill and frack. These aquifers are unique and important and support a number of fragile and unique ecosystems such as mound springs which deserve and require protection from threatening processes including fracking.
- Fracking poses the risk of cross contamination and the release of hydrocarbons and chemicals into these aquifers threatens not only the natural environment but also the community and industry in the region which rely on this water source for drinking and other water uses.
- The draw-down of water associated with this activity is not an appropriate use of this limited, crucial and irreplaceable water source of the Great Artesian Basin.

We have this beautiful country and no one wants to see it spoilt by the above process!

This country doesn't have much excess water anyway, (HAVING A DESERT IN THE MIDDLE!)

SO - FOR THE SAKE OF US ALL, PLEASE DO NOT APPROVE THIS PROPOSAL!!

THANK YOU FOR YOUR CONSIDERATION OF THIS MATTER

Yours truly,
Donovan Moseley

From: [Umoona Opal Mine And Museum](#)
To: [DPC:Engineering](#)
Subject: Written submission against the proposed Fracking, from Umoona Opal Mine and Museum.
Date: Thursday, 31 May 2018 5:14:23 PM

To whom it may concern,

FRACKING IN THE ARCKARINGA BASIN.

Management at Umoona Opal Mine and Museum are against the proposed fracking at the PEL 122/PEL 123 in the Arckaringa Basin. Stated below, are our reasons, questions, and concerns.

- Our concerns as an underground business, is work place safety for our staff, and customers. We are concerned about earth movement, and fracking induced earth quakes. We provide guided daily Tours through our old and modern dugouts, and our mine, which we are concerned about the danger and risk to these people, if there was to be a collapse in one of these locations. We also have bunkhouse accommodation for school groups, and large Tour groups, which would also be affected by ground movement, or structural damage.
- If there comes a time that there is structural damage caused by ground movement, will tri star be financially compensate these business/ Dugout/ Home owners?
- We are also concerned we may lose business, if people are afraid to enter or stay underground, for fear of the danger and the risks of being underground, if there are tremors, or earth movements, or the potential of collapsing underground infrastructure.
- We are concerned that there has not been testing near underground homes before, and the risks to the structure of the underground businesses and homes, and if they are covered by insurance if they are damaged by fracking induced earth quakes. We would like to know what calculation of risk there is. This leaves us with financial uncertainty, especially as we are locked into a commercial lease for 20 years.
- Will this devalue our businesses and residential dwellings, and if we do have structural damage to our properties, we are concerned we will be left with unsellable dwellings.
- Has there been a risk assessment done with fracking near underground living.
- Is it true that new research has linked minor tremors to faults, that have been weakened by human activities?

- Is it made known to the public what chemicals are in the fracking liquid in Coober Pedy, and if so, what chemicals are they, and are they safe?
- Is it true that scientists have claimed to have found evidence, that even if earthquakes do not occur directly after water is injected underground, the damage they do to fault lines, can lead to tremors triggered by shockwaves from large earthquakes?
- If there is a chemical, or fuel leak, what is the time frame for this to be addressed and cleaned up, and will the public be informed?
- In the Texan Desert, the landscape is like Coober Pedy, it is believed that years of fracking has caused sinkholes in the Permian Basin, and significant ground movement, in some places up to a meter in 2.5 years, is there a risk that the Arckaringa Basin will also develop this hazard.
- What is the potential pollution of ground water above wells, and the effect of flooding due to excessive rain fall.
- What are the hazards and risks of air pollution to the people living in Coober Pedy.
- In 2012 researchers from the Colorado School of Public Health, released a study showing that air pollution caused by fracking, could contribute to immediate, and long term health problems, for people living near fracking sites. If this occurs, will tri-star be responsible for the medical bills that are to follow, for the rest of their lives?
- Research by over 150 studies suggests that chemicals released during natural gas extraction, may harm human reproduction and development, and cause birth defects.
- Has there been any studies carried out on the effects of fracking, in areas prone to seismic activity, that could result in underground homes/businesses collapsing?
- Coober Pedy's only water supply is from the Great Artesian Basin, if this is compromised, and the water is polluted, what are the plans involved, to get safe drinking water to the people living in Coober Pedy, and who is responsible for paying for it?
- There have been 17 reported earthquakes within Australia in the last 7 days. Is this linked to the hundreds of Drill holes actioned in the Arckaringa basin.?
- Will ground movement increase the cost of Opal Mining, if costs go up to safely extract Opal out of mines?

- In case of large ground movement, will mines and dugouts/businesses have to be structurally supported for safety, and if so, who will be responsible for paying for these adjustments?

Kind Regards,
Management from Umoona Opal Mine and Museum.

Umoona Opal Mine & Museum
P.O. Box 372
COOBER PEDY SA 5723
Australia
Ph: 08 86725288
Fax: 08 86725731
Email: umoona@ozemail.com.au
Web: www.umoonaopalmine.com.au



From: [Rosemary Sargeant](#)
To: [DPC:Engineering](#)
Subject: NO FRACKING IN THE COOBER PEDY REGION
Date: Thursday, 31 May 2018 1:57:22 PM

- I object to fracking in the Coober Pedy region. Specific concerns include:
-
-
- **The draw-down of water associated with this activity is not an appropriate use of this limited, crucial and irreplaceable water source of the Great Artesian Basin.**
-
- The large Great Artesian Basin is the only water source for Coober Pedy's 2,000 residents. Fracking could impact and put at risk not just the water resources but also underground housing in Coober Pedy.
- Fracking represents an unacceptable risk the Great Artesian Basin aquifers through and around which this proposed activity would drill and frack.
-
- Fracking poses the risk of cross contamination. The release of hydrocarbons and chemicals into these aquifers threatens not only the natural environment but also the community and industry in the region which rely on this water source for drinking and other water uses.
-
- I ask that you reject this fracking proposal.

Rosemary Sargeant
Campbelltown SA

From: [Deirdre Mills](#)
To: [DPC:Engineering](#)
Subject: Fracking
Date: Thursday, 31 May 2018 11:57:36 AM

Please do not frack anywhere in the Cooper Pedy area. The Great Artesian Basin is too precious a resource to be damaged by commercial greed.

D Mills

From: [Debbie Tsagatos](#)
To: [DPC:Engineering](#)
Subject: No fracking in South Australia
Date: Thursday, 31 May 2018 5:45:13 PM

I object to any fracking in South Australia. It is dangerous for the environment including our water supply, it infringes on Indigenous and local peoples rights, pollutes the environment both above and below the ground and is a risk to the valuable tourism industry.

Regards,
Debbie Tsagatos
4 Sewell Ave, Payneham, SA, 5070



Virus-free. www.avg.com

From: [Gregory Fitzgerald](#)
To: [DPC:Engineering](#)
Subject: No fracking in s.a
Date: Thursday, 31 May 2018 10:55:52 AM

Enough proof is around now,that fracking is not good for the environment or for people,i
DONT want fracking anywhere in my home state of south australia, if politicians cant do
what the people want,dont become a bludging sit on your ass poli

From: [Lee Mickan-Winter](#)
To: [DPC:Engineering](#)
Subject: No fracking
Date: Thursday, 31 May 2018 1:09:10 PM

I strongly object to fracking in the Great Artesian Basin. This is detrimental to not only the water supply but the environment and ecosystems that exist. A big no from me and my family who are strongly against this as well.

Lee Winter

From: [Joe Selway](#)
To: [DPC:Engineering](#)
Subject: Attn: Jarrod Spencer Re: SAPEX Limited PEL 122 & 123 Fracture Stimulation Activities
Date: Friday, 1 June 2018 10:22:19 AM

Dear Jarrod,

I am writing to express my concern and objection to the approval of these activities.

Fracture stimulation is an extremely risky method of increasing production for which I believe the environmental risk strongly outweighs the economic benefit.

I am by no means an extreme greeny and believe in achieving the right balance between environment and economy. However also as a pragmatic individual and small business owner myself, I believe that the risk here is far too great for the amount of economic gain.

Please consider SA's strong position as a world leader in renewable energy and environmental practice, with our recent investments into solar and battery technology and our unique advantage as the non-GMO state with organic agriculture booming, SA is on the world map in a very positive light. I believe that exploiting this trend and reputation has much greater potential economic benefit than contrary activities such as proposed by SAPEX.

I implore you to take this into consideration before jeopardising this hard earned reputation, the water supply in a very dry part of our state and the well being of a major community in pursuit of a quick buck from some low grade petroleum.

Sincerely,
Joe Selway
Lifetime SA resident and small business owner

From: [Allan Addams](#)
To: [DPC:Engineering](#)
Subject: Don't frack near Coober Pedy
Date: Saturday, 2 June 2018 2:31:20 AM

I read with concern of plans to test frack the Arckaringa Basin.

I urge you not to approve this invasive and potentially damaging practice.

The environmental risks include chemical pollution, wasted water resources and possible damage to underground dwellings.

Sincerely

Allan Addams

From: [Carolyn Sprigg](#)
To: [DPC:Engineering](#)
Subject: Fracking
Date: Saturday, 2 June 2018 9:21:48 PM

SAPEX/Tri-Star fracture stimulation (fracking) proposal not be approved.

Regards

Carolyn Sprigg

Sent from my iPhone

From: [Judy Cram](#)
To: [DPC:Engineering](#)
Subject: SAPEX Limited PEL 122 & 123. Fracture Simulation Activities
Date: Saturday, 2 June 2018 10:24:55 AM

ATTENTION: Jarrod Spencer,

My concerns for the Arckaringa Basin are many.

We have rare & unique wildlife and bird species, that will be adversely affected by any toxic gases being emitted. Vegetation won't thrive in these conditions either. Vegetation & wildlife will be compromised with the harsh chemicals being used continuously.

Any changes to the natural underground water pressure could see 3 states remote areas without water. Toxic water would have detrimental side affects to humans, animals and the natural landscape.

Any increases in seismic activity would severely impact our underground homes, mines and businesses.

Our tourism would be forever damaged by any changes or impacts to the aforementioned issues.

We have invested millions into Coober Pedy through our opal mining, shops, homes, services and our time here. We recently celebrated 100 years living and opal mining in Coober Pedy.

Please don't try to "sugar coat" it or cover up for the sake of \$\$\$ now, when the future consequences will be far more devastating for all of us. Australia is an ongoing tourist attraction, don't destroy it.

I have grave concerns for Australia if "fracking" continues to spread out unopposed. Not enough independent research is being done before approval is given. \$\$\$\$\$\$ is being given power over the devastating reality of fracking. There are no good reports about fracking that don't involve money. Plenty of bad reports about the impact of fracking on the environment, wildlife, water and toxic gases exposed. Not to mention long term health issues, only now coming to light.

Please consider everything before approving any future leases.

Kind Regards

Judy Cram



Virus-free. www.avg.com

From: [Angela](#)
To: [DPC:Engineering](#)
Subject: Fracking
Date: Saturday, 2 June 2018 2:51:22 PM

It has been proven that fracking is not safe for anyone so to grant the company SAPEX/Tri-Star a license to frack in the Coober Pedy is not a safe practice. Even though it looks like there is no life outback there is . The people of Coober Pedy rely on the water from the great artesian basin which is a huge inland aquifer. As well as all the native animals and ecosystems.

The fracking process uses chemicals to fracture the ground and the point it breaks at is unknown with all the engineering knowledge available. The chemicals contaminate the earth and eventually find their way into the water system along with all the water they use in the process and the unknown of if there is gas in the area which often comes out of taps with the water.

This can be lit with lighters.

Water is too precious to risk especially when so many rely on it in the drier areas of Australia.

Please don't grant this exploratory license or any other ,there is no planet B. Why spoil the natural state of the country as remediation is impossible.

Angela Butler

Sent from [Mail](#) for Windows 10

From: [IanS](#)
To: [DPC:Engineering](#)
Subject: Fracking
Date: Sunday, 3 June 2018 7:41:59 AM
Sensitivity: Personal

I am against fracking in the Arckaringa Basin for many reasons because of;

- The unknown faults and fractures between the water of the Great Artesian Basin and the deeper Arckaringa Basin and the impact of high pressure fracking through these basins with chemicals.
 - The impacts of fracking on seismic activity, risking water resources and underground housing in Coober Pedy.
 - The reputational impacts on tourism and other business in the region potentially caused by expansive gasfield impacts.
 - Impacts on Indigenous cultural sites and activities.
 - The above and below ground pollution impacts from released gases, chemicals, radioactive materials and noise.
- What's more fracking represents an unacceptable risk the Great Artesian Basin aquifers through and around which this proposed activity would drill and frack. These aquifers are unique and important and support a number of fragile and unique ecosystems such as mound springs which deserve and require protection from threatening processes including fracking.

It poses the risk of cross contamination and the release of hydrocarbons and chemicals into these aquifers threatens not only the natural environment but also the community and industry in the region which rely on this water source for drinking and other water uses.

In addition the draw-down of water associated with this activity is not an appropriate use of this limited, crucial and irreplaceable water source of the Great Artesian Basin.

Sincerely

Ian Spiller

VoIP +61.87231 5698 : **Mb Optus Aust** +61 419 035 882 : **Mb True Thai** +66.640 546 089

TO: Jarrod Spencer DPC.Engineering@sa.gov.au

FROM: Amandine Caire (Coober Pedy Resident)

RE: SAPEX Limited PEL 122 & 123 Fracture Simulation Activities: public submission

OBJECTION ON SOCIAL GROUND

I object to unconventional oil and gas development in the Arckaringa Basin as no 'social license to operate'¹ has been obtained by the company in Coober Pedy. A vote recently organised by DCCP showed about 75% of the population is against hydraulic fracture stimulation. Although I note that the mining company did engage with the community on two separate occasions in 2018, the company has failed to secure community support.

I also object to unconventional oil and gas development in the Arckaringa basin as some of the Arabana people I have been in contact with are concerned about the proposal. Some representatives of the local Antikirinja Matu Yankunytjatjara people are also strongly opposed to the proposal.

OBJECTION ON MORAL GROUND

As a resident, I find it hard to trust the mining company Tri-Star which took over from Linc Energy, a company which made the headlines recently for 'willfully and unlawfully causing environmental harm' in Queensland.²

I believe the lack of correct information is damaging to people's trust. In a State Government booklet, it states that fracture stimulation has been done safely for 45 years³ but it is agreed that the new technique used in fracture stimulation has only been used since 2012:

'While the committee does not dispute that hydraulic fracturing has been practised in South Australia for many years, the records of Parliament show that the current form of unconventional gas development is said to have commenced in Moomba in 2012. On 29 November 2012, Premier Jay Weatherill said during Question Time: Our energy industry is benefiting from the burgeoning growth in shale gas, and this year we have seen Santos launch the first unconventional gas well for commercial supply in Australia at Moomba.' (p17)⁴

OBJECTION ON SCIENTIFIC GROUND

I object to hydraulic fracture stimulation used in unconventional oil and gas development in the Arckaringa basin and fully support the scientific evidence exposed in Damien Bachmann⁵, Janet Walton and Colin Pitman⁶'s submissions. Their concerns will have to be addressed by Tri-Star and the State Government. I would like to see an independent and thorough scientific report on the risks associated with unconventional oil and gas development in the Arckaringa basin in PEL 122 and 123. This report would have to assess every single stage of development and address the specific environmental and geological challenges of the area, not just provide some general risk analysis.

¹ I refer to the terminology 'social license to operate' as explained in INQUIRY INTO UNCONVENTIONAL GAS (FRACKING) IN THE SOUTH EAST OF SOUTH AUSTRALIA

² <http://www.abc.net.au/news/2018-04-10/gas-company-court-ruling-sounds-a-warning-lawyer-says/9637874>

³ <https://statedevelopment.sa.gov.au/upload/Fracking/thefactsguide.pdf>

⁴ INQUIRY INTO UNCONVENTIONAL GAS (FRACKING) IN THE SOUTH EAST OF SOUTH AUSTRALIA

⁵ www.phonolite.com.au/Submission.pdf

⁶ 28th March DCCP Agenda p3 fracking update

A report by an independent seismologist would also be welcome as earthquakes can happen in Coober Pedy (for instance a 3.7 magnitude earthquake 32 km from Coober Pedy, 20 years ago⁷).

May I note that the proposed project areas are not 'a very very long way away from Coober Pedy' as State Mining minister Dan van Holst Pellekaan⁸ stated. The closest project area is only 30 kms away from Coober Pedy.

ECONOMIC IMPACT

I object to unconventional oil and gas development because it could impact our local economy if tourists perceived a threat to their lives by staying underground (which is the main tourist attraction along with opals in Coober Pedy). With about 150 000 tourists visiting Coober Pedy every year, it would be detrimental to put the community's economic sustainability at risk. People here have invested in businesses and properties and their livelihoods should not be jeopardised.

LACK OF POLITICAL CONSISTENCY ON FRACTURE STIMULATION AT STATE, NATIONAL AND INTERNATIONAL LEVELS

'A State Liberal Government will continue to support exploration for and development of unconventional gas resources in the Cooper and Eromanga Basins in the State's Far North where the potential is higher and the impacts on other existing activities and the environment are minimal.'⁹

This quote from Premier Steven Marshall would definitely not apply to the neighbouring basin: the Arckaringa basin. The environmental impact would be irrevocable if contamination occurred. Indeed the repercussions could be catastrophic for all life forms and human activities. The potential might be higher than in other areas, but the risks should be deemed extreme and not worth taking.

How can we ask a community to trust that fracture stimulation is safe when some states in Australia have banned it and SA has put a moratorium on fracking in SE?

How can we ask Coober Pedy residents to agree to such proposal when a political party 'SA Best' was ready to put a moratorium on fracture stimulation in the Arckaringa basin if elected?

In fact how can we ask Coober Pedy residents to trust such industry when countries all over the world have banned or put a moratorium on the contentious practice?

⁷ <https://www.earthquaketrack.com/au-05-coober-pedy/recent>

⁸ [ABC North and West 9 April](#)

⁹ <https://www.stevenmarshall.com.au/fracking>

From: [Tanya Lauder](#)
To: [DPC:Engineering](#)
Subject: SAPEX Limited PEL 122 & PEL 123 Fracture Stimulation Activities
Date: Monday, 4 June 2018 3:56:34 AM

To whom it may concern,

I object on the following grounds:

1. That no information has been given to council on whether a security bond (and if so what amount) has been requested by the government
2. It has not been noted that an independent assessment under s .100(3)(a) has been committed to
3. That this has been rated Medium Impact activity, please state who classified this
4. That the community's plebiscite gave evidence that the majority of the town is against fracking
5. That no information has been provided regarding the frequency and procedures of reviews and studies after each stage and if the community is consulted
6. That no information has been provided to the community on how the government has assessed Tri-Star and SAPEX Limited
7. That we have not been advised if the community will be informed on any incidents, ie: will the community be advised of any contamination or aquifer impact (is this classified as a serious incident). Will these incidents be made public immediately.
8. That no emergency response plan has been provided in case of cross-contamination of aquifers/loss of containment
9. That no information was given on the reviewer of the document (EIR) and their level of competency
10. That no information has been given as to how they are going to manage the risk human error in design and operation of a stimulation event
11. That no information has been given as to how the will manage the risk of equipment/instrumentation miscalibration and failure
12. That no independent study has been prepared on the effects of fracking on the tourism of our town
13. That no independent study on the effects of our population. It is very low at this current time and nothing should be allowed to impede its increase to past numbers.
14. That no independent study on the loss of income, ie: many Mining companies have gone bankrupt and have left owing great sums of money to local businesses
15. That no independent study has been done on the science of this particular activity
16. It will ruin the unique, untouched, arid, outback vistas, many of which are used in Movies
17. That it is unclear if the Arabana People were aware of the potential fracking when they signed, since it was signed back in 2006
18. That the PEL should be modified if the AMYAC Native Title is not being classified as a Key Stakeholder
19. That no long term study has been provided into fracking
20. That the EIR was poorly presented, as in the following cases:
 - a. Figure 1 - Did not provide the name of the other Native Title

Determination, ie: AMYAC. It also does not indicate what the red outline means in the key.

- b. Figure 4 - Blue outline not identified in key.
- c. Figure 6 – Does not state who modified the Figure and where the information came from
- d. Figure 8 – Where has this figure been sourced from and the Figure is too confusing too understand given that there is labels in the Figure not explained.
- e. Table 2 – Unclear who filled in table
- f. Figure 15 – No Legend
- g. Figure 16 – No scale given and map did not include Coober Pedy
- h. Section 4.9.1 - Does not state how far Coober Pedy is from PEL areas.
- i. Section 6.5.6 - Not enough data has been provided to adequately state that this is not a credible risk
- j. Table 11 – Incorrectly evaluated – biased
- k. In Appendix 6 -DEWNER has mentioned the word EPBC, but this abbreviation is not listed in the Glossary
- l. None of the Figures showed the watercourses underneath the ground

CLEANING UP LARGE CONTAMINATION IN AQUIFERS MAY BE IMPOSSIBLE – EPA AT PENOLA MEETING

The question of cleaning up aquifers was raised at a public meeting in Penola in April 2014. As recalled, the EPA representative admitted that small contaminations can be cleaned up, but not large contaminated areas. What was perplexing was the explanation of how contamination of aquifers was dealt with. According to the EPA representative, as recalled by attendees, the water and contamination is pumped out of the aquifer. The question is, what is then done to dispose of the contaminated water once at the surface? Even with the water being treated, there is always a second lot of residue water in a concentrated form that will always remain.

HEALTH IMPACTS

In Sept. 2014, a study by Yale University found that people living near gas wells had a higher prevalence of skin conditions and upper respiratory conditions that lived closer to the wells. In Jan. 2014, a study published in the Environmental Health Perspectives showing an association between congenital heart defects and possible neural tube defects of newborn babies increasing with density and proximity of gas wells of the mother's home. At the same time, preliminary data from Princeton University, Columbia University and MIT showed low birth weight in the same circumstances. October 2013 Cornell University also found decreased birth weight and premature birth.

FOUR HUNDRED PEER-REVIEWED PAPERS SHOWING FRACKING ISSUES ARE OF THE MOST SERIOUS NATURE

There are now around 400 peer-reviewed papers that have been evaluated in USA regarding unconventional gas and fracking issues that are of the most serious nature. These can be found at the following link.

<http://www.ernstversusencana.ca/state-of-science-on-harms-by-fracking-to-public-healthand-water-health-professionals-scientists-release-analysis-of-400-peer-reviewed-studies-on-fracking-along-with-major-scientific-compendium>

73% of all available scientific peer-reviewed papers have been published in the past 24 months. The credible scientific report is available now to prove that hydraulic fracture stimulation is having massive detrimental effects.

FRACTURES CAN EXTEND 600 - 900 METRES

In the report "SUPPORT TO THE IDENTIFICATION OF POTENTIAL RISKS FOR THE ENVIRONMENT AND HUMAN HEALTH ARISING FROM HYDROCARBON OPERATIONS INVOLVING HYDRAULIC FRACTURING IN EUROPE" done for the European Commission DG Environment, 2012, on Page 6 states that the "toe" of the horizontal leg can be up to 3 km from the vertical leg (Zoback et al., 2010 NPR). This suggests that a typical horizontal section can be expected to be 1200 to 3000 metres in length. This document also states that in a report by Fisher and Warpinski, 2012, a vertical fracture extended around 600 metres.

http://ec.europa.eu/environment/integration/energy/pdf/fracking_study.pdf

RJ Davies prepared a document "MARINE AND PETROLEUM GEOLOGY". Page 3 –Unintentional hydraulic stimulated fractures can occur, such as an underground blowout (e.g. Tingay 2003), or through injection of waste - water at high enough rates to generate pore pressures which exceed pressure required for hydraulic fracturing (e.g. Loseth et al., 2011). Page 5 – A petroleum company in the Tordis field offshore from Norway injected produced wastewater from oil production 900 metres below the surface. This caused hydraulic fractures to extend 900 metres to the seabed. This caused fracturing of the overburden. As the result the injection only lasted 5 ½ months and leakage to the seabed may have occurred for up to 77 days. One of the concerns is that if hydraulic fracture stimulation is allowed

EARTHQUAKES OVERSEAS BLAMED ON FRACKING ACTIVITIES

In the "COMPENDIUM OF SCIENTIFIC, MEDICAL, AND MEDIA FINDINGS DEMONSTRATING RISKS AND HARMS OF FRACKING (UNCONVENTIONAL GAS AND OIL EXTRACTION)"

December 2014, it is stated that "A growing body of evidence, from Ohio, Arkansas, Texas, Oklahoma and Colorado, links hydraulic fracture stimulation wastewater injection (disposal) wells to earthquakes of magnitudes as high as 5.7, in addition to "swarms" of minor earthquakes and fault slipping."

<http://concernedhealthny.org/wp-content/uploads/2014/07/CHPNY-FrackingCompendium.pdf>

There are reports of hydraulic fracture stimulation leading to earthquakes in Canada and across the Atlantic in the United Kingdom. Since 2008, when hydraulic fracture stimulation has been taking place for shale, earthquakes have spiked in central and eastern United States. Before 2008 Oklahoma averaged just one earthquake greater than magnitude 3.0 a year. So far this year there have been 430 of them, Holland said. (2014)

<http://phys.org/news/2014-11-scientists-fracking-earthquakes-heartland.html> - jCp

In an article "INJECTION INDUCED EARTHQUAKES by Dr. William L Ellsworth, of the Earthquake Science Centre, Ellsworth reports that injection into deep wells can induce large earthquakes as is a higher risk and causes larger earthquakes. There was a 5.6 magnitude earthquake in central Oklahoma that destroyed 14 homes, along with other earthquakes in 2011 and 2012. This was blamed on injection wells. This activity appeared to weaken a pre-existing fault by elevating the fluid pressure. If the deeper aquifer system is under pressured with the right circumstances, this can cause fault failure by raising the water table and the pore pressure acts on the faults. Beach Energy Ltd. has indicated that the waste -water may be re-used. Even if this is so, the used waste – water has to go somewhere eventually.

50 earthquakes were recorded in Oklahoma in 2009. The following year, there were over 1000 but most were not felt in 2013 there were 253. According to seismologist Austin Holland of the Oklahoma Geological Survey told Reuters: "We have had almost as many magnitude 3 and greater already in 2014 than we did for all of 2013... We have already crushed last year's record for number of earthquakes." There have been 1562 earthquakes in past year

in Oklahoma. According to the Washington Post, there were 183 earthquakes with a magnitude over 3 between October 2013 and October 2014. These have all been blamed on fracking. According to the Journal of Geophysical Research, Prague, 44 km from Oklahoma City had a 5.6 magnitude earthquake blamed on fracking activities.

<http://earthquaketrack.com/p/united-states/oklahoma/recent>

A 2011 fracking operation in the Bowland Shale near Blackpool, England set off 50 minor earthquakes. In British Columbia, the industry, which uses three times more water and often at higher pressures than other shale gas formations, set off more than 200 quakes in the Horn River Basin between April 2009 and Dec. 2011. At least 19 of the quakes ranged between a magnitude of two and three, and one reached a magnitude of 3.8, an event that surprised most scientists. In Azle, Texas and other shale fractured landscapes, scientists suspect the culprit may not be fracking but its companion industry: dirty water disposal. A 2012 study by Cliff Frohlich, a senior researcher at the University of Texas in Austin, noted that a swarm of tremors in the Barnett Shale near Dallas were all located near deep well disposal sites. "You can't prove that any one earthquake was caused by an injection well," said Frohlich. "But it's obvious that wells are enhancing the probability that earthquakes will occur." William Ellsworth, a geophysicist with the USGS, argues that several of the largest earthquakes in the U.S. Midcontinent in 2011 and 2012 were probably triggered by the practice of disposing of salt and drilling fluids more than 10,000 feet underground in disposal wells.

HYPO-CENTRES OF EARTHQUAKES OCCUR WITHIN DISPOSAL FORMATIONS BETWEEN 2 AND 5 KM IN DEPTH

A paper "EARTHQUAKES BLAMED ON FRACKING ACTIVITIES SINCE 2008" by Keranen, Weingarten, Abers, Benkins and Ge, from the following institutions respectively - Department of Earth and Atmospheric Sciences, Cornell University, Department of Geological Sciences, University of Colorado and Lamont-Doherty Earth Observatory of Columbia University it is stated that earthquake hypo-centres occur within disposal formations and upper basement, between 2 and 5 km depth. According to seismologist Dave Wolney: "If you are doing deep well injection, you are altering the stress on the underlying rocks and at some point, (it) will be relieved by generating an earthquake."

SCHLUMBERGER AND THE RUSSIAN ACADEMY OF SCIENCES DO STUDY ON PRODUCTION AND SEISMICITY IN THE OIL FIELD

– by Vitaly Adushkin, Vladimir Rodionov and Sergey Turuntaev, Institute of Dynamics of Geospheres, Russian Academy of Sciences Moscow, Russia – it is stated that in some regions, hydrocarbon production can induce seismic activity. To help understand how production affects seismicity, a recording network was installed in a producing field in Russia. In a cooperative project between Schlumberger and the Institute of Dynamics of Geospheres at the Russian Academy the findings on page 16 were "Few will deny that there is a relationship between hydrocarbon recovery and seismic activity, but exactly how strong a relationship exists has yet to be determined. Furthermore, what can or should be done about it sparks another debate." In regions of high tectonic potential energy, hydrocarbon production can cause severe increases in seismic activity and trigger strong earthquakes, as in Gazli, Uzbekistan (magnitude 7.3). In regions of lower tectonic stress, earthquakes of that magnitude are less likely, but relatively weak earthquakes could occur and damage surface structures." When the industry is prepared to admit, as the result of scientific testing, that there is a relationship between hydrocarbon recovery, which includes shale gas, then all activities relating to shale gas and tight gas in the SE of SA must cease.

http://www.slb.com/~media/Files/resources/oilfield_review/ors00/sum00/p2_17.ashx

There are a number of other earthquakes around the world that have also been blamed on

fracking activities, including Holland but too much to include here.

INSTITUTIONAL FAILURE IN SOUTH AUSTRALIA

Although not related to unconventional gas, it is important to mention that there are problems state wide. It is believed that there are only two government logging trucks operating in South Australia. There are thousands of drill holes around the state, including mineral exploration and hydrology observation drill holes. All auditing for both Mineral and Petroleum drill holes comes under the Department of the Premier and Cabinet. This shows an inadequacy of auditing previous drill and hydrology observation holes, let alone hundreds more, including gas drill holes and wells in the future including for generations to come. On Eyre Peninsula, farmers forced DMITRE to do an audit on Eyre Iron. They only looked at 136 of the 406 drill holes. 109 were non compliant. It is believed the remaining 270 drill holes were never audited. Department of the Premier and Cabinet is the regulator of licences, the promoter and the regulator. This is clearly a conflict of interest.

Regards

Tanya Lauder

tanyalauder@bigpond.com

0408 030 974

**ARABANA ABORIGINAL CORPORATION RNTBC Written Submission to
Public Consultation on SAPEX Limited PEL 122 & PEL 123 Fracture
Stimulation Activities (Fracking) in the Great Artesian Basin
PEL 122 & PEL 123**

Attention: Mr Jarrod Spencer
Department of the Premier and Cabinet
Energy Resource Division
GPO Box 320, Adelaide 5001

The Arabana Aboriginal Corporation (AAC) RNTBC is the Prescribe Body Corporate that manages Arabana Country on behalf of the Arabana People since the Native Title Determination in May 2012.

“Justice Finn made a consent determination over the claim for Arabana People, to recognise their non-exclusive native title rights and interest over an area located central north of South Australia, covering approximately 68,823 square kilometres.

The claimed area includes two significant geographical features of south Australia, namely Lake Eyre and the Wabma Kadarbu Mound Springs Conservation Park.

Lake Eyre is a popular tourist destination, including for overseas visitors, and sits at the top of the Lake Eyre Basin and is the lowest point in Australia at approximately 15 metres below sea level. The area encompasses Marree in the southeast, Oodnadatta in the northwest, and Lake Eyre and the Wabma Kadarbu Mound Springs Conservation Park is well known for its natural springs that rise from the Great Artesian Basin.”

The AAC is a significant land holding body with an Indigenous Land Use Agreement with the Department of Environmental Water (DEW) over the Wabma Kadarbu Mound Springs Conservation Park and Kati Thanda (Lake Eyre).

The Arabana Aboriginal Corporation RNTBC does not support “ the Fracture Stimulation Activities at PEL 122 and PEL 123, “fracking,” in the Great Artesian Basin/Lake Eyre Basins which are culturally significant to the Arabana People.

To do fracking in the Great Artesian Basin/Lake Eyre Basin is a risk to our cultural and heritage.

Mr Marshall said a moratorium would “protect current and future jobs and prosperity in the world-famous agricultural region”. “The South-East relies upon groundwater for irrigation — risking the safety of the groundwater could be devastating for the South Australian economy and the thousands of people who live and work in the South-East,” he said.

Mr Marshall put a 10year moratorium on fracking in the South East and the Arabana Aboriginal Corporation RNTBC asks that equal consideration be given to stop fracking in the Great Artesian Basin.

The fracking is a risk to the Arabana Cultural heritage, destruction of site and culture, not to mention the effect on employment and industries that derive a livelihood and rely on the Great Artesian Basin for survival, industries such as the pastoral and agricultural industries.

The area in and around the Great Artesian Basin relies upon groundwater for industry, risking safety of the ground water could be devastating for the South Australian economy and the thousands of people who live and work in the Great Artesian Basin area.

The Great Artesian Basin is a significant water resource in a very dry continent and any discussions relating to its potential destruction of the Great Artesian Basin should at least involve COAG and a broader discussion with the wider community affected by government decisions. The Arabana People need to be front and centre of any of these discussions.

Mr Marshall, we ask that you protect our Arabana Cultural Heritage and that you decline the request to allow fracking in the Great Artesian Basin.

Lorraine Merrick

General Manager

Arabana Aboriginal Corporation RNTBC

Objection to the SAPEX/Tri-Star PEL 122 and 123 fracture stimulation proposal

June 2018

Introduction and overview

Lock the Gate Alliance is a national grassroots organisation made up of thousands of individuals and over 250 local groups who are concerned about unsafe or inappropriate mining. The mission of the Lock the Gate Alliance is to protect Australia's agricultural, environmental, and cultural resources from inappropriate mining and to educate and empower all Australians to demand sustainable solutions to food and energy production. Lock the Gate Alliance is committed to advocating for environmental and community health, and the productivity of local economies.

Lock the Gate Alliance objects to the fracture stimulation activities as outlined by the SAPEX/Tri-Star PEL 122 and 123 fracture stimulation activities proposal.

The overview of the SA Government website and in the submission by the proponent plays down the use of harmful chemicals required in fracture stimulation, and does not deal with the risks of storage and transport of chemicals and wastes. Notably, the proposal even at this early stage goes dangerously close to having polluting gasfield activities taking place near significant Great Artesian Basin (GAB) springs.

The shallow depth of the target formations in relation to the GAB aquifers is very concerning. Not nearly enough information is known about the interconnectivity of these formations and the fault lines that will act as conduits for pollution. Fracking represents an unacceptable risk the Great Artesian Basin aquifers through and around which this proposed activity would drill and frack. These aquifers are unique and important and support a number of fragile and unique ecosystems such as mound springs which deserve and require protection from threatening processes including fracking.

Fracking poses the risk of cross contamination and the release of hydrocarbons and chemicals into these aquifers threatens not only the natural environment but also the community and industry in the region which rely on this water source for drinking and other water uses.

The draw-down of water associated with this activity is not an appropriate use of this limited, crucial and irreplaceable water source of the Great Artesian Basin.

The submissions by the proponent also do not give sufficient recognition to the extremely high pressure required to frack open the target formation and the risks of high pressure, high heat environments for polluting aquifers.

As made clear by the US EPA in their final report into water cycle impacts from the Hydraulic Fracturing process on their website:¹

Q: Have you found scientific evidence that hydraulic fracturing can impact drinking water resources?

A: Yes. EPA has found scientific evidence that activities in the hydraulic fracturing water cycle can impact drinking water resources under some circumstances. Impacts can range in frequency and severity, depending on the combination of hydraulic fracturing water cycle activities and local- or regional-scale factors. The following combinations of activities and factors are more likely than others to result in more frequent or more severe impacts:

- *Water withdrawals for hydraulic fracturing in times or areas of low water availability, particularly in areas with limited or declining groundwater resources;*
- *Spills during the management of hydraulic fracturing fluids and chemicals or produced water that result in large volumes or high concentrations of chemicals reaching groundwater resources;*
- *Injection of hydraulic fracturing fluids into wells with inadequate mechanical integrity, allowing gases or liquids to move to groundwater resources;*
- *Injection of hydraulic fracturing fluids directly into groundwater resources;*
- *Discharge of inadequately treated hydraulic fracturing wastewater to surface water resources; and,*
- *Disposal or storage of hydraulic fracturing wastewater in unlined pits, resulting in contamination of groundwater resources.*

The above conclusions are based on cases of identified impacts and other data, information, and analyses presented in the report. Cases of impacts were identified for all stages of the hydraulic fracturing water cycle. Identified impacts generally occurred near hydraulically fractured oil and gas production wells and ranged in severity, from temporary changes in water quality to contamination that made private drinking water wells unusable.

¹ <https://www.epa.gov/hfstudy/questions-and-answers-about-epas-hydraulic-fracturing-drinking-water-assessment>

Fracking for unconventional oil and gas is dangerous, and this proposal does not alleviate risks

Following two and a half decades of rapid development that has seen a massive expansion in the unconventional gas (UG) industry across twenty one states of the USA, there is a growing body of scientific literature detailing the many negative impacts of unconventional gas extraction, in particular shale gas extraction, including hydraulic fracturing (fracking) processes.

In the last few years, the state of knowledge about the risks and harms of unconventional gas mining has grown exponentially. When the New York State (NYS) Department of Health released its final Public Health Review² of fracking in December 2014, the number of studies in the peer-reviewed scientific literature exceeded 400, up from the 60 studies that existed two years previously in a similar review by the NYS Department of Conservation.

Summarized below is a list from the NYS Public Health Review outlining some of the environmental impacts and health outcomes that have been associated with UG operations:

- Air impacts that could affect respiratory health due to increased levels of particulate matter, diesel exhaust, or volatile organic chemicals.
- Climate change impacts due to methane and other volatile organic chemical releases to the atmosphere.
- Drinking water impacts from underground migration of methane and/or fracking chemicals associated with faulty well construction.
- Surface spills potentially resulting in soil and water contamination.
- Surface-water contamination resulting from inadequate wastewater treatment.
- Earthquakes induced during fracturing.
- A range of health complaints and impaired health outcomes among residents living near HVHF [fracking] activities.

Community impacts associated with boom-town economic effects such as increased vehicle traffic, road damage, noise, odor complaints, increased demand for housing and medical care, and stress.

² New York State Department of Health (2014) A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development:
http://www.health.ny.gov/press/reports/docs/high_volume_hydraulic_fracturing.pdf

Additionally, the NYS Health Department review notes that an evaluation of the available research on fracking impacts reveals critical information gaps. They state: “These need to be filled to more fully understand the connections between risk factors, such as air and water pollution, and public health outcomes among populations living in proximity to HVHF [fracking] shale gas operations.”³

The environmental impacts outlined in the NYS Health Department review and their potential adverse effects on public health led the Department to recommend to the state government that fracking should not proceed in the State of New York. (The NYS legislature subsequently announced plans to impose a ban on fracking in the state).

The New York based health organization, the *Concerned Health Professionals of New York*, have compiled the *Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking*⁴ (the *Compendium*) - “a fully-referenced compilation of the evidence for the risks and harms of fracking that brings together findings from the scientific and medical literature, government and industry reports, and journalistic investigation.”

The growing evidence of actual harm, and the potential environmental and health risks from shale gas development, has now resulted in decisive action from governments across the globe to halt the expansion of this industry. Internationally, jurisdictions with some form of ban or moratorium in place include Scotland, Wales, Germany, Bulgaria, Romania, the Netherlands, Northern Ireland, Wales, the Czech Republic, Luxembourg and France as well as the US States of New York, Maryland, Florida and Vermont and the Canadian Provinces of New Brunswick, Newfoundland, Nova Scotia and Quebec.

In addition to the science, the Lock the Gate Alliance developed initial concerns with unconventional gas extraction from the lived experience of farmers and rural communities in Queensland. There are over 5000 coal seam gas (CSG) wells producing gas in that state⁵, with an additional 20,000 wells already approved. The rush to exploit CSG in Queensland and convert it to LNG, never previously attempted, has done lasting damage to the water resources and communities of the affected areas, and has had drastic negative economic consequences, rapidly driving up the price of gas for domestic consumers and industry, and throwing regional economies into turmoil. In Queensland, the approvals for large scale CSG projects were done in haste and implemented before communities knew of the potential impacts and without any opportunity for them to object to the industry being imposed upon them.

³ Ibid.

⁴ Concerned Health Professionals of New York & Physicians for Social Responsibility. (2016, November 17). Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction) (4th ed.). http://concernedhealthny.org/wp-content/uploads/2016/12/COMPENDIUM-4.0_FINAL_11_16_16Corrected.pdf

⁵ QLD CSG Production, 6 Monthly Statistics: <https://data.qld.gov.au/dataset/petroleum-gas-production-and-reserve-statistics/resource/63a8a6cc-7fb6-4040-b4e7-9d453b14d3ed>

The expanding scientific literature, coupled with the lived experience of unconventional gas extraction operations in Australia, and concurrent research of the impacts of shale and tight gas extraction from across North America, provides the basis of this objection.

The difference between conventional and unconventional gas

We recommend further information is included by the proponent in their comparison.

As unconventional gas is found in less permeable deposits or spread more diffusely throughout rock substrates than conventional (or so-called “natural”) gas, rather than in discrete pockets or reservoirs, it is more difficult to extract and therefore requires more specialized (i.e. ‘unconventional’) extraction techniques and processes. The methods required for the extraction of unconventional gas include hydraulic fracturing (fracking), horizontal drilling and multiple drilling. In addition to these extra processes, unconventional gasfields involve the industrialisation of entire landscapes with hundreds and often thousands of wells and ancillary infrastructure.

Unconventional Oil and Gas Magazine uses the following statement to highlight some of the differences and the need for more wells in unconventional gas extraction: *“High permeability rock equals higher flow rates and lower cost development by virtue of requiring a lesser number of wells (e.g. for sandstone and limestone reservoired gas) and by contrast lower permeability rock (e.g. shale, coal, and tight sandstone reservoired gas) equals lower flow rates and higher cost development as more wells are required to achieve the same flow rate.”*⁶

More wells equals more risk. Shale gas fracking equals more water and more chemicals injected under higher pressures, producing more waste to get less gas. Whether shale wells are placed closely together or evenly spread across the landscape at about 1km intervals, the number of high number wells remains an inescapable reality of the industry.

This infrastructure includes vast networks of roads and pipelines, gas compressor stations and processing plants, and wastewater holding dams and treatment facilities. The number of wells required and area of land impacted is exponentially larger than for conventional gasfields. In summary, the technologies of scale and spatial intensity of unconventional gas development, both at the surface and underground, makes it an entirely different proposition to conventional gas extraction. (For a useful explanation of scale and intensity of shale gas activities in comparison to conventional gas, see Professor Tony Ingraffea’s December 2015 testimony to the South Australian Fracking Inquiry, **Attachment A**).

⁶ Unconventional Oil and Gas, (2016). <http://www.unconventionaloilandgas.com.au/east-coast-gas-prices-will-stimulate-the-search-for-new-resources/>

Chemicals used in hydraulic fracturing

The proponent needs to provide more recent peer reviewed science and analysis of the measured impacts of chemical use in hydraulic fracturing. For example, the 2014 paper *Environmental Public Health Dimensions of Shale and Tight Gas Development* discusses the body of scientific literature relevant to the environmental public health impacts of shale gas production.

Based on the literature available, here is an excerpt regarding chemicals used in hydraulic fracturing⁷:

Hydraulic Fracturing Fluids: Chemical Toxicology and Exposure Pathways

Shale gas development uses fracturing fluids that contain organic and inorganic chemicals known to be health damaging ([Aminto and Olson 2012](#); [U.S. House of Representatives, Committee on Energy and Commerce 2011](#)). Fracturing fluids can move through the environment and come into contact with humans in a number of ways, including surface leaks, spills, releases from holding tanks, poor well construction, leaks and accidents during transportation of fluids, flowback and produced water to and from the well pad, and run-off during blowouts, storms, and flooding events ([Rozell and Reaven 2012](#)). Further, the mixing of these compounds under conditions of high pressure—and often high heat—may synergistically create additional potentially toxic compounds ([Kortenkamp et al. 2007](#); [Teuschler and Hertzberg 1995](#); [Wilkinson et al. 2000](#)). Compounds found in these mixtures may pose risks to the environment and to public health through numerous environmental pathways, including water, air, and soil ([Leenheer et al. 1982](#)).

Chemicals are used in drilling and fracturing processes as corrosion inhibitors, biocides, surfactants, friction reducers, gels, and scale inhibitors, among others ([Aminto and Olson 2012](#); [New York State Department of Environmental Conservation 2011](#); [Southwest Energy 2012](#)). These chemicals include methanol, ethylene glycol, naphthalene, xylene, toluene, ethylbenzene, formaldehyde, and sulfuric acid, some of which are known to be toxic, carcinogenic, or associated with reproductive harm ([Colborn et al. 2011](#); [New York State Department of Environmental Conservation 2011](#)). Many of these compounds are considered hazardous water pollutants and are regulated in other industries ([Clean Water Act of 1972](#); [Safe Drinking Water Act of 1974](#); [U.S. House of Representatives 2011](#)).

Many of the chemical compounds used in the fracturing process lack scientifically based maximum contaminant levels, making it more difficult to quantify their public health risks ([Colborn et al. 2011](#)). Moreover, uncertainty about the chemical makeup of fracturing fluids persists because of the limitations on required chemical disclosure, driven by the [Energy Policy](#)

⁷ Shonkoff, Hays and Finkel, 2014, Environmental Public Health Dimensions of Shale and Tight Gas Development, *Environ Health Perspect*; DOI:10.1289/ehp.1307866 <https://ehp.niehs.nih.gov/1307866/>

Act of 2005. For instance, in many states, companies are not mandated to disclose information about the quantities, concentrations, or identities of chemicals used in the process on the principle that trade secrets might be revealed (Centner 2013; Centner and O'Connell 2014; Maule et al. 2013).

The possible risks or issues associated with hydraulic fracturing

Firstly, unconventional gas development comes with a large number of known deleterious impacts. These include land use intensification, fragmentation, earthquakes, large water demand, vegetation clearing and the production of polluting waste. These are not risks – they are known impacts. It is also known that the development of unconventional gas will produce substantial greenhouse gases that will contribute to global warming both during the extraction process and when finally used to create electricity or in other industrial processes.

On top of those known and accepted impacts, there are many very serious risks, which are frequently more difficult to quantify or assess. These include risks to groundwater and surface water resources, risks to public health and risks of induced seismicity, damage to existing industries, as well as far-reaching risks to social cohesion and wellbeing.

In the Coober Pedy region of SA, drinking water supplies, stock water, industry, tourism places, cultural sites and regional economies are entirely dependent on groundwater. Any level of risk to groundwater poses a direct risk to regional communities and the economy.

Overall, the scale of the risks is perhaps best quantified by reference to recent US research which involved a literature review of all 685 peer reviewed papers on unconventional gas in the US as of the end of 2015⁸. The review found that:

- 84% of public health studies contain findings that indicate public health hazards, elevated risks, or adverse health outcomes;
- 69% of water quality studies contain findings that indicate potential, positive association, or actual incidence of water contamination; and
- 87% of air quality studies contain findings that indicate elevated air pollutant emissions and/or atmospheric concentrations.

We believe that summary of the peer reviewed literature on risks combined with the known serious impacts caused by this industry, is sufficient to confirm that the risks are far, far too high.

⁸ Hays J, Shonkoff SBC (2016) Toward an Understanding of the Environmental and Public Health Impacts of Unconventional Natural Gas Development: A Categorical Assessment of the Peer-Reviewed Scientific Literature, 2009-2015. PLoS ONE 11(4): e0154164. doi:10.1371/journal.pone.0154164

This submission offers an overview of recent scientific evidence to demonstrate the risks and measured negative impacts of the unconventional gas industry, both in Australian and internationally.

Water

Unconventional gas development has the potential to negatively impact on the surrounding regions water resources, including the Great Artesian Basin.

Water resources can be impacted by both contamination and depletion as a result of UG development, as outlined by the following evidence.

Water Quality

Groundwater

During fracking processes, contamination of underground water resources with flowback fluids can occur via a number of pathways. These include: migration of fluids via natural pathways in underground geologies; via pathways created by the fracking process; or as a result of well blow outs and well casing failure⁹. Flowback fluids contain hazardous fracking chemicals as well as naturally occurring toxic substances released from target geological zones such as methane, BTEX (benzene, toluene, ethylbenzene, xylene), polycyclic aromatic hydrocarbons (PAHs), naturally occurring radioactive materials (NORMs), heavy metals and other volatile organic compounds (VOCs)¹⁰.

Researchers have shown that liquid waste from shale gas fracking operations is chemically different than waste flowing out of conventional wells and hypothesize that the hydraulic fracturing process itself liberates elements from clay minerals in the shale formations, including boron and lithium, which then enter the liquid waste.¹¹

International science now clearly confirms the fact that drilling, fracking and other aspects of unconventional gas development inherently threaten groundwater and have contaminated drinking water sources in the United States.

⁹ National Toxics Network, 2013, Toxic Chemicals in the Exploration and Production of Gas from Unconventional Sources http://www.ntn.org.au/wp/wp-content/uploads/2013/04/UCgas_report-April-2013.pdf

¹⁰ Ibid.

¹¹ Warner, N. R., Darrah, T. H., Jackson, R. B., Millot, R., Kloppmann, W., & Vengosh, A. (2014). New tracers identify hydraulic fracturing fluids and accidental releases from oil and gas operations. *Environ. Sci. Technol.*, 48(21), 12552–12560. doi: 10.1021/es5032135

For example:

- Widespread drinking water contamination throughout the heavily drilled Barnett Shale region in northern Texas, where 550 water samples from public and private water wells, found elevated levels of 19 different hydrocarbon compounds associated with fracking (including the carcinogen benzene and the reproductive toxicant, toluene), detections of methanol and ethanol, and strikingly high levels of 10 different metals.¹²
- In the first fully documented case of a commonly used fracking chemical entering a drinking water source, researchers found the presence of a fracking-related solvent in private drinking water wells near drilling and fracking operations. Study authors propose that “the most likely explanation of the incident is that stray natural gas and drilling or [hydrofracking] compounds were driven ~1-3 km along shallow to intermediate depth fractures to the aquifer used as a potable water source.”¹³
- Elevated levels of methane in groundwater discharging into a stream near drilling and fracking operations in Pennsylvania along with high levels of methane in nearby private water wells as a result of gas migration near a gas well with a defective casing. The monitoring technique used in this study allowed researchers to demonstrate that the source of the methane was shale gas from the Middle Devonian period, which is the kind of gas found in the Marcellus Shale.¹⁴
- Comparison of pre-drill and post-drill data on water quality found changes in water chemistry that coincided with the advent of drilling and fracking activities. Elevated levels of chloride, iron, barium, strontium, and manganese were found with concentrations exceeding health-based maximum contaminant levels in some cases. Methane was also detected in most houses tested in this study.¹⁵

A 2016 study by Stanford University scientists determined that fracking and related oil and gas operations have contaminated drinking water in the town of Pavillion, Wyoming where residents have long complained about foul-tasting water. The researchers found substances in the water that match those used in local fracking operations or found in nearby pits used for

¹² Hildenbrand, Z. L., Carlton, D. D., Fontenot, B. E., Meik, J. M., Walton, J. L., Taylor, J. T., . . . Schug, K. A. (2015) A comprehensive analysis of groundwater quality in the Barnett Shale region. *Environmental Science & Technology*, 49(13), 8254-62. doi: 10.1021/acs.est.5b01526

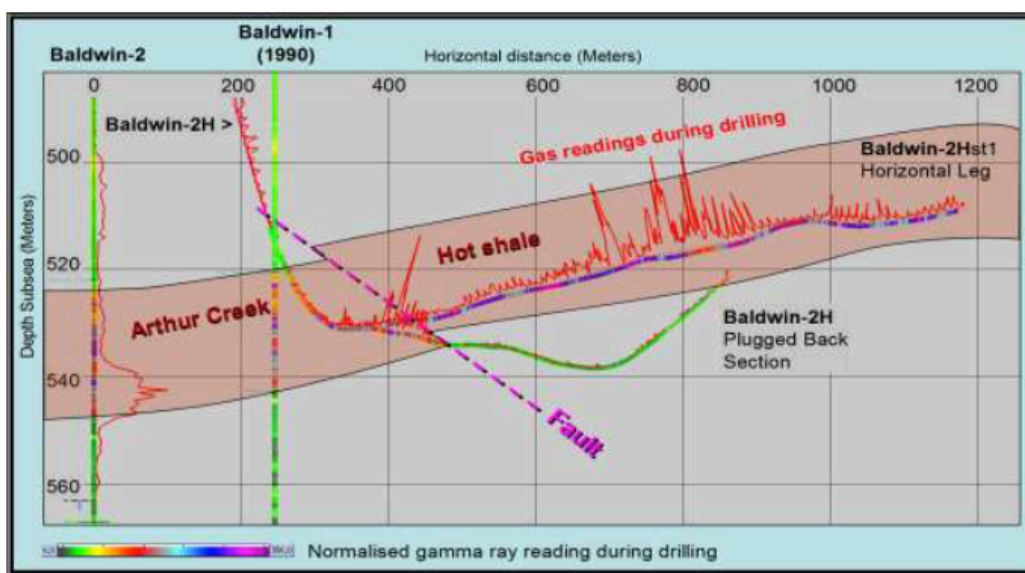
¹³ Llewellyn G. T., Dorman, F., Westland, J. L., Yoxtheimer, D., Grieve, P., Sowers, T., Brantley, S. L. (2015). Evaluating a groundwater supply contamination incident attributed to Marcellus Shale gas development. *Proceedings of the National Academies of Science*, 112, 6325-30. doi: 10.1073/pnas.1420279112/-/DCSupplemental

¹⁴ U.S. Geological Survey. (2015, April 1). New stream monitoring method locates elevated groundwater methane in shale-gas development area. Retrieved from http://www.usgs.gov/newsroom/article.asp?ID=4176&from=rss&utm_source=dlvr.it&utm_medium=facebookhttp://www.readcube.com/articles/10.1002%2F2014WR016382?r3_referer=wol&tracking_action=previe w_click&show_checkout=1&purchase_site_license=LICENSE_DENIED_NO_CUSTOMER#.VaPKNYsqd yA

¹⁵ Alawattegama, S. K., Kondratyuk, T., Krynock, R., Bricker, M., Rutter, J. K., Bain, D. J., & Stolz, J. F. (2015). Well water contamination in a rural community in southwestern Pennsylvania near unconventional shale gas extraction. *Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering*, 50, 516-528. doi: 10.1080/10934529.2015.992684

the disposal of drilling waste. Chemical contaminants included benzene, a known carcinogen, and toluene, a neurotoxicant. Possible mechanisms for contamination include defective cement well casings; spills and leaks from disposal pits; and underground migration of chemicals into aquifers from the fracked zone, which, in this area, is quite shallow.¹⁶

In 2011, trials of horizontal hydraulic fracturing by Petrofrontier in the Georgina Basin in the Northern Territory were ultimately unsuccessful for shale gas extraction. However, these old wells could be leading to ongoing methane and other contamination being brought to the surface. No one from the drilling company (which has since changed hands to Statoil) or the NT Government is monitoring these abandoned wells.



Fault lines can act as a conduit for methane migration¹⁷. While in this case the fault eventually led to the unviable nature of this well, the potential increased risk of a long term pollution pathway forming from intersecting this fault line is completely unknown. While the risk from just one well may not be considered great, the risk of a percentage of hundreds or thousands of shale gas wells across SA intercepting deep fault lines is worthy of consideration.

¹⁷http://energy.unimelb.edu.au/data/assets/pdf_file/0019/2331604/Migratory_emissions_20160913.pdf

One year later in 2012, Petrofrontier provided another media update. Here, they admit that *during the hydraulic stimulation program of the Baldwin-2Hst1 well (pictured above), a shallow casing failure occurred and as a result, PetroFrontier was unable to complete the program.* The release continues: *As expected, the multiple casing design protected the shallow aquifers. PetroFrontier plans to carry out remedial work to repair this well so that the planned hydraulic stimulation program can be completed.*¹⁸

Methane Contamination

A review by Klohn Crippen Berger Free¹⁹ for the Queensland Department of Natural Resources and Mines considered methane migration from CSG extraction in Queensland. It concluded that gas from CSG development can even occur in water bores that do not experience a water level decline from CSG development. It also found that the presence of free gas in a water bore also directly and indirectly affects its capacity to supply water, unless remedial actions are taken. These impacts have also been reported by numerous landholders dealing with CSG in the Western Downs. They have suffered bore impairment caused not from drawdown, but from excess gas. This has led the Queensland Government to recently amend the Queensland *Water Act 2000* to formally recognise gassy bores as a form of impairment for which CSG companies are required to make good.

Surface Water

After fracking at each well, the large volumes (tens of thousands of litres per well) of hazardous flow back fluid (the 15 - 80% of the fracking fluid mixture that returns to the surface²⁰) must be stored and disposed of. Contamination of surface water may occur from release of insufficiently treated or untreated wastewater onto land surfaces or directly into waterways and as a result of leakage from storage facilities. Soil and surface water contamination may also occur from accidental spills or leakage of fracking fluids at the surface and via surface well blow outs.^{21 22} Researchers found high levels of iodide, bromide, and ammonium in samples of wastewater from fracking operations in two US shale formations, with the same chemicals found to be present present when fracking wastewater was discharged into rivers and streams at three treatment sites in Pennsylvania and during an accidental spill in West Virginia.²³

¹⁸ Petrofrontier (2013) <http://www.prnewswire.com/news-releases/petrofrontier-corp-provides-operational-update-173879181.html>

¹⁹ Klohn Crippen Berge 2016. *Potential effects of free gas on bore water supply for CSG development.* Final report to the CSG Compliance Unit of the Department of Natural Resources and Mines.

²⁰ http://www.karooplaces.com/wp-content/uploads/2011/06/coop_shale_gas_report_final_200111.pdf

²¹ NTN: Toxic Chemicals in the Exploration and Production of Gas from Unconventional Sources; http://www.karooplaces.com/wp-content/uploads/2011/06/coop_shale_gas_report_final_200111.pdf

²² Fracking: a serious concern for surface water as well as groundwater: <http://ec.europa.eu/environment/integration/research/newsalert/pdf/275na3.pdf>

²³ Harkness, J. S., Dwyer, G. S., Warner, N. R., Parker, K. M., Mitch, W. A., & Vengosh, A. (2015). Iodide, bromide, and ammonium in hydraulic fracturing and oil and gas wastewaters: environmental implications. *Environmental Science & Technology*, 49, 1955-63. doi: 10.1021/es504654n

Using geochemical and isotopic tracers to identify the unique chemical fingerprint of Bakken region brines, a 2016 Duke University study found that accidental spills of fracking wastewater have contaminated surface water and soils throughout North Dakota where more than 9,700 wells have been drilled in the past decade. Contaminants included salts as well as lead, selenium, and vanadium. In the polluted streams, levels of contaminants often exceeded federal drinking water guidelines. Soils at spill sites showed elevated levels of radium.²⁴

The study concluded that, “inorganic contamination associated with brine spills in North Dakota is remarkably persistent, with elevated levels of contaminants observed in spill sites up to 4 years following the spill events.” In a comment about this study, lead author and Duke University geochemist Avner Vengosh said, “Until now, research in many regions of the nation has shown that contamination from fracking has been fairly sporadic and inconsistent. In North Dakota, however, we find it is widespread and persistent, with clear evidence of direct water contamination from fracking.”²⁵

A 2015 study in Wyoming showed that the arrival of drilling and fracking activities coincided with an increase in salinity in a creek that drains public land in a semi-arid region of the state. The study found that the dissolved minerals associated with the rise in salinity matched those found in native soil salts, suggesting that disturbance of naturally salt rich soils by ongoing oil and gas activities, including pipeline, road, and well pad construction, was the culprit. “As [shale gas and oil] development continues to expand in semiarid lands worldwide, the potential for soil disturbance to increase stream salinity should be considered, particularly where soils host substantial quantities of native salts.”²⁶

Water quantity

According to a 2015 water study from the United States, horizontal shale gas fracking uses the most water, requiring up to 36.6 million litres of water per well²⁷, or around 1200 truckloads of water for just one fracked well. In relation to water use, the European Commission report on fracking notes:

²⁴ Lauer, N. E., Harkness, J. S., & Vengosh A. (2016). Brine spills associated with unconventional oil development in North Dakota. *Environmental Science & Technology*, 50(10). doi: 10.1021/acs.est.5b06349

²⁵ Nicholas School of the Environment, Duke University. (2016, April 27). Contamination in North Dakota linked to fracking spills [press release]. Retrieved from <https://nicholas.duke.edu/about/news/ContaminationinNDLinkedtoFrackingSpills>

²⁶ Bern, C. R., Clark, M. L., Schmidt, T. S., Nolloway, J. M., & McDougal, R. R. (2015). Soil disturbance as a driver of increased stream salinity in a semiarid watershed undergoing energy development. *Journal of Hydrology*, 524, 123-136. doi: doi.org/10.1016/j.jhydrol.2015.02.020

²⁷ Gallegos et al, 2015, Hydraulic fracturing water use variability in the United States and potential environmental implications, *Water Resources Research Journal*.

“The hydraulic fracturing process is water-intensive and therefore the risk of significant effects due to water abstraction could be high where there are multiple installations. A proportion of the water used is not recovered. If water usage is excessive, this can result in a decrease in the availability of public water supply; adverse effects on aquatic habitats and ecosystems from water degradation, reduced water quantity and quality; changes to water temperature; and erosion. Areas already experiencing water scarcity may be affected especially if the longer term climate change impacts of water supply and demand are taken into account. Reduced water levels may also lead to chemical changes in the water aquifer resulting in bacterial growth causing taste and odour problems with drinking water. The underlying geology may also become destabilized due to upwelling of lower quality water or other substances.”²⁸

The large number of wells needed to develop unconventional resources and the requirement for multiple fracturing of wells multiplies the overall take of water by the industry. The threat to water resources is greater in lower rainfall regions, and on a regional and local scale where water resources are already under pressure. In particular, future issues could arise in areas where water resources are relied upon by a range of existing industries and may already be subject to over allocation.

The extraction of water from underground aquifers for fracking has the potential to place significant stress on groundwater systems, particularly if they are already utilized by existing rural industries. This demand on groundwater for supplying fracking operations will be critical in semi-arid regions, where underground aquifers are often the sole or principal source of water, and more broadly, during extended drought periods and during periods of reduced rainfall.

A 2015 Californian study shows that while the volume of water used in fracking represents a small percentage of overall annual water consumption in California, fracking-related water use is disproportionately concentrated in areas of the state already suffering from water shortages, and further drawdowns of these aquifers may interfere with agricultural and municipal water needs²⁹.

Interestingly, a 2015 research paper from Southwest China states that, “data analysis indicates a significant correlation between water consumption and lateral length of wells.”³⁰

Whilst industry suggests overall water use could be minimised by reuse of fracking wastewater in new fracking operations, a 2013 US water report notes that whilst the oil and gas industry continues to talk about water recycling technologies, few operators in the US are using recycled

²⁸ European Commission: DG Environment (August 2012) Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing in Europe

²⁹ Long, J. C. S, Birkholzer, J. T., & Feinstein, L. C. (2015, July 9). Summary report. In: An Independent Scientific Assessment of Well Stimulation in California. California Council on Science and Technology, Sacramento, CA. <http://ccst.us/publications/2015/2015SB4summary.pdf>

³⁰ Yang, B. Huang, X. Yang Q. ... (2015) Water Requirements for Shale Gas Fracking in Fuling, Chongqing, Southwest China, Energy Procedia 76 (2015) 106 – 112

fracking water in fracking operations. The study states: “with few exceptions, the rest of the water used for fracking is gone for good from the hydrological cycle” and “data on actual use of recycling are hard to come by, and it appears that these technologies are not yet widely used.”³¹

Aquatic ecosystems and biodiversity

There is increasing and ongoing evidence of point source impacts from the UG industry on ecosystems and biodiversity, while large scale regional assessments of impacts have been hampered by lack of baseline data.

In 2013, a joint USGS and U.S. Fish and Wildlife Service study documented a causal link between a fracking wastewater spill and the widespread death of fish in the Acorn Fork, a creek in Kentucky.³²

A survey of streams in Arkansas, led by the University of Central Arkansas, found alterations in macroinvertebrate communities to be related to drilling and fracking operations in the Fayetteville Shale. Fracking activity near streams was associated with greater sediment and more chlorophyll. “This study suggests that land disturbance from gas development affected stream communities.”³³

In 2009, a leaking pipe carrying fracking waste in Washington County, Pennsylvania, polluted a tributary of Cross Creek Lake, killing fish, salamanders, crayfish, and aquatic insect life in approximately three-quarters of a mile of the stream.³⁴

A team of environmental scientists, biologists, and engineers, from institutions including the University of Michigan and McGill University, assessed the current state of understanding of the impact fracking and its associated activities have on the ecological health of surface waters. Though various approaches such as geographic information systems and site monitoring provide insights into potential risks to aquatic ecosystems, the authors concluded that inadequate data currently exist. They identified possible outcomes such as, “erosion and sedimentation, increased risk to aquatic ecosystems from chemical spills or runoff, habitat fragmentation, loss of stream riparian zones, altered biogeochemical cycling, and reduction of

³¹ Western Organisation of Research Councils (2013) Gone for Good: Fracking and Water Loss in the West, http://www.worc.org/media/Gone_for_Good1.pdf

³² Papoulias, D., & MacKenzie, T. (2013, August 28). Hydraulic fracturing fluids likely harmed threatened Kentucky fish species. USGS Newsroom. <http://www.usgs.gov/newsroom/article.asp?ID=3677>

³³ Johnson, E., Austin, B. J., Inlander, E., Gallipeau, C., Evans-White, M. A., & Entekin, S. (2015). Stream macroinvertebrate communities across a gradient of natural gas development in the Fayetteville Shale. *Science of the Total Environment*, 530-531, 323-32. doi: 10.1016/j.scitotenv.2015.05.027

³⁴ Pittsburgh Post-Gazette. (2009, June 5). Waste from Marcellus shale drilling in Cross Creek Park kills fish. Pittsburgh Post-Gazette. <http://www.post-gazette.com/washington/2009/06/05/Waste-fromMarcellus-shale-drilling-in-Cross-Creek-Park-kills-fish/stories/200906050136>

available surface and hyporheic water volumes because of withdrawal-induced lowering of local groundwater levels.”³⁵

In Australia, Environmental Engineer Stuart Khan of the University of NSW expressed in 2011 serious reservations about the disposal and use of produced water, claiming that: “Disposing of CSG waters directly to surface waters will significantly impact the quality of those surface waters. Attempts to beneficially reuse CSG water without treatment for application’s such as irrigation, poses risks to soil quality and shallow groundwater quality.” And further: “poorly managed discharge of reverse osmosis waters to the environment may also pose a risk to some surface water systems by disrupting (diluting) natural mineral and nutrient compositions, essential for many aquatic ecosystems. Uncontrolled discharges to ephemeral streams will disrupt natural flow regimes with potentially significant ecological implications.”³⁶

Additional water risk: Fluid treatments and waste disposal are ineffective and/or cause additional problems

The treatments to remove contaminants from produced water are limited by the chemicals they can remove, the energy needed and their economic costs. Reverse osmosis has significant limitations and cannot remove many of the organic chemicals used in UG activities. Low molecular weight, non polar, water-soluble solutes such as the methanol and ethylene glycol are poorly rejected by reverse osmosis filtration.³⁷ As the costs and difficulties of dealing with large quantities of wastewater grow, Australian UG companies are trialing reinjection into aquifer formations, despite the risks of seismic events, as experienced in the US.³⁸

Recent research from the US highlights the following issues with current waste disposal methods in the US unconventional gas industry:

Alterations of local hydrology caused by the injection of large volumes of hydraulic fracturing fluids that may have mobilized contaminants left over from legacy oil, gas, and mining operations as well as opened pathways for the migration of fracking fluids themselves.³⁹

³⁵ Burton Jr., G. A., Basu, N., Ellis, B. R., Kapo, K. E., Entekin, S. & Nadelhoffer, K. (2014). Hydraulic “fracking”: are surface water impacts an ecological concern? *Environmental Toxicology and Chemistry*, 33(8), 1679-1689.

³⁶ Khan, S. (2011) Submission to the NSW Parliamentary Inquiry into CSG, <https://www.parliament.nsw.gov.au/committees/DBAssets/InquirySubmission/Summary/39431/Submission%200330.pdf>

³⁷ Chemicals unable to be treated successfully include bromoform, chloroform, naphthalene, nonylphenol, ctylphenol, dichloroacetic acid, trichloroethylene. See www.industry.qld.gov.au/documents/LNG/csg-water-beneficial-use-approval.pdf; http://www.aquatechnology.net/reverse_osmosis.html; Stuart J. Khan Quantitative chemical exposure assessment for water recycling schemes, Waterlines Report Series No 27, March 2010 Commissioned by the National Water Commission

³⁸ Watson, B. A. (2016). Fracking and cracking: strict liability for earthquake damage due to wastewater injection and hydraulic fracturing. *Texas Journal of Oil, Gas and Energy Law*, 11(1). <http://ssrn.com/abstract=2735862>

³⁹ Alawattegama, S. K., Kondratyuk, T., Krynock, R., Bricker, M., Rutter, J. K., Bain, D. J., & Stolz, J. F. (2015). Well water contamination in a rural community in southwestern Pennsylvania near unconventional

Identified risks in disposal practices include the use of wastewater for crop irrigation (whereby contaminants may seep from the surface of agricultural areas into groundwater), the use of unlined pits for waste storage and reinjection into potable aquifers.⁴⁰

In the Northern Territory, above ground pits for storing waste water from shale fracking are set to be banned, in line with the recommendations of their Inquiry's Final Report. The SA Government must do the same. This proposal cannot go ahead as drafted.

Spills – a risk to surface and groundwater

Analysis published Feb. 21 2017 in the journal *Environmental Science & Technology*, revealed 6,648 spills from the fracking industry from just the four states that they studied alone—Colorado, New Mexico, North Dakota and Pennsylvania—in 10 years⁴¹. The researchers determined that up to 16 percent of fracked oil and gas wells spill hydrocarbons, chemically laden water, fracking fluids and other substances. They found that 75% to 94% of spills occurred within the first three years of well life when wells were drilled, completed, and had their largest production volumes. Across all four states, 50% of spills were related to storage and moving fluids via flowlines. The team also designed an interactive spills data visualization tool (<http://snappartnership.net/groups/hydraulic-fracturing/webapp/spills.html>) to illustrate the value of having standardized, public data.

In Australia, during the exploration phase of coal seam gas development in NSW, there have been a number of recorded contamination events around the state. Santos' CSG operations in the Forest region of NW NSW recorded at least 20 coal seam gas waste water spills and continuing leaks from evaporation ponds. Santos' records show spills and leaks from all parts of the operations, from evaporation ponds, pipelines, the wastewater treatment facilities and at well sites⁴².

Pollution offences occurred under the former site operator Eastern Star Gas. The NSW EPA issued the following statement, "The EPA issued two penalty notices with fines of \$1,500 each to Eastern Star Gas for discharging polluted water containing high levels of salt into Bohena

shale gas extraction. *Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering*, 50, 516-528. doi: 10.1080/10934529.2015.992684

⁴⁰ Long, J. C. S, Birkholzer, J. T., & Feinstein, L. C. (2015, July 9). Summary report. In: An Independent Scientific Assessment of Well Stimulation in California. California Council on Science and Technology, Sacramento, CA. <http://ccst.us/publications/2015/2015SB4summary.pdf>

⁴¹ Patterson, L. Konschnik, K. Wiseman, H... (2017) Unconventional Oil and Gas Spills: Risks, Mitigation Priorities, and State Reporting Requirements, *Environ. Sci. Technol.*, 2017, 51 (5), pp 2563–2573, DOI: 10.1021/acs.est.6b05749 <http://pubs.acs.org/doi/abs/10.1021/acs.est.6b05749?journalCode=esthag>

⁴² Santos Ltd Energy NSW (2014) Report into Eastern Star Gas Limited prepared for Government of New South Wales

Creek in March and November 2010; offences under section 120 of the Protection of Environment Operations Act 1997.”⁴³

In 2014, Santos was found guilty of polluting an aquifer in the Pilliga Forest⁴⁴ with radioactive uranium 20 times safe levels as well as toxic heavy metals⁴⁵.

A spill in June 2011 in the Pilliga resulted in 10,000 litres of untreated toxic coal seam gas wastewater containing a mix of heavy metals (including arsenic, lead and chromium), salts and petrochemicals that killed vegetation and wildlife. Santos was found guilty in the NSW Land and Environment Court and fined \$52,000⁴⁶.

Well integrity failure risks

Issues surrounding well integrity failure pose specific risks across many themes, including surface and groundwater, landscapes, air quality and greenhouse gas emissions and health.

The industry has been arguing for years that they are improving their practice, and science and industry papers have been calling for improvements for decades, yet the problems persist. Well failures have not improved with time – the industry has not engineered a way out of well casing failure and annual flow.

A 2014 study published in the Proceedings of the National Academy of Sciences of the United States of America provides a useful and more recent overview of the industry and scientific data produced to that date, specifically considering unconventional extraction.

In a technical sense, “well integrity” refers to the zonal isolation of liquids and gases from the target formation or from intermediate layers through which the well passes. In a practical sense, it means that a well doesn’t leak. Drilling companies emphasize well integrity because a faulty well is expensive to repair and, in the rarest of cases, costs lives, as in the Deepwater Horizon disaster in the Gulf of Mexico. Drillers use steel casing (pipes), cement between nested casings and between the outside casing and rock wall, and mechanical devices to keep fluids inside the well.

Faulty casing and cementing cause most well integrity problems. Steel casing can leak at the connections or corrode from acids. Cement can deteriorate with time too, but leaks also happen when cement shrinks, develops cracks or channels, or is lost into the surrounding rock when applied. If integrity fails, gases and liquids can leak out of the

⁴³ NSW EPA (2012) Eastern Star Gas fined for pollution in the Pilliga,

<http://www.epa.nsw.gov.au/epamedia/EPAMedia12070601.htm>

⁴⁴ <http://www.epa.nsw.gov.au/epamedia/EPAMedia14021802.htm>

⁴⁵ <http://www.smh.com.au/environment/water-issues/epa-defends-its-actions-over-natural-uranium-in-contaminated-aquifer-20140309-34fhp.html>

⁴⁶ <http://australianresources.com.au/1833/santos-fined-pilliga-spill>

*casing or, just as importantly, move into, up, and out of the well through faulty cement between the casing and the rock wall.*⁴⁷

Risk of biogenic hydrogen sulfide gas

The 2012 media release from Petrofrontier in relation to their Georgina Basin fracking program also states: *A successful hydraulic stimulation was performed on the MacIntyre-2H well over nine open-hole stages. However, after recovering approximately one-third of the hydraulic stimulation fluid, traces of biogenic hydrogen sulfide gas, produced from naturally occurring organisms in the completion fluid, were detected and the well had to be suspended.*⁴⁸

According to a 2007 paper, hydrogen sulfide gas (H₂S) is a toxic and corrosive gas and a precursor to the formation of sulfuric acid, H₂SO₄, which causes the destruction of metal and concrete substrates. This bacterially induced process of forming hydrogen sulfide gas and the subsequent conversion to sulfuric acid that attacks concrete and steel within wastewater environments is known as biogenic sulfide corrosion⁴⁹.

Biogenic sulphide corrosion of shale gas infrastructure could have major implications for risks to local water supplies into the future. It is problems rarely admitted by the industry when they talk up their three layers of cement and steel. However, the natural bacterial corrosion of well casings into the future creates a very difficult risk to ignore and is difficult to measure what impact it could have, particularly in the long term after wells are abandoned.

Conoco Philips authored a paper in 2012 that states:

*Internal pipeline corrosion in the presence of hydrogen sulfide has become a major issue for both oil and gas industries. Problems resulting from hydrogen sulfide corrosion have started to draw attention to the oil and gas industry since the 1940's. Since then, researchers have done a tremendous amount of work, studying the mechanism of hydrogen sulfide corrosion. However, the corrosion mechanisms initially proposed are still not fully understood and well acceptable around the world. Although the corrosion mechanism is still confusing, many attempts have been made by the industry to mitigate hydrogen sulfide corrosion problems.*⁵⁰

⁴⁷ Jackson, R. (2014) The integrity of oil and gas wells, [Proc Natl Acad Sci U S A](#). 2014 Jul 29; 111(30): 10902–10903. Published online 2014 Jul 9. doi: [10.1073/pnas.1410786111](#), <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4121783/>

⁴⁸ Ibid.

⁴⁹ O'Dea, V. (2007) Understanding biogenic sulfide corrosion, <https://www.environmental-expert.com/articles/understanding-biogenic-sulfide-corrosion-36635>

⁵⁰ Conoco Philips (2012) Investigation of Effects of Iron Sulfide On Corrosion And Inhibition of Carbon Steel In H₂S Containing Conditions, <https://www.onepetro.org/conference-paper/NACE-2012-1651>

Land

In assessing the rehabilitation of land that has been hydraulically fractured, the European Commission report⁵¹ on fracking notes: “The evidence suggests that it may not be possible fully to restore sites in sensitive areas following well completion or abandonment, particularly in areas of high agricultural, natural or cultural value. Over a wider area, with multiple installations, this could result in a significant loss or fragmentation of amenities or recreational facilities, valuable farmland or natural habitats.” A recent US study documents the failure of plant and soil systems disturbed by drilling and fracking activities to return to pre-drilling conditions following rehabilitation- even after 20 to 50 years⁵².

An interdisciplinary study published in *Science* 2015 demonstrated that the accumulating land degradation has resulted in continent-wide impacts of the unconventional gas industry in the United States, as measured by the reduced amount of carbon absorbed by plants and accumulated as biomass. This is a robust metric of essential ecosystem services, such as food production, biodiversity, and wildlife habitat, and its loss “is likely long-lasting and potentially permanent.” The land area occupied by well pads, roads, and storage facilities built during this period is approximately three million hectares, roughly the land area of three Yellowstone National Parks. The authors concluded that new approaches to land use planning and policy are “necessary to achieve energy policies that minimize ecosystem service losses.”⁵³

Fragmentation and Biosecurity

There is very little empirical data available on the ecological impacts of fragmentation from unconventional gas development, nor on the biosecurity threats it poses or the actual contribution its development has made to date to the spread of invasive weeds and feral animals.

Research that is available identifies significant ecological impacts arising from landscape fragmentation. A thesis on the landscape consequences of unconventional gas development in Pennsylvania’s old growth forest found that gas development increased edge length and the number of forest patches and decreased interior forest cover⁵⁴. A 2012 study in Pennsylvania

⁵¹ European Commission: DG Environment (August 2012) Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing in Europe

⁵² Minnick, T. J. & Alward, R. D. (2015). Plant–soil feedbacks and the partial recovery of soil spatial patterns on abandoned well pads in a sagebrush shrubland. *Ecological Applications* 25(1), 3-10.

⁵³ Allred, B. W., Kolby Smith, W., Tridwell, D., Haggerty, J. H., Running, S. W., Naugle, D. E., & Fuhlendorf, S. D. (2015). Ecosystem services lost to oil and gas in North America. *Science*, 348 (6233), 401-402.

⁵⁴ Bernau, Jeremiah. 2013. [Landscape Consequences of Pennsylvania Natural Gas Development: Fragmentation effects of unconventional gas development upon the future of Pennsylvania’s old growth forests.](#)

found that shale gas development would fragment forest cover and entail intensive disturbance of core forests where headwater streams occur⁵⁵.

One of the few studies available on individual species impacts from the US, shows marked alterations in deer habitat selection patterns in response to unconventional gas development in Colorado⁵⁶. Deer were forced to alter habitat use to avoid gas activities and infrastructure, leading to a 50% variation during the day time within their critical winter range.

Ecological experts in Australia have identified that *'fragmentation and loss of native vegetation resulting from the considerable surface footprint of CSG infrastructure represent a serious threat to biodiversity, threatened species and landscape function'*⁵⁷. They suggest that, *"Evidence from CSG developments to date indicates that severe effects are possible. Potential impacts include direct clearing of bushland, fragmentation of important remnant vegetation, spread of invasive species and increased fire risk"*.

Similarly, the sheer scale of proposed shale production, including the number of likely gas wells and the extent of associated infrastructure, presents genuine risks for the unique natural landscapes of this region of SA.

In Queensland, farmers have reported serious invasions of weeds following CSG development. One cattle farmer has initiated legal action against a CSG company after he had to destock his property at Dalby after a sudden infestation of the noxious African lovegrass weed following CSG activities⁵⁸.

Lawyers in Queensland representing farmers dealing with the CSG industry consider that weeds may ultimately be one of the biggest legacies of the CSG industry. Shine Lawyers have spoken out against the weaknesses of biosecurity measures, stating that: *'We are informed by a leading expert that current washdown procedures have difficulty removing more than 10% of the weed or pathogen load from machinery. If correct, no amount of insistence upon constant monitoring of access and the production of weed hygiene declarations (washdown certificates) will truly protect a landholder. Furthermore, having companies or subcontractors able to self-monitor and write the certificates themselves is hardly of comfort'*.⁵⁹

⁵⁵ Drohan, P. J., Brittingham, M., Bishop, J., & Yoder, K. (2012). Early trends in landcover change and forest fragmentation due to shale gas development in Pennsylvania: A potential outcome for the northcentral Appalachians. *Environmental Management*, 49(5), 1061 - 1075

⁵⁶ Joseph M. Northrup, Charles R. Anderson Jr. and George Wittemyer, "Quantifying Spatial Habitat Loss from Hydrocarbon Development through Assessing Habitat Selection Patterns of Mule Deer," [Global Change Biology](#), 12 August 2015.

⁵⁷ Williams J., Stubbs T. & Milligan A. (2012) An analysis of coal seam gas production and natural resource management in Australia. A report prepared for the Australian Council of Environmental Deans and Directors by John Williams Scientific Services Pty Ltd, Canberra, Australia

⁵⁸ <http://www.abc.net.au/news/2014-08-23/farmer-claims-csg-companies-spread-weeds-on-southern-qld-property/5661016>

⁵⁹ <https://www.shine.com.au/blog/coal-seam-gas-law/weeds-csg-insidious-legacy/>

Seismic Activity

Evidence arising in just the past 18 months has had a significant impact on our understanding the links between fracking and waste fluid reinjection with increased seismicity and earthquakes.

January 2016: An international research team investigated a swarm of earthquakes in California's Central Valley that occurred in 2005. Using hydrogeological modeling, the researchers concluded that the underground injection of wastewater from oil drilling operations had contributed to seismicity via changes in localized pressures along an active fault.⁶⁰

February 2016: An article in the Texas Journal of Oil, Gas, and Energy Law exhaustively reviewed the literature on earthquake activity in areas of six states (Arkansas, Colorado, Kansas, Ohio, Oklahoma, and Texas) where fracking takes place or drilling wastes are disposed underground and concluded that courts should impose strict liability for earthquake damage caused either by fracking itself or by the underground injection of fracking fluids. "Earthquakes sometimes occur when subsurface formations are properly fractured. Likewise, the risk of earthquake damage is not substantially mitigated by the exercise of due care when frack fluids are injected into the ground."⁶¹

March 2016: A summary of the evidence linking drilling and fracking activities to earthquakes appeared in Scientific American. Emerging data suggests that pressure changes caused by fracking wastewater injection can migrate for years before encountering a geological fault and altering stresses in ways that allow for slippage. In this way, earthquake risks can spread out over both time and space—traveling for miles beyond the disposal well and persisting for a decade or more as injected fluids travel underground. In spite of increasing scientific clarity about these mechanisms, regulators have been slow to respond.⁶²

May 2016: In a study that has "far-reaching implications for assessment of induced seismicity hazards," a Canadian team of researchers determined that hydraulic fracturing itself is linked to earthquake swarms in western Canada, in contrast to the central United States where disposal

⁶⁰ Goebel, T. H. W., Hosseini, S. M., Cappa, F., Hauksson, E., Ampuero, J. P., Aminzadeh, F. & Saleeby J. B. (2016). Wastewater disposal and earthquake swarm activity at the southern end of the Central Valley, California. *Geophysical Research Letters*, 43. doi: 10.1002/2015GL066948

⁶¹ Watson, B. A. (2016). Fracking and cracking: strict liability for earthquake damage due to wastewater injection and hydraulic fracturing. *Texas Journal of Oil, Gas and Energy Law*, 11(1). <http://ssrn.com/abstract=2735862>

⁶² Kuchment, A. (2016, March 28). Drilling for earthquakes. *Scientific American*. Retrieved from <https://www.scientificamerican.com/article/drilling-for-earthquakes/>

of fracking waste is the cause of most induced seismicity. Furthermore, lowering the volume of injected fluid may not be sufficient to prevent quakes.⁶³

Further study is needed to assess the impact of this increased seismicity and earthquakes with contamination to groundwater.

Air

A 2012 study detected 44 hazardous air pollutants at unconventional gas well sites⁶⁴, whilst other recent US studies⁶⁵ show that drilling and fracking emissions often contain strikingly high levels of benzene. The NYS Dept. of Health Public Health Review (the NYS Review) noted that “studies provide evidence of uncontrolled methane leakage, emissions of other volatile organic chemicals, and particulate matter from well pads and natural-gas infrastructure [as well as]... intermittently high dust and benzene concentrations.”

Exposure to a range of harmful substances associated with unconventional gas operations constitutes a serious health hazard to those working on and living adjacent to or surrounded by UG development. The NYS Review⁶⁶ states that emissions from UG operations have the potential to contribute to community odour problems and respiratory health impacts such as asthma exacerbations.

A less discussed impact on air quality is raising ethane levels. According to University of Michigan researchers, the Bakken shale emits 250,000 tons of ethane per year.⁶⁷ They found, “emissions we observed in this single region are 10 to 100 times larger than reported in inventories. They directly impact air quality across North America. And they’re sufficient to explain much of the global shift in ethane concentrations.”⁶⁸ Ethane is a gas that affects climate and decreases air quality. Ethane contributes to ground-based ozone pollution as it breaks down and reacts with sunlight to create smog. This surface-level ozone is linked to respiratory problems, eye irritation, and crop damage. Global ethane levels were decreasing until 2009, leading the researchers to suspect that the U.S. shale gas boom may be responsible for the global increase in levels since 2010.

⁶³ Atkinson, G. M., Eaton, D. W., Ghofrani, H., Walker, D., Cheadle, B., Schultz, R. ... Kao, H. (2016). Hydraulic fracturing and seismicity in the Western Canada Sedimentary Basin. *Seismological Research Letters*, 87(3). doi: 10.1785/0220150263

⁶⁴ NTN: Toxic Chemicals in the Exploration and Production of Gas from Unconventional Sources

⁶⁵ See footnotes 3–8, 12, 57, 174 in *Fracking Compendium*, Vol. 2

⁶⁶ A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development: http://www.health.ny.gov/press/reports/docs/high_volume_hydraulic_fracturing.pdf

⁶⁷ Kort, E. A., Smith, M. L., Murray, L. T., Gvakharia, A., Brandt, A. R., Peischl, J., ... Travis, K. (2016). Fugitive emissions from the Bakken shale illustrate role of shale production in global ethane shift. *Geophysical Research Letters*, 43, 4617–4623. doi: 10.1002/2016GL068703

⁶⁸ Moore, C. S. & Human K. (2016, April 26). One oil field a key culprit in global ethane gas increase. *Michigan News*. <http://ns.umich.edu/new/multimedia/videos/23735-one-oil-field-a-key-culprit-in-globalethane-gas-increase>

Climate Change

Methane is a more powerful greenhouse gas than carbon dioxide – 86 times more powerful when considered over a 20-year timeframe and 34 times more over a 100-year timeframe. The near term consequences of methane emissions are very important in the context of the risks of climate tipping points and near term temperature thresholds over the coming two decades.

A recent report by the Melbourne Energy Institute (MEI) reviewed the latest research on methane fugitive emissions from unconventional gasfields in the US⁶⁹. It found that:

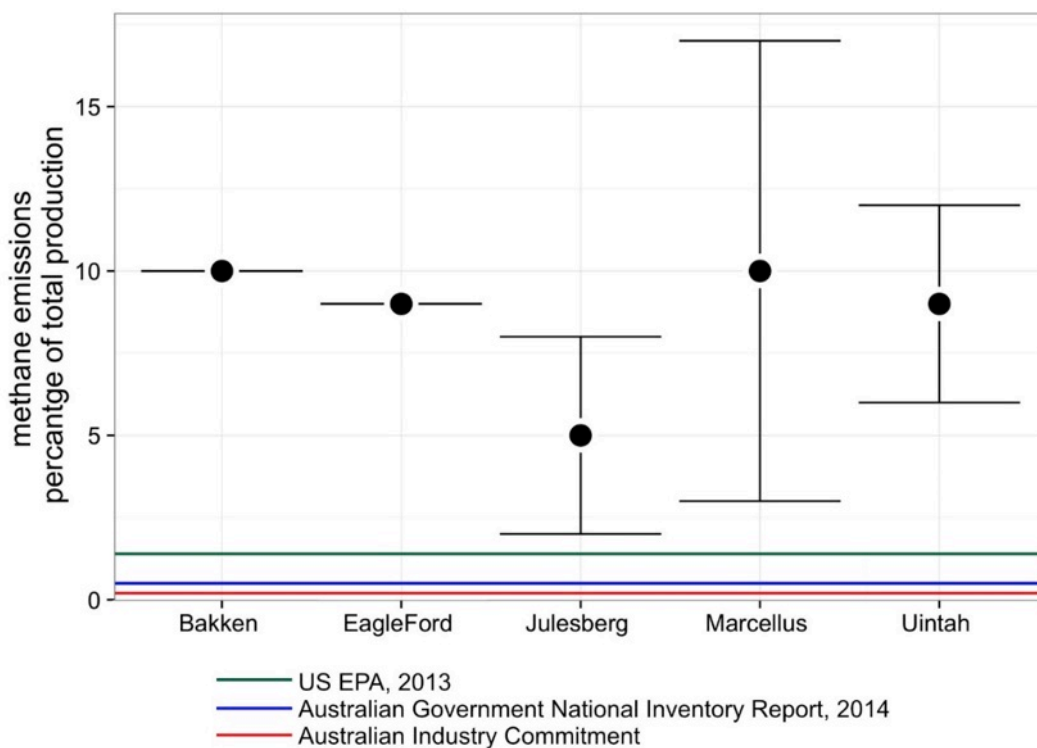
1. Actual measurements above US gasfields have recorded fugitive emissions of up to 17% of production. For comparison, the unconventional gas industry in Australia claims that its fugitive emissions amount to only 0.1% of production⁷⁰.
2. 'Top down' methods of measuring fugitive emissions, such as satellite imagery and aerial borne surveys, have revealed methane emissions that are many orders of magnitude greater than emissions recorded from 'bottom up' surveys using ground measurements'.

It is widely recognized that at more than about 3% leakage, gas is actually more polluting than coal when used to generate electricity⁷¹.

⁶⁹ Lafleur, D., Forcey, T., Saddler, H., and Sandiford, M. (2016) A Review of Current and Future Methane Emissions from Australian Unconventional Oil and Gas Production. Melbourne Energy Institute.

⁷⁰ Clark, T., R. Hynes, P. Mariotti, A. P. Production and E. Association (2011). Greenhouse gas emissions study of Australian CSG to LNG, Australian Petroleum Production & Exploration Association Limited.

⁷¹ See, for example, Hardisty, P. E., T. S. Clark and R. G. Hynes (2012). "Life cycle greenhouse-gas emissions from electricity generation: A comparative analysis of Australian energy sources." *Energies* 5(4): 872-897.



Measured fugitive emissions at US gas fields compared to Australian industry and government reporting.

Comparison of emission estimates and measurements (Table 11 from MEI 2016)

Reported oil and gas-related methane-emission estimates and top-down measurements				
		Basis	% of production	Reference
Australia	Oil and gas industry media release	limited well-pad measurements	0.02%	Footnote ⁷²
	Fugitive emissions reported in Queensland CSG-LNG environmental impact statements	factor-based estimates	0.1%	Clark, Hynes et al. (2011), Prior (2011), Hardisty, Clark et al. (2012)
	Australian Government reported (for the year 2014)	largely factor-based estimates	0.5%	See Section 5.3 MEI report
U.S.	U.S. EPA (for the year 2013, latest revision)	largely factor-based estimates	1.4%	See Section 4.6 MEI report

⁷² APPEA (2014) http://www.appea.com.au/media_release/csiro-report-points-to-environmental-benefits-of-csg/

	U.S. Denver-Julesberg basin	aircraft measurements	2 to 8%	Petron, Karion et al. (2014), see Table 2 MEI report
	U.S. Eagle Ford Basin (Texas)	satellite-based measurements	9%	Schneising, Burrows et al. (2014), see Table 2 MEI report
	U.S. Bakken Basin (North Dakota)	satellite-based measurements	10%	Schneising, Burrows et al. (2014), see Table 2 MEI report
	U.S. Uintah Basin (Utah)	aircraft-based measurements	6 to 12%	Karion, Sweeney et al. (2013), see Table 2 MEI report
	U.S. Marcellus Basin (southwestern Pennsylvania)	aircraft-based measurements	3 to 17%	Caulton, Shepson et al. (2014), see Table 2 MEI report

Emissions Factors Used in Australia

The MEI report found that in Australia to date, there has been almost complete reliance on pre-determined emission ‘factors’ in reporting of unconventional gas emissions to the UNFCCC. It also noted that actual measurements of emissions have been almost non-existent (confined only to extremely limited bottom up studies), and that there have been no baseline measurements in Australia.

Therefore, it is currently not possible to accurately assess emissions from Australian gasfields, but evidence from the US points to the fact that our emissions reporting, based as it is on factors, is likely to significantly understate the true level of emissions. Specifically, methane leakage rates recorded in the atmosphere at US unconventional gas fields are 10-25 times higher than those the Australian government reports to the UNFCCC (see Figure above).

The report highlighted one particularly notable are of likely underestimation in the use of emissions factors. The emission factor used for reporting methane leaked during the production phase of gas extraction for UNFCCC reports; categorized as “*fugitive emissions-general leaks*” – which is very low at just 0.0058% of production. Within that production category, emissions are set to zero for the following sources of emissions, despite the likelihood that emissions from these sources are very large:

1. In field compressor stations
2. Water and gas gathering lines and associated venting
3. Water treatment facilities
4. Migratory emissions

The 'production' emissions factor relies on a CSIRO 2014⁷³ report that claims to have validated the 0.0058% factor, but that report:

- Was artificially restricted to well head emissions only
- Ignored leaks from the large network of gathering lines, compressors and pumps connecting gas wells to the transmission pipeline.
- Noted far larger leaks in the pipeline system outside wellheads that overwhelmed well head measurements, but didn't measure them
- Relied on a very small sample of 43 wells selected by the gas industry

The CSIRO 2014 report, however, gives some insight into the scale of production emissions that were outside its study and that are currently set to zero in Australian reporting, as follows:

"We found a significant CH₄ emission point from a water gathering line near Well B13. Methane was being released from two vents ... at a rate sufficient rate to be audible a considerable distance from the vents. ... Based on the prevailing wind speed, we estimate that the CH₄ emission rate from the two vents was at least 130 [grams per minute].... This is a factor of three more than the highest emitting well examined during this study."

Recorded Methane Venting in Australia

The substantial nature of emissions from vents has been verified recently with the deployment of a FLIR GF-320 infrared camera in the Queensland coal seam gasfields. An independent energy advisor, Tim Forcey, deployed the camera in February 2017 near Chinchilla and found⁷⁴:

1. Continuous releases of methane from "high-point vents" on water-gathering pipelines
2. Intermittent releases of methane from other gas field equipment
3. Methane bubbling from the Condamine River and Wambo Creek.

Given the very large number of high point vents and other gas field equipment vents which are located throughout the Queensland CSG fields, if the scale of venting detected by the FLIR camera was replicated, it would represent a potentially vast, unmeasured contribution to global warming.

Estimates of Emissions and Implications for Paris Targets

Whilst the paucity of data makes it difficult to assess the likely scale of emissions from unconventional gas in Australia, the Melbourne Energy Institute utilised recorded 'top down' measurements from the US to derive a set of estimated emission scenarios for the Australian context and associated liabilities should there be a price on carbon⁷⁵.

⁷³ Day, S., M. Dell'Amico, R. A. Fry and H. Javanmard Tousi (2014). Field Measurements of Fugitive Emissions from Equipment and Well Casings in Australian Coal Seam Gas Production Facilities, CSIRO, Australia.

⁷⁴ Tim Forcey. 2017. Infrared Video Recording Methane Emissions in the Queensland Coal Seam Gas Fields. February 2017.

⁷⁵ Lafleur, D., Forcey, T., Saddler, H., and Sandiford, M (2016) A Review of Current and Future Methane Emissions from Australian Unconventional Oil and Gas Production. Melbourne Energy Institute.

Table 12 from MEI 2016

Liabilities for differing scenarios for methane emissions from Australian unconventional oil and gas production, in terms of lost value and potential carbon impost.					
Column	A	B	C	D	E
Case	Unconventional gas production rate	Methane emissions rate	Methane greenhouse-gas emissions (100 yr – 20 yr GWP)	Sales value of lost gas (at \$A 10 / gigajoule)	Carbon impost (\$A 25/tonne CO ₂ -e; 100 yr – 20 yr GWP)
	PJ/yr	% of gas production	million tonnes CO ₂ -e/yr	million \$A/yr	million \$A/yr
1	1,500 (*)	0.5	5 - 12	75	115 - 290
2	"	2	18 - 46	300	459 - 1,162
3	"	6	55 - 139	900	1,367 - 3,485
4	"	10	92 - 232	1,500	2,296 - 5,808
5	"	15	136 - 348	2,250	3,443 - 8,712
6	3,000	0.5	9 - 23	150	230 - 581
7	"	2	37 - 93	600	918 - 2,323
8	"	6	110 - 279	1,800	2,755 - 6,969
9	"	10	184 - 465	3,000	4,590 - 11,615
10	"	15	275 - 697	4,500	6,887 - 17,423
* 1,500 PJ/yr is approximately equal to current or near-term (2016, 2017) CSG production capacity.					

As the table above shows, MEI concluded that a 10% methane leakage rate for the production of 1,500 PJ/annum of gas would lead to fugitive emissions of 92MtCO₂-e/yr using the 100 year global warming potential of methane, or to 232MtCO₂-e/yr using the 20 year GWP.

In light of the serious risks of large-scale fugitive emissions identified by the MEI 2016 report, they recommended that:

- Reported methane-emission measurements should be independently verified by a regulatory body funded by a levy on the industry.

- Methane emissions volumes should be explicitly limited by regulation.
- Independently collected and analysed methane-emissions baseline data should be established for any area being considered for oil and gas development.
- Piloted and unpiloted aircraft should be used for top-down emission investigations
- Real time, top down methane emissions monitoring should be made publicly available on a website.
- A widespread network of ground based air quality monitoring towers should be established.
- Sedimentary basin management plans should be developed.

Other Australian work

Another report released this year by the Melbourne Energy Institute explores the risks of methane gases from a coal seam migrating to the surface as a result of coal seam dewatering and depressurisation for coal seam gas production⁷⁶. It identifies that such migratory emissions are a potentially significant source of greenhouse gases from unconventional gas extraction, but concludes that there is very limited data available to assess the full scale of the risk.

It finds that migration of methane along existing natural faults and fractures is possible and may increase with continued depressurization by unconventional gas mining. It notes that presence of free methane in water bores can be the direct consequence of depressurisation of the coal seams.

It finds that due to a lack available data the likelihood of migratory emissions occurring as a result of gas extraction is difficult to assess, and highlights that to date the presence or scale of such emissions has been completely un-measured. It finds that there is an urgent need for holistic sedimentary basin management plans and integrated geological-hydrological models to allow for a thorough analysis of the risks of gas migration.

Public Health

Drilling and fracking chemicals

A 2017 peer reviewed study found that evaluations for chemicals used in other routine oil and gas development activities, such as maintenance acidizing, gravel packing, and well drilling, have not been previously conducted, in part due to a lack of reliable information concerning on-field chemical-use. Through their extensive research, the results of the 2017 study indicate

⁷⁶ Lafleur, D., Sandiford, M. (2016) The risk of migratory methane emissions resulting from the development of coal seam gas in QLD. Melbourne Energy Institute.
http://www.tai.org.au/sites/default/files/Migratory_emissions_20170417-LowerRes.pdf

regulations and risk assessments focused exclusively on chemicals used in well-stimulation activities may underestimate potential hazard or risk from overall oil field chemical use⁷⁷.

The National Toxics Network identifies a range of issues in relation to the chemicals used in fracking and their regulation. These include:

- Many chemicals used in fracking operations in Australia have not been assessed for their toxicity to the environment and humans. “The mixtures used in drilling and fracking fluids are also not assessed for toxicity or persistence and can form new compounds when exposed to sunlight, water, air, radioactive elements or other natural chemical catalysts.”
- Large numbers of hazardous products were identified in US fracking operations.
- There is a reliance on industry reporting of fracking chemicals in the US, with many potentially toxic chemicals not being reported as they are classed as ‘trade secrets’.⁷⁸

Under the *Industrial Chemicals (Notification and Assessment) Act 1989* (the Act), chemicals that are already listed on Australian Index of Chemical Substances (AICS) may be used for any industrial purpose (subject to conditions of use, if any), including for purposes related to CSG or shale fracking, without further assessment by NICNAS.

If an ingredient is already on the AICS (this Index includes around 38,000 chemicals) then it can be used with no further assessment. The vast majority (around 85%) of those chemicals have never been assessed, as they were grandfathered into the scheme.

Supposedly new chemicals must be assessed, however there is not evidence it is a ‘rigorous’ process. Importantly, the assessment only relates to individual chemicals, and not the chemical combination ‘products’ used by the fracking companies. One problem with fracking chemicals is they are often imported as a ‘product’ and NICNAS doesn’t investigate the entire product ingredients.

It is also worth noting there is no assessment of the interactions between chemicals used in the fracking process and the chemicals released naturally from the coal or shale seams.

NICNAS has established the Inventory Multi-tiered Assessment and Prioritisation (IMAP) framework to accelerate the assessment of existing chemicals on the AICS. Specifically, NICNAS

⁷⁷ Stringfellow WT, Camarillo MK, Domen JK, Shonkoff SBC (2017) Comparison of chemical-use between hydraulic fracturing, acidizing, and routine oil and gas development. PLoS ONE 12(4): e0175344. <https://phys.org/news/2017-04-hazardous-chemicals-unregulated-routine-oil.html>

⁷⁸ National Toxics Network, 2013, Toxic Chemicals in the Exploration and Production of Gas from Unconventional Sources http://www.ntn.org.au/wp/wp-content/uploads/2013/04/UCgas_report-April-2013.pdf

was given the task back in 2012 of assessing the safety or otherwise of fracking chemicals under their IMAP program.

However the Federal Minister for the Environment has not released a public outcome of that investigation to date. It is also important to remember it is only for coal seam gas extraction chemicals and not for shale. Plus, the chemicals used in the fracking process are likely to have changed since 2012, and it is not clear (even to those sitting on the NICNAS advisory board) whether newer chemicals have been assessed under IMAP or not.

The investigation will not deal with the impacts on groundwater aquifers nor will it look at the mixture of chemicals released to the environment, which has been highlighted as a serious issue by the EU.

Further, under future reforms proposed by NICNAS, if an individual chemical is deemed to be low-medium risk, then the industry will essentially self regulate and self assess the risks of that chemical. It is only when a chemical ingredient (NB ingredient, not a product) is a high risk that NICNAS will do any assessment. Again, the chemical combination risks are not considered.

There are a number of very significant impacts on the mental, emotional and physical well-being of communities facing and experiencing the rapid industrialization of their local area for UG development. These impacts are outlined in the following paragraphs.

Health Impacts Associated with Air and Water Pollution

Studies increasingly show that air pollution associated with drilling and fracking operations is a grave concern with a range of impacts, with researchers documenting dozens of air pollutants from drilling and fracking operations that pose serious health hazards⁷⁹. Hazardous air pollutants are released from a range of processes in UG operations. These include: the burning of diesel in machinery, generators, construction equipment and chemical, water, and waste transport vehicles; off-gassing from wastewater holding ponds; flaring and venting at wellheads; and emissions and leaks from wells, pipelines, processing plants and compressor stations.⁸⁰

Importantly, the risks of exposure to harmful substances occur not only as a result of drilling and fracking stages of gas operations but throughout the life time of UG operations from emissions from infrastructure and other processes including silica and sand mining activities, compressor stations, pipelines and wastewater holding ponds. Exposure to harmful substances

⁷⁹ Concerned Health Professionals of New York & Physicians for Social Responsibility. (2015, October 14). Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction) (3rd ed.). <http://concernedhealthny.org/compendium/>

⁸⁰ NTN: Toxic Chemicals in the Exploration and Production of Gas from Unconventional Sources

can also occur through direct skin contact with fracking chemicals and wastes; drinking or bathing in contaminated water and through contaminated dust particulates⁸¹.

The Compendium notes that “among residents living near drilling and fracking operations, documented indicators variously include increased rates of hospitalization, self-reported respiratory problems and rashes, motor vehicle fatalities, trauma, drug abuse, and low birth weight among infants,” Some of the public health effects of UG development that researchers have documented, outlined in the Compendium of Fracking Risks, include:

- increased rates of hospitalization for cardiological complaints, cancer, skin conditions, and urological problems;
- increase in frequency of health symptoms reported by residents as distance between households and gas wells decreased; with rashes and upper respiratory problems more prevalent among persons living less than one kilometre from drilling and fracking operations;
- increases in commercial vehicle accidents;
- a sharp rise in ambulance calls and emergency room visits for drug related cases and oilfield related injuries and accidents;
- increase in infant deaths to six times the normal rate over three years;
- congenital heart defects, and possibly neural tube defects in newborns, associated with the density and proximity of natural gas wells within a 10-mile radius of mothers’ residences;
- elevated rates of low birthweight among infants born to mothers living near drilling and fracking operations during their pregnancies;
- reductions in average birthweight and length of pregnancy as well as increased risk for low birthweight and premature birth associated with proximity to fracking operations.⁸²

In a 2013 US study, surface and groundwater near areas experiencing high levels of unconventional gas activity in Colorado were shown to contain endocrine-disrupting chemicals (EDC) with moderate to high levels of EDC activity.⁸³ The concentrations of chemicals detected in surface and ground water were in high enough concentrations to interfere with the response of human cells to male sex hormones and estrogen. Samples taken from sites with little drilling showed little EDC activity. Exposure to EDCs can increase the risk of reproductive, metabolic, neurological, and other diseases, especially in children and young organisms.

⁸¹ Ibid.

⁸² Concerned Health Professionals of New York & Physicians for Social Responsibility. (2015, October 14). Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction) (3rd ed.). <http://concernedhealthny.org/compendium/>

⁸³ Kassotis et al (2013) Estrogen and Androgen Receptor Activities of Hydraulic Fracturing Chemicals and Surface and Ground Water in a Drilling-Dense Region, Endocrinology doi: 10.1210/en.2013-1697 <http://www.endo.endojournals.org>

Hydrocarbons and BTEX

A team of researchers established that petroleum-based hydrocarbons can break down underground in ways that promote the leaching of naturally occurring arsenic, a known human carcinogen that causes bladder, lung, and skin cancer, into groundwater.⁸⁴

A 2015 routine monitoring at AGL's (now abandoned) Waukivory CSG Project at Gloucester detected elevated levels of toxic BTEX (Benzene, Toluene, Ethylene, Glycine) chemicals in flowback water from wells following hydraulic fracturing. Given that the fracking chemicals and raw water used both tested negative for these chemicals, it was assessed that the likely source of BTEX was the coal seams and that the chemicals were mobilized as a result of the fracking process.⁸⁵

Mental Health and Wellbeing

The social stressors associated with the large-scale heavy industrial activities that accompany UG development take a heavy toll on the mental and emotional health of rural families and communities impacted by UG development. Doctors for the Environment Australia note that "water and air pollution, water shortages, permanent degradation of productive agricultural land and loss of livelihood and landscape... all have mental health consequences for communities living in a gas field."⁸⁶

A 2013 study investigating the impacts of mining and CSG operations on the mental health of landholders in south west Queensland established that these operations placed rural communities "under sustained stress".⁸⁷ The study conducted twelve workshops within the region, asking community members, among other things, about the issues, which were affecting their mental health. Study participants reported that mining and CSG operations "significantly impacted or exacerbated issues such as the health, social fabric and economy of the community", and the authors noted that local health services faced "unsustainable pressure". A 2014 article in the Medical Journal of Australia notes that "gas developments can

⁸⁴ U.S. Geological Survey (2015, January. 26) Natural breakdown of petroleum underground can lace arsenic into groundwater. http://www.usgs.gov/newsroom/article.asp?ID=4110&from=rss&utm_source=dlvr.it&utm_medium=facebook#.VavGXIsqdyA

⁸⁵ EPA NSW (2015) <http://www.epa.nsw.gov.au/resources/licensing/150311-agl-gloucester.pdf>

⁸⁶ Doctors for the Environment Australia, Submission to the NSW Parliamentary Inquiry into Coal Seam Gas, 16/09/2011

⁸⁷ Hossain D. et al. Impact of the mining industry on the mental health of landholders and rural communities in southwest Queensland (2013). *Psychiatry*, 21:32-37

have numerous and considerable social and psychological effects, which may exacerbate more direct health risks.”⁸⁸

A 2014 CSIRO study⁸⁹ noted that local farmers perceived the nature of CSG development in South West Queensland to date as an “invasion” or “occupation”, whilst a previous study in Chinchilla found residents describing a ‘tsunami of change’.⁹⁰

Interacting and engaging with CSG companies has also been reported⁹¹ as having a significant negative impact on farmer’s wellbeing. The interactions between farmers and CSG companies resulted in issues of stress, conflict and disconnection.

More recently, researchers assessed the contribution of coal seam gas extraction in Queensland to the global stress burden and mental health of Australian farmers. Dr. Methuen Morgan surveyed 378 Australian farmers, predominantly from Queensland and NSW, on the factors associated with their work that can impact mental health and wellbeing⁹².

The study, reported in the Journal of Environmental Psychology in 2016, found that farmers concerned about the impacts of coal seam gas on their health, community and the environment, were more likely to report symptoms of depression and decreased levels of wellbeing. It found that farmers who were classified as ‘CSG-stressed’ exhibited clinically significant levels of psychological morbidity.

Impact on Traditional Owners

A 2014 Powerpoint presentation from the Fort Nelson First Nation group from Canada covers insights and issues from the perspective of local Traditional Owners.

For example, their presentation reads:

Fort Nelson First Nation (FNFN) rights, interests and lands

- *FNFN’s experience with hydraulic fracturing*
 - *Significant adverse impacts on land, water, air and treaty rights*
 - *BC LNG export poses tremendous risk to FNFN Inadequate regulatory framework*
 - *Inadequate consultation and accommodation*
 - *FNFN bearing greater burden than benefit*

⁸⁸ Coram, Moss and Blashki (2014) Harms unknown: health uncertainties cast doubt on the role of unconventional gas in Australia's energy future, Med J Aust 2014; 200 (4): 210-213. doi: 10.5694/mja13.11023 <https://www.mja.com.au/journal/2014/200/4/harms-unknown-health-uncertainties-cast-doubt-role-unconventional-gas-australias>

⁸⁹ Huth N.I., Cocks B., Dalgliesh N., Poulton, P., Marinoni O., Navarro J. (2014) Farmers’ perceptions of coexistence between agriculture and a large scale coal seam gas development: working paper, June 2014, CSIRO, Australia.

⁹⁰ Walton, A.M., McCrea, R., Leonard, R., Williams, R., 2013. Resilience in a changing community landscape of coal seam gas: Chinchilla in Southern Queensland. Journal of Economic and Social Policy 15, Article 2

⁹¹ Huth N.I., Cocks B., Dalgliesh N., Poulton, P., Marinoni O., Navarro J. (2014) Farmers’ perceptions of coexistence between agriculture and a large scale coal seam gas development: working paper, June 2014, CSIRO, Australia.

⁹² Morgan, M., Hine, D., Bhullar, N., Dunstan, D., and Bartik, W. Fracked: Coal Seam Gas Extraction and Farmers Mental Health. *Journal of Environmental Psychology* 47 (2016), 22-32.

Over the past ten years there has been enormous oil and gas development in FNFN territory, with more anticipated.

- *Hydraulic fracturing and horizontal drilling technologies have brought rapid change to FNFN territory*
- *Regulated by the Province of BC (Oil and Gas Commission) on an incremental basis, with little or no attention to cumulative impacts*
 - *Habitat fragmentation & loss (caribou, grizzly bear, bison)*
 - *Increased predation (caribou, moose)*
 - *Populations of furbears decline with industrial development (lynx, marten, fisher, beaver)*
 - *Introduction of invasive Species*
 - *Reduction in plant and ecotype diversity*
 - *Contamination*
 - *Rare plants lost*
 - *Fragmentation of forested lands reduces ecological vitality*

As of June 2013, the OGC had approved the use of up to 2,623,000 m³ /day or 20,405,000 m³ /year (equivalent to +8,000 Olympic swimming pools) for fracking in FNFN territory

- *Significant hydrologic impacts (reduced stream flow, drought vulnerability, degraded fisheries habitats and wetlands)*

Please see the full presentation here: http://www.legassembly.gov.yk.ca/pdf/rbhf_FNFN-Presentation.pdf

Fort Nelson First Nation also have uploaded a useful time lapse video of the industrialisation of their lands over the decades, first from conventional gas, and more recently from shale gas fracking.

http://lands.fnnation.ca/sites/default/files/industry_activity_2.mp4

Social Impacts

Infrastructure - onshore unconventional gas led to a degradation of public resources in QLD

In 2013, the University of QLD published in depth research into the impacts of mining and onshore gasfields across the regional QLD communities where they were operating. The research team interviewed people from across all sectors of the local communities to gather a broad range of evidence and feedback on the impacts⁹³.

⁹³ Everingham, J., Collins, N., Rodriguez, D. Cavaye, J., Vink, S., Rifkin, W. & Baumgartl, T. (2013) Energy resources from the food bowl: an uneasy co-existence. Identifying and managing cumulative impacts of mining and agriculture. Project report. CSRM, The University of Queensland: Brisbane.

Their detailed research found that while those working in the coal seam gas industry in the Darling Downs region had a positive view of the impact of the industries, people working in local businesses, agriculture, government and the community sector consistently believed UG development and mining had led to a deterioration of:

- Financial capital- revenue streams and economic resources.
- Built capital- local infrastructure including buildings, transport, equipment and communications.
- Human capital- skills, knowledge, abilities and good health.
- Social capital- organisations, networks and relationships, based on shared values, mutual trust and reciprocity.

The main reasons for these social and financial impacts are the loss of skilled staff to the gas industry and the increased cost of labour, rent, transport and goods and services for local businesses.

The outcomes of discussions are summed up in the below table. It is worth noting that even stakeholders representing the mining and gas sector conceded that built capital such as roads in the area were made worse due to the operations of mining and gas in the area.

Stakeholders groups	Financial capital	Human capital	Built capital	Social capital	Natural capital
Gas	Better	Better	Worse	Better	Better
Mining	Better	Better	Worse	Better	Better
Agriculture	Worse	Worse	Worse	Worse	Worse
Local business	Worse	Worse	Worse	Worse	Worse
Local government	Worse	Better	Worse	Same	Same
Community	Worse	Better	Worse	Worse	Worse
Advocacy	Worse	Worse	Worse	Worse	Worse

Table sourced from report by The Australia Institute (2015) Be careful what you wish for⁹⁴.

⁹⁴ Ogge, M. (2015) Be careful what you wish for. Report for The Australia Institute

Community cohesion and wellbeing:

The Queensland and NSW experience with the expansion of coal seam gas operations has shown that when this industry is forced upon communities against their wishes, there is potential for significant conflict and social upheaval and disruption as a result, even at the exploration phase of the industry. Lock the Gate members and local community groups report a range of impacts from proposed and actual UG development on their mental and emotional wellbeing. These include:

- A sense of injustice that they do not have the right to refuse access to companies for UG activities and that this industry is being forced on an unwilling population.
- Fear and anxiety about the impacts of the UG industry on their family's health and the quality of the air and water they rely upon.
- Concern about the impact of UG development on the economic viability of their farms and property values.
- A sense of anger and betrayal that governments are supporting industry rather than communities in the development of the UG industry.
- A sense of anger that the industry is being pushed ahead rapidly without proper consideration of the impacts and before proper scientific studies have been done and baseline data collected.

In discussing the broader social impacts of UG development, Doctors for the Environment Australia note: "Informed consent of landholders is often lacking in the contract process when mining companies first approach landholders about unconventional gas extraction.... The injustice and powerlessness that this engenders contributes to solastalgia and poorer mental health outcomes." Overall, DEA maintain that UG development can "divide previously close-knit rural communities, increasing tension and disharmony."

The lack of a veto right for landholders in relation to UG development, the stress involved in dealing with UG companies (often against their will), the lack of full information and disclosure on the realities of UG development, and the often underhanded tactics employed by companies contributes to a sense of powerlessness, betrayal and frustration amongst landholders and affected communities. According to DEA, in eastern Australia, "the stress and disruption caused to farmers has already been shown to force some of them to leave a CSG drilling area, allowing once productive lands to lapse into disuse," whilst in the US "longtime residents are moving, unable to bear the changes the gas industry has wrought on their landscape and community."

In their submission to the 2015 Victorian Parliamentary Inquiry⁹⁵ DEA note:

“The migratory, boom and bust nature of UG developments can carry significant social and psychological effects for those who live in communities near operations and on those who may travel to work at these developments. A study⁹⁶ of impacts of mining and unconventional gas operations on landholders in Queensland found that these operations placed rural communities “under sustained stress”, with study participants describing significant impacts on the health, social fabric and economy of local communities.”

The health and social impacts of UG development will necessarily have a flow on negative impact on the overall wellbeing of rural communities, as well as the functionality of other industries in which rural residents are engaged. This impact will be magnified due to the fact that farming and rural communities are the very same communities who are already at most risk from the adverse health effects of drought, climate change and the degradation and depletion of Australia’s river systems and groundwater resources.⁹⁷

The impacts of the use of fly-in, fly-out and drive-in, drive-out workforces, used extensively in existing unconventional gas developments in Australia, also has a range of negative social impacts which were documented in a recent Parliamentary Inquiry⁹⁸. The use of FIFO and DIDO workforces have come under scrutiny for their negative influence on community cohesion, increased rents and other living expenses, and their association with elevated levels of alcohol and drug use, as well as mental health issues and violence.

Crime – risk of increase:

A recently release paper from the Journal of Environmental Economics and Management shows that the energy boom in the United States has affected regional crime rates throughout the country. Researchers found positive effects on rates of various property and violent crimes in shale-rich counties. In 2013, the cost of the additional crimes in the average treatment county was roughly \$2 million⁹⁹.

⁹⁵ Doctors for the Environment Australia (2015)
[http://www.parliament.vic.gov.au/images/stories/committees/EPC/Submission_416 -
Doctors for Environment Australia .pdf](http://www.parliament.vic.gov.au/images/stories/committees/EPC/Submission_416_-_Doctors_for_Environment_Australia.pdf)

⁹⁶ Hossain D. et al. Impact of the mining industry on the mental health of landholders and rural communities in southwest Queensland (2013). *Psychiatry*, 21:32-37.

⁹⁷ Doctors for the Environment Australia, Submission to the Inquiry into Coal Seam Gas, 16/09/2011

⁹⁸ House of Representatives Standing Committee on Regional Australia. *Cancer of the bush or salvation for our cities? Fly-in, fly-out and drive in, drive-out workforce practices in regional Australia*. Canberra: Commonwealth of Australia, 2013.
<http://trove.nla.gov.au/work/176479103?selectedversion=NBD50509223>

⁹⁹ James, Smith et al, 2017, There will be blood: Crime rates in shale-rich U.S. counties, *Journal of Environmental Economics and Management* [Volume 84](#), July 2017, Pages 125–152,
<http://dx.doi.org/10.1016/j.jeem.2016.12.004>,
<http://www.sciencedirect.com/science/article/pii/S0095069616305459>

The Western Criminological Review Journal found in 2013 that law enforcement and human service personnel reported that the rapid growth in oil and gas producing areas and communities leads to increased crime and other social ills. Researchers made a comparison of 2012 crime rates in a matched sample of counties revealed that crime rates were higher in oil impacted counties. A pre-post analysis found that violent crime in boom counties increased 18.5% between 2006 and 2012 while decreasing 25.6% in a matched sample of counties that had no oil or gas production¹⁰⁰.

A Multi-State Shale Research Collaborative published a report in December 2014 on the relationship of the shale drilling to crime, traffic fatalities, STDs and rents. Researchers found that communities with the highest intensity of natural gas drilling have seen increased rate of crime, motor vehicle fatalities and sexually transmitted diseases. While the influx of energy workers hasn't significantly increased population figures, it coincided with a surge in rental prices across the Marcellus Shale region¹⁰¹.

Boom Bust

The scale of the 'bust' after the short unconventional gas construction period ends is severe, and long-term job opportunities are extremely limited. Queensland Treasury figures reveal that more than 10,000 FIFO/DIDO jobs have been lost in the Surat Basin since the CSG construction boom peaked in 2014. In June 2014 there were 14,490 non-resident jobs in the region, and by June 2016 that had reduced to just 3,820 jobs¹⁰², similar to pre-CSG levels.

Long-term employment is low because the oil and gas industry is highly capital intensive. The Office of the Chief Economist estimates that the entire oil and gas industry in Australia employed just 29,000 people in 2015/16¹⁰³, which is less than a quarter of the Australian workforce. That is an extraordinarily low employment given that Australia is set to become the world's largest exporter of gas.

The gas industry frequently also makes claims about delivering substantial flow-on jobs in regional communities, particularly in the services industry, and job multipliers are frequently used to derive large job estimates. However, research into the local economic impacts of CSG in Queensland provides evidence, which disputes those claims. Specifically, research by

¹⁰⁰ Ruddell, Rick, Dheeshana S. Jayasundara, Roni Mayzer, and Thomasine Heitkamp. 2014. "Drilling Down: An Examination of the Boom-Crime Relationship in Resource Based Boom Counties" Western Criminology Review 15(1):3-17 (<http://wcr.sonoma.edu/v15n1/Ruddell.pdf>).

¹⁰¹ Multi-State Shale Research Collaborative, 2016: http://www.pennlive.com/midstate/index.ssf/2014/12/fracking_brought_spikes_in_vio.html

¹⁰² <http://www.qgso.qld.gov.au/products/reports/surat-basin-non-resident-pop-proj/surat-basin-non-resident-pop-proj-2017-2023.pdf>

¹⁰³ <https://industry.gov.au/Office-of-the-Chief-Economist/Publications/Pages/Resources-and-energy-quarterly.aspx>

Fleming and Measham for GISERA found that job spillovers into non-mining employment in the Surat Basin were negligible¹⁰⁴. The table below provides a summary of their findings.

Table 4.2. CSG employment spillovers over different sectors

	Elasticity	Additional job for each new CSG job
Local goods sector		
Construction	0.832 (0.426) *	1.412
Professional services	0.704 (0.259) **	0.412
Retail trade	0.011 (0.140)	0.024
Services [†]	-0.205 (0.230)	-0.732
Traded sector		
Manufacturing	0.068 (0.199)	0.160

Notes: Elasticity values are 2SLS estimations for coefficient ψ in equation (2). The number of CSG wells in an SLA is used as instrument for the log change of mining employment. Values estimated using sample 3 (n = 48). F-stat first-stage = 10.74. Robust clustered std. errors at LGA levels in parentheses. *p < .10. **p < .05. [†]Services sector include employment in accommodation, rental agencies, transport and 'other services'.

Amenity – risk of adverse impacts on those living on the land

A recent CSIRO study¹⁰⁵ examining farmers' perceptions of coexistence between agriculture and a large scale coal seam gas development in Queensland found that "issues regarding atmospheric pollution (dust, light, noise) has a significant impact on many aspects of farmers' lives." The impact of significantly increased traffic, both on and off the farm, was also a significant concern to farmers.

The expansion of CSG production in Queensland has demonstrated the potential for UG developments to severely disrupt virtually every aspect of agricultural production and potentially even remove the land from production.

In the course of its work supporting landholders and communities facing the impacts of unconventional gas developments, Lock the Gate Alliance hears firsthand about the myriad effects these development are having on the livelihoods, health and well-being of Australian farming families living adjacent to and surrounded by gas activities. These harmful impacts include: intimidation, coercion and bullying by UG companies; intolerable noise and light pollution from flaring, traffic and UG infrastructure; contamination and depletion of water in

¹⁰⁴ Fleming, D. and Measham, T. (2013) Local economic impacts of an unconventional energy boom: the coal seam gas industry in Australia. [Report to the Gas Industry Social and Environmental Research Alliance \(GISERA\)](#). June 2013. CSIRO, Canberra.

¹⁰⁵ Huth N.I., Cocks B., Dalgliesh N., Poulton, P., Marinoni O., Navarro J. (2014) Farmers' perceptions of coexistence between agriculture and a large scale coal seam gas development: working paper, June 2014, CSIRO, Australia.

farm bores; rivers bubbling with methane; bores running dry; stock losses associated with pipeline construction and water contamination; costly and time consuming interruptions to farming operations; huge trucks and heavy machinery on small local roads affecting lifestyle, safety and road infrastructure; dust impacts on pasture; increases in weed infestation; industry workers leaving mess from pipeline construction in farm paddocks; workers destroying fences and leaving gates open; properties not able to be sold; mental health impacts resulting from dealing with companies and the impacts of industry development; and physical health symptoms including respiratory ailments, headaches, rashes, nausea and vomiting, and nose, throat and eye irritations.

For many affected landholders, these impacts affect all facets of life and are making their living situation untenable. Personal testimonies of a number of affected landholders can be viewed in a series of short films compiled by the Lock the Gate Alliance talking about the impacts on them: https://www.youtube.com/watch?v=4OG9JkzB_3M

In relation to the cattle industry, there have been measured impacts of exposure to fracking related spills in the United States. A 2012 study by Bamberger and Oswald cited the following example:

*Two cases involving beef cattle farms inadvertently provided control and experimental groups. In one case, a creek into which wastewater was allegedly dumped was the source of water for 60 head, with the remaining 36 head in the herd kept in other pastures without access to the creek. Of the 60 head that were exposed to the creek water, 21 died and 16 failed to produce calves the following spring. Of the 36 that were not exposed, no health problems were observed, and only one cow failed to breed. At another farm, 140 head were exposed when the liner of a wastewater impoundment was allegedly slit, as reported by the farmer, and the fluid drained into the pasture and the pond used as a source of water for the cows. Of those 140 head exposed to the wastewater, approximately 70 died and there was a high incidence of stillborn and stunted calves. The remainder of the herd (60 head) was held in another pasture and did not have access to the wastewater; they showed no health or growth problems. These cases approach the design of a controlled experiment, and strongly implicate wastewater exposure in the death, failure to breed, and reduced growth rate of cattle.*¹⁰⁶

A follow-up study published in 2015 by the same authors further investigated 21 case studies from five states. They found that the distribution of symptoms in animals and humans affected by nearby fracking operations was, since 2012, unchanged for humans and companion animals. In food animals, reproductive problems decreased over time while respiratory problems and growth problems increased. Researchers also found, “More than half of all exposures were related to drilling and hydraulic fracturing operations; these decreased slightly over time. More

¹⁰⁶ Bamberger, M. and Oswald, R (2012). IMPACTS OF GAS DRILLING ON HUMAN AND ANIMAL HEALTH, NEW SOLUTIONS, Vol. 22(1) 51-77, 2012, http://www.psehealthyenergy.org/data/Bamberger_Oswald_NS22_in_press.pdf

than a third of all exposures were associated with wastewater, processing and production operations; these exposures increased slightly over time.”¹⁰⁷

Unprofitable – risk that SA shale gas is not profitable, leads to bankruptcies

In shale gasfields of the United States, Bloomberg reported that many fracking companies were losing money on shale drilling. A damning case study of shale drilling in Oklahoma revealed that the drilling was financed on cheap debt, with drillers spending \$2 for every \$1 they made from shale.

The Bloomberg report includes: *As Stanley Druckenmiller, an investor with one of the best long-term records in money management, said of Texans in January 2015: “Those guys know how to gamble, and if you let them stick a hole in the ground with your money, they’re going to do it.” Shale wasn’t sustaining the frenzy; cheap debt was.*¹⁰⁸

A 2016 Reuters report revealed a wave of bankruptcies across the United States that year¹⁰⁹. One question for the SA Government might be: who pays the clean up bill if these shale gas drilling and fracking companies go bankrupt? How do these economic risks relate to regulatory risks and failure to protect the environment and local communities?

¹⁰⁷ Bamberger, M. & Oswald, R. E. (2015). Long-term impacts of unconventional drilling operations on humans and animal health. *Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering*, 50, 447-59. doi: 10.1080/10934529.2015.992655

¹⁰⁸ Bloomberg, 2016, <https://www.bloomberg.com/news/articles/2016-03-10/the-shale-reckoning-comes-to-oklahoma>

¹⁰⁹ Reuters, 2016, <http://www.reuters.com/article/us-usa-shale-telecoms-idUSKCN0XV07V>



NATURAL RESOURCES COMMITTEE

FRACKING

Balcony Room, Parliament House, Adelaide

Friday, 4 December 2015 at 10:10am

(OFFICIAL HANSARD REPORT)
PARLIAMENT OF SOUTH AUSTRALIA

WITNESSES—*continuing*

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Mr P.A. Treloar MP

WITNESS:

INGRAFFEA, ANTHONY, Dwight C. Baum Professor of Engineering and Weiss Presidential Teaching Fellow, Cornell University

[Via Skype videoconferencing]

956 The PRESIDING MEMBER: Thank you very much for your time today, Professor Ingraffea. We have a number of people here in the Balcony Room in Parliament House, and we also have the media here, so no pressure, but we are looking forward to hearing from you. As you know, our committee, the Natural Resources Committee, is looking at the issue of fracking in the South-East of South Australia, and we have our members here. Can you see us, or can you only hear us?

Prof. INGRAFFEA: Yes, I can see you all very fine, thank you.

957 The PRESIDING MEMBER: Good. I would like to introduce the committee to you. We have the Hon. Robert Brokenshire, the Hon. John Dawkins and the Hon. Gerry Kandelaars. Those three gentlemen are all part of our Legislative Council, our upper house. We have Mr Jon Gee, who is the member for Napier, and my name is Steph Key, and I am the member for Ashford. Jon and I are in the lower house, the House of Assembly. Next to me is our research officer, Barbara Coddington, and on my other side is our executive officer, Patrick Dupont.

Because this is a parliamentary hearing, I just need to read you your rights so that you know your status. We have some people here from Hansard who are taking down what you have to say, which you will get a copy of. As I said before, we also have media people here who are very interested in what you have to say, as well as a gallery of interested both members of parliament and people from the community who are here to hear you. I will just get on with the introduction and then hand it over to you.

Prof. INGRAFFEA: Okay.

958 The PRESIDING MEMBER: Perhaps you could just wave if you cannot hear at any stage—that might work—because we can see you.

Prof. INGRAFFEA: Sure.

959 The PRESIDING MEMBER: You have agreed to give evidence to the Natural Resources Committee in South Australia by electronic means from a location outside Australia. Accordingly, parliamentary privilege may not apply in the same way that it would have if you had given evidence in South Australia. Should you publish your evidence to a third party, that publication may be subject to defamation laws in the state in which you publish it.

We really appreciate your attendance today. The committee is a standing committee of the Parliament of South Australia. Its powers and functions are set out in the Parliamentary Committees Act 1991. Sections 28 and 31 of the Parliamentary Committees Act set out the privileges, immunities and powers of this committee and the protection afforded to witnesses. Section 26 of the Parliamentary Committees Act provides that members of the public may be present during the examination of witnesses; as I said, we have a number of members here.

A request to make a statement in private will be considered by the committee and, if agreed to, members of the public will leave the room for the duration of that statement. So, if you feel that you would like to say something just to the committee, that can be arranged.

Prof. INGRAFFEA: Okay, thank you.

960 The PRESIDING MEMBER: The audio of today's proceedings will be streamed electronically within the parliamentary precinct, and the transcript of these proceedings will be available to the public once you have had an opportunity to ensure they are factually correct. As you know, today's hearing is in relation to fracking, unconventional gas inquiry. Could you introduce yourself and then continue with your presentation. As I said, thank you very much. We appreciate your doing this, so over to you, professor.

Prof. INGRAFFEA: Before I start, I am going to try to share my computer screen and make sure that works. Can you see my screen now?

961 The PRESIDING MEMBER: Yes, thank you. I will ask one of the committee members to move and second that your presentation form part of our evidence.

Moved by Hon. R.L. Brokenshire.

Seconded by Hon. G.A. Kandelaars.

Carried.

Prof. INGRAFFEA: Let me begin by thanking you very much for giving me the honour to give testimony to your committee. I'm taking this very seriously, and I'm going to do my very best to report to you facts, data, information that I believe to be completely true, and I will deliver it in the most honest way I can.

While you were speaking to me, there were a couple of times when the sound dropped out. I think that's because of the long distance we are communicating over Skype, so if I say something, if you see my mouth moving but you don't hear anything, let me know and I'll go back and repeat.

962 The PRESIDING MEMBER: Thank you.

Prof. INGRAFFEA: For your benefit, you will also note that in the lower right-hand corner of each of my slides there is a number, so if you have any questions about any particular information on any of these slides you can make a note and tell me later during Q&A and we can return to that particular numbered slide.

963 The PRESIDING MEMBER: Thank you.

Prof. INGRAFFEA: Let me begin with some preliminary comments. Did the screen change? Are you now looking at slide No. 2?

964 The PRESIDING MEMBER: Yes.

Prof. INGRAFFEA: Good. First, bravo, my compliments. I've extracted two quotes here from your interim report of past November and I've underlined two particular lines in those quotes. The first one is:

Fracking is only one part (though a complex one) of the overall process of gas extraction.

I can tell you that I have had interaction with many legislative and regulatory bodies in the US and around the world over the last six years and you are the first—the very first—legislative body to acknowledge that the issue about which we are speaking is not fracking: it's shale gas in its entirety—in its entirety. Fracking is a part, as you notice, but it's one of only many parts, and as you will hear during the rest of my testimony, in my opinion it is that part that brings with it the least risk.

So, I think it's perfectly appropriate, knowledgeable and wise of you to up-front acknowledge that we're really talking about in South Australia everything having to do with shale gas development, storage, transmission and end use. So, my compliments.

I would also note that you are only one of three legislative bodies that I am aware of on the entire planet that decided to do an inquiry into shale gas before any production occurred in

your territory. Again, my compliments. If you are curious to know who the others are, I'll let you know later, but you're in good company.

965 The PRESIDING MEMBER: Thank you.

Prof. INGRAFFEA: Having said wonderful, laudatory complimentary things, I want to go to my second opening comment which perhaps you won't find so delectable. When I was first contacted to give testimony to your committee and I started to investigate the geology, geochemistry and hydrocarbon history of your state, I was frankly astounded. I couldn't figure out why in South-East South Australia you are really seriously considering developing shale gas.

The reason I say that is because, in a way, similar to a couple of states in the United States like Illinois, North Carolina, Maryland, where there might be, but have not yet been confirmed, some shale gas resource, those states in the US have gone to great lengths to go through the entire process multiyear—all kinds of debate, all kinds of legislative gnawing and gnashing of teeth—and when they finally did some investigation they found out there was nothing there.

My second point is, as you know, the negotiations in Paris about climate change are underway right now and the fundamental basis for those negotiations is to decrease the development and use of fossil fuels. With only the possibility of a relatively small shale gas resource in one corner of South Australia, and with the science acknowledging that we need to keep roughly three-quarters of all the undeveloped fossil fuels underground if we are going to meet our climate-change objectives, I'm a little concerned that South Australia has already done its part to produce fossil fuels; you are producing oil and gas in the north-east.

At some point you as a state and you as a legislative body are going to have to decide which of your fossil fuels you are not going to develop. So, I think I have told you already, by implication, that I would hope you do not develop the shale gas fields in the south-east corner of your state for these reasons and other reasons I am about to describe.

The rest of my testimony will be built around your terms of reference, of which there are four, and I will explicitly address each of those. But before I do that I want to make sure we are on the same page about what we are talking about here when we say shale gas development because of all the legislative and regulatory bodies with which I have had interaction very few of them have appreciated the fundamental differences, and there are two of them, the two fundamental differences between developing shale gas and developing conventional gas. So, I want to take a few moments to make sure that you understand what I mean by those two fundamental differences.

One of them is spatial intensity and I will show what that means in a couple of pictures, but here I am using a graphic produced by one of our gas companies, Chesapeake, that tries to depict, in essence, the entire process of getting shale gas out of the ground. What you will notice is that there is a regular grid of pads, roughly three kilometres by 1½ kilometres, and some thousands of metres in south-east South Australia—I suspect 3,000 to 4,000 metres underground—there is a shale layer, and supposedly in that shale layer there is gas, methane.

That shale is effectively impermeable. That's the reason why the oil and gas industry has waited till the very end of its epic to try to get gas and oil out of the ground through shale, because it basically doesn't want to give it up. To give it up, as you can see here, they have to drill a lot of wells, and they have to drill the wells not only vertically but deviated and laterally. When they have done that, this whole process that is depicted in this picture is inherently inefficient.

By that, I mean current data from all the shale gas production in the United States, across all the plays in the United States, shows that a process that is being depicted here with this density of wells produces only 7 to 10 per cent of the gas in place. It's inherently inefficient, and that is why they have to drill so many wells and they have to drill the laterals so close together. So, that is underground spatial intensity and surface spacial intensity.

They also have to use what I call the second fundamental difference, and that's technologies of scale. To get gas out of shale, everything is bigger, longer, more powerful. So let me show you through a series of pictures what I mean by technologies of scale and spatially intense development. I am looking at slide No. 6. I hope you are too. This is a Google Earth image of an area just west of Dallas, Fort Worth, Texas, and this is in the Barnett shale play, the oldest and most mature shale play in the US, where they are currently over 15,000 wells drilled in the last 15 years.

Every one of the white dots that you see in this picture is a pad. I am going to go to the next slide and zoom in, and you will notice that the scale will change from a four-kilometre scale to a one-kilometre scale, and again (I hope you can see my cursor) every one of these white dots, either a small dot or a larger rectangular dot, is a pad.

So, I am sure you are all geographically unchallenged, and you will note that this is an area that is roughly five kilometres by four kilometres, and there are over 60 pads in this area. That is spatial intensity. Why spatial intensity? Because the shales are inherently impermeable; whether it is South Australian shale or Texas shale, it is impermeable, and to get 7 to 10 per cent of the gas out of it you have to beat it to death with many wells.

I am extracting another quote from your interim report, and I want to point out that this quote is inherently incorrect. It says that since multiple wells will be drilled with horizontal segments from one pad there will be reduced overall impact on the landscape compared to coal seam gas. Well, show me reduced impact here. Right now in South-East Australia you have no impact, so any impact is great impact. This is spatially intense impact and it's the only way that any operator can get reasonable production out of a shale play.

I'm going to ask you to use your imagination now and let's go to the South-East corner of South Australia. I suspect some of you have been to the Jolly 1 well. Here it is, here is Penola. You will note that this map I'm showing you right now is to the same scale as this one, so I'm going to ask you to use your imagination and map these 60-plus pads into that area, and ask whether that is spatially intense and whether there is significant area impact. I think the answer to both those questions is yes.

Technologies of scale: I mentioned that getting gas out of shale is difficult. Everything is longer, bigger, higher, deeper. I listed a bunch of aspects of shale gas development to emphasise what I mean by technologies of scale.

Larger drill rigs: you drill not only 2,000 or 3,000 metres down, but you're going to have to turn that well and drill another 2,000 or 3,000 metres laterally. That requires very large drill rigs that we call them triples. Those drill rigs require much more diesel horsepower on the drilling engines than traditional drill rigs. More diesel horsepower, more noise, and more NO_x emissions.

Fracking equipment: the fracking that has occurred in the north-east part of your state is traditional fracking. It uses perhaps a few hundred thousand litres of fracking fluid. To get gas out of shale you will need 20 million litres of fracking fluid per well. You will also need pressures three or four times higher than are currently being used for frack jobs in your state. I'm using English units here in Australia but typically 15,000 pounds per square inch of fluid pressure, so higher fluid volume, higher pressures—you will need 25,000 horsepower pumps.

Because you're pumping 20 million litres of flowback down the well, you're going to get five to 10 to 15 million litres back up the well as flowback. That's waste; it's contaminated fluid, no longer drinkable, no longer able to be put back into the water cycle. So you have to figure out what to do with large volumes of fluid waste from each well, and remember that each well is on a multi-well pad. There are going to be longer and larger flares and venting of methane; more truck traffic to bring water, fracking chemicals, pumps, proppant—10 to 20 times more truck traffic than for conventional wells.

Every one of these pads is connected by a pipeline, so you're going to see a lot of pipeline construction and that disturbs the surface, and more and large compressor stations and processing plants. Compressor stations to increase the pressure from the wells that rapidly deplete—that's another characteristic of shale gas wells that make them different from conventional gas wells. The depletion rate is extremely quick. The pressure drop is extremely quick. That means you need compressor stations to get the gas out of the gathering lines and into your transmission lines. If you develop the gas and it turns out to be wet, you will need processing plants. Throughout this whole process you will have much higher emissions than you would have on conventional well pads because everything is bigger, longer and more powerful.

With that as background—those two fundamental differences—let's address each of your terms of reference. The first one I choose to address is the risks of groundwater contamination. I'm going to take you to the state of Pennsylvania. The state of Pennsylvania overlies the Marcellus

gas play which is the largest shale play in the world. The state of Pennsylvania prides itself on having very tough regulations; regulations that have twice been revised in the last five years.

We published a study in a peer-reviewed journal last year where we attempted to determine how many of those shale gas wells were leaking. That's what we mean here by 'impairment rate'—what percentage of the shale gas wells drilled in Pennsylvania in the Marcellus were known to be leaking within the first five years of their having been drilled. We compared that leak rate in the shale gas wells to the leak rate in the non-shale gas wells and we used the statistics provided to us by the Pennsylvania Department of Environmental Protection—that's the regulatory body in Pennsylvania—and their records show that shale gas wells were showing a leak rate of about 6.2 per cent in the first five years as compared to an overall failure rate in conventional wells of 1 per cent—one in 100 conventional wells and six in 100 shale gas wells.

In some regions of the state where drilling occurred very, very quickly, where operators were totally inexperienced, the failure rate in the wells was almost 10 per cent—one in 10—within the first five years, leaking. If you have leaking gas wells, you have a risk to groundwater contamination.

I am going to show you another map. This is a map of the state of Pennsylvania, and I am going to draw a correlation between the leaking gas wells and the contaminated water wells. This is from an industry presentation to its shareholder group. You will note that the south-western region of Pennsylvania and the north-eastern region of Pennsylvania are the areas where the gas in place has the highest density and where the largest number of shale gas wells have been drilled. Keep that picture in mind.

This is the same state of Pennsylvania and this is a map which colour codes the density of complaints by private landowners of water well contamination. The counties that are coloured here (and that's not all of the counties but it comprises most of the north-eastern region and the south-western region), in those counties there have been over 2,300 complaints of water well contamination from shale gas wells. The colour gives you the density of complaints.

We will visit Bradford County again. There have been over 400 individual complaints from landowners in that county of their water wells being contaminated by shale gas development. In Greene County in the south-western corner there have been over 600 complaints.

A complaint isn't the truth, necessarily. If someone complains that their water well is contaminated doesn't mean it has been, so the Pennsylvania Department of Environmental Protection, as the regulatory body, is legally required to investigate each of these cases, so you can imagine the workload that that regulatory body has had in one state, having drilled 9,000 shale gas wells and received over 2,300 complaints.

Of those 2,300 complaints, 260 of them have been determined by the state to be positive, that is, yes: your water well was contaminated by methane or another hydrocarbon from nearby shale gas development. That's a 10 per cent hit rate, so far. Over 1,000 of those complaints have not yet been investigated. There is just too much of a workload to do it.

Let's go to the next term of reference: the effectiveness of existing legislation and regulation. You provided me with your Petroleum and Geothermal Energy Regulations version 2013. I think those are the most up-to-date: if they aren't, let me know now. I read them thoroughly and then I started doing word searches on them. The first word I searched for was 'shale', and the word 'shale' does not occur in your regulations, nor do the words 'green completions'. I could go on and on. There are many examples in which your regulations are, in my opinion, laissez-faire. They are not explicit with respect to important elements regarding wellbore integrity.

The reason I can say that is that I have read the regulations of virtually every shale gas producing state in the United States and all of the shale gas producing provinces in Canada. I have read those regulations and analysed those regulations, and I can tell you that your regulations are not yet up to snuff, compared to those of peer states and provinces.

I mentioned previously that our state of Pennsylvania, which saw commercial shale gas development in 2007 has twice made major revisions to its regulations to account for the fact that the regulations that were in existence in 2007 were not appropriate for shale gas development. As the regulatory body learns from the mistakes of industry, they revise their regulations.

I am strongly suggesting that, as additional homework for your committee, you do a thorough review of regulations from other regulatory bodies if you have not already done so, and I think you will see what I mean when I say that your current regulations are vague, laissez-faire, written such that the industry is given all the responsibility to interpret things the way they want and the state in this case is left, in my opinion, holding the bag.

I would suggest that you start with the regulations in Pennsylvania. It is the place where we have the largest shale gas development going on in the US and I also suggest that you look at the regulations that were written for New Brunswick, Canada. They do not yet have any shale gas development but they are one of the bodies that I mentioned before that did a very thorough investigation and actually wrote regulations before allowing it. I think you will find stark differences between those two sets of regulations and those for South Australia.

I want to show you some other pictures of what shale gas development looks like. I know some of you have visited other states in Australia to see where some shale gas development is going on, but I am not sure you have seen what it really looks like when it gets going. This is a seven-well pad in Pennsylvania. Here is the pad and there are seven wells here. You will notice that there are a number of retention ponds for both waste and fresh water. You will notice large vegetation removal. These are no longer the small pads that you are used to for conventional oil and gas development. They are large.

Flowback impoundments: I did not see anything at all in your regulations regarding surface containment or underground containment or tank containment or lake containment of flowback. This is a major issue in the United States. It was when it got started in Texas in 2000: it is still a major issue now. Where do you put the waste? Where do you store it temporarily? How do you protect the public from the noxious odours from the waste and from surface spills from transporting and storing the waste?

Flaring: the word 'flare' does occur in your regulations, but it does not say anything about when the flaring has to start, when the flaring has to stop. Flaring for a shale gas well can go on for weeks—not hours, weeks. That is a 200 metre tall flare 120 dB at its base.

I already mentioned compressor stations. Compressor stations have evolved. I didn't see anything at all in your regulations regarding the different types of compressor stations that can be installed. Noise pollution and gaseous emissions from compressor stations are common and are common complaints. If you have wet gas, you're going to need processing plants. Think of them as mini-refineries—again, lots of noise, lots of flares, lots of noxious emissions.

In sum, shale gas development, as it is practised, requires a large number of spatially intense, large, multi-well, clustered pads and significant ancillary infrastructure—pipelines, compressor stations, flowback storage, truck farms, processing units. All that has to be taken into account by regulation.

I want to conclude by pointing out that you've done tremendous homework. Again, I am lauding your committee for the research it has done, but there's more research available, so I'm pointing you here to the largest current database archive of peer reviewed science literature on shale gas. My organisation put this together starting about a year ago. I want to point it out to you. This is a bar graph that shows the publication history of peer reviewed science on shale gas development, actually shale and tight gas development. You will note that in 2009, a few years after things had started in the US, there was a total of six peer-reviewed publications in the entire world—six. What you're seeing now is exponential growth. We're now seeing about one new publication per day.

Fifty per cent of all the published peer-reviewed science on shale gas has been published in the last 1½ years. We didn't know much when we got started in the US. You're in a much better position; you haven't started. I'm a professor and I'm used to giving people assignments, but it would be way above me to give you the assignment of reading all 650 of these papers. But you are now aware of them; you can't duck the issue. The science is now there. You're in a much better position to make informed decisions about what you're going to do with shale gas development and what you're going to put into your regulations if you go ahead with it. You have no excuse for ignorance. Many states in the US went ahead without this knowledge—you can't.

We have taken that database and divided it into 12 categories to make it easier. This is a screenshot which shows all the categories listed on the left. You pick a category and it will show

you every one of the papers, and to the extent that we have the legal right to distribute the paper, you can download it from this website. If we do not have the legal right to distribute it, you can go to your library and get it.

If you do an analysis of some of these subtopics, you will find startlingly clear consensus. These are science papers. If we ask what the science says about health impacts, human health impacts, you can go into that database and you will find that there are 16 peer-reviewed papers, so far only 16 peer-reviewed papers, on health impacts. Of those 16 papers, 87 per cent of them—14—say the health impacts are bad. None of them say the health impacts are good. Thirteen per cent of them say we haven't measured any health impacts.

It is a similar situation on air quality: 92 per cent find negative impact, bad impact on air quality; 8 per cent say no measurable impact on air quality. Water quality impacts: three-quarters of the papers published so far find that there have been bad impacts on water; about one-quarter say no measurable impact. There's a growing consensus, the number of papers is growing, and the consensus is growing, and it's now your responsibility to learn about this and decide what to do about it.

To summarise: again, because of the two fundamental differences between shale gas development and conventional gas development—spatial intensity and technologies of scale—I am making the following four assertions with regard to your terms of reference. The risks of groundwater contamination in your state, if you go ahead with shale gas development, are very high. Why would they not be? What makes you think you're going to be different from Pennsylvania?

Fracking is not the issue with water contamination. Well bore integrity and surface spills are the issue so again, you are wise to make sure that your committee is investigating not just fracking but all aspects, including drilling, wellbore integrity, surface fills, transportation of chemicals, transportation of waste, and the impacts on the landscape. I showed you images and photographs; I showed you maps. They will be considerable. You will be changing the landscape of that part of your state.

The effectiveness of existing legislation and regulation: I think your regs are wholly insufficient in their current state. They do not address the problems and the issues that have occurred in other provinces and other states that have been addressed and revised in much tougher regulations.

I didn't say anything at all at this point about the potential net economic outcomes to the region and the rest of the state, partially because the economics in Australia are different from the economics in the US, but I would point out that in the US the shale gas boom has busted. It's done; it's over. Let me repeat that: the shale gas boom is over in the US. The US will never again produce as much shale gas as it did in 2014. All the major shale gas plays are in decline except for one.

Shale gas is an extension of the fossil fuel era. It is not a 100-year supply. It is not a 50-year supply. In the US, it will wind up being about 10 to 15 years' supply. That's my testimony. I want to thank you once again for allowing me to testify to you. I would be anxious to try to address any questions you have at this point.

966 The PRESIDING MEMBER: Thank you, professor. We appreciate your comprehensive presentation and also overview. We do have some questions from our members. Mr Brokenshire, do you want to start the ball rolling?

967 The Hon. R.L. BROKENSHIRE: Thank you, Chair, and thank you, professor. On one of your slides, professor, you had a photograph of Barnett, Texas, where there were 15,000 wells, and there was a lot of agricultural production still occurring with and around those wells. Are you seeing coexistence or are there problems in production declines, being able to operate the agriculture properly there, and any possible issues regarding livestock and contamination?

Prof. INGRAFFEA: Sometimes the sounds breaks up, and I'm not sure that I heard, but I think you're referring to this slide and impacts on livestock?

968 The Hon. R.L. BROKENSHIRE: Yes, livestock and cropping, cereal cropping, etc. You can clearly see a lot of arable country there and a hell of a lot of wells.

Prof. INGRAFFEA: I'm glad you asked that question. I can point you to a paper that was published just recently addressing exactly that issue, not only in the Barnett play but also in the Bakken play in North Dakota and the Marcellus play in Pennsylvania, that investigated animal health impacts, both direct, because animals need to drink water, and indirect, because of the air impacts, dust impacts and the surface spills. There is now a one-paper database in the open literature that discusses exactly the question you asked.

There are impacts. There is a lot of anecdotal information, certainly in an area like this which is known for not only its farm but its cattle grazing. There is a well-known incident in the Haynesville shale play, which is in Louisiana, in which a few dozen cattle died within a day because they unfortunately drank from a spill, a flowback spill. Flowback, as you know, is salty, and livestock frequently are attracted to salty water, and they drank it and they died. That's anecdotal. There are anecdotal cases in Pennsylvania and North Dakota which are similar—livestock dying.

But the big picture here is yet to be painted. When you see this image I am showing you, and you have all those wells and all the air emissions and all of the possibilities for water contamination—I don't know what to say. I am not an animal health expert. I am not a crop-growing expert. I defer to the veterinarians and the agronomists who are saying that there is a growing concern that this high density of development inside of what was an agricultural area, inside of what was a grazing area, is problematic.

That is another basic problem with shale gas in general: it envelops you. If you look over on the right here, this is a housing development. There are places in Dallas, Fort Worth, where you have multimillion dollar homes with shale gas wells in their backyard and compressor stations across the street. Because of the spatial intensity, the companies drill where they can.

In most jurisdictions in the US, zoning law does not trump oil and gas law. You can have a community that has zoned residential areas, but oil and gas law trumps that. If someone owns the mineral rights—I guess, in Australia, the state owns the mineral rights—if the state decides to put an oil or gas well in the middle of a residential area—I suspect that they wouldn't; in the US they would because the mineral rights are owned by private individuals. That's a long answer to your question, and probably an unsatisfactory one, but I did the best I could.

969 The Hon. J.S.L. DAWKINS: Thank you very much, professor, for your evidence to us this morning. As a bit of a follow-on from the Hon. Mr Brokenshire, I wonder whether you could tell me what the attitude of the farmer organisations in Pennsylvania, North Dakota and perhaps the other states you have described to the shale gas activity—

Prof. INGRAFFEA: I can't hear the question, I'm sorry.

970 The Hon. J.S.L. DAWKINS: Okay, I will repeat it. I wonder whether you could tell me what you know of the attitude of the farmer organisations that exist in Pennsylvania, North Dakota and the other relevant regions to the gas activity, particularly in relation to what the Hon. Mr Brokenshire just asked you. Also, has there been a focus from the agricultural sectors on being able to produce clean, green agricultural products, particularly in exports? If so—

Prof. INGRAFFEA: I'm sorry, I really apologise. I wish I could be there with you, but I only got every third or fourth word. If someone could repeat the question very close to the microphone and loud, I will do my best to answer, but I'm sorry—

971 The Hon. J.S.L. DAWKINS: I do not want to shock you, but I will come even closer. I have never been accused of having a quiet voice. Firstly, about the attitude of farmer organisations in Pennsylvania and North Dakota particularly.

Prof. INGRAFFEA: Sorry, the attitude of?

972 The PRESIDING MEMBER: Farmers and farming organisations.

973 The Hon. J.S.L. DAWKINS: Farming organisations. The groups of farmers who have bodies that represent them. We call them here the National Farmers' Federation or Primary Producers South Australia.

Prof. INGRAFFEA: I think what I am hearing you say is the 'attitude of farmers'?

974 The Hon. J.S.L. DAWKINS: And their peak bodies, the organisations that represent them to government and to politicians.

Prof. INGRAFFEA: I am going to try something. I am going to try to stop sharing my screen and maybe the sound will come through better. Just try it now.

975 The Hon. J.S.L. DAWKINS: Okay, I will try again; I apologise.

Prof. INGRAFFEA: No, you shouldn't apologise; it's my fault because I am not there.

976 The Hon. J.S.L. DAWKINS: Not at all. I suppose I am interested in the attitude of the peak bodies that represent farmers in North Dakota and Pennsylvania in relation to the activity you have described to us, and also if those bodies and individual farmers focus on a clean, green image when marketing their products. And, if so, has there been any impact?

Prof. INGRAFFEA: Okay, I think I'm finally getting it. Let's see if my answer comes close to your question. In the US, as I mentioned before, in general mineral rights are not owned by the state, they're owned by individuals and, in cases like Pennsylvania and Texas that I'm describing here, those individuals very often are farmers.

So, on the one hand you have farmers who might be struggling to make ends meet. Texas has had drought for five years. Pennsylvania farmers are getting very low prices for their dairy. They saw shale gas development as a godsend. It was magic. It was like winning the lottery.

At first, they welcomed shale gas development with open arms. They were all going to become 'shaleionaires'. They were going to get big cheques for free in their mailbox every month. Then, the water started going bad and then the cheques started getting smaller and then the bust happened and the cheques stopped altogether. Many farmers became millionaires overnight, or close to it. Many of them improved their farms, they bought new equipment, improved their stock herds. Many of them sold out and moved to Florida. They said, 'Why do I want to be a farmer anymore? I'm a millionaire.' So, you saw a whole range of responses.

The farming organisations, in general, had been pro shale gas development because they see it as additional income for farms which, in many cases, were struggling. On the other hand, we have a growing organic farming industry in the US and the organic farming industry is uniformly against shale gas development for obvious reasons. They can no longer sell their product. No-one will buy from an organic farm that is surrounded by shale gas wells.

So, we have a complex situation in the US. I suspect it's much different than the situation you have in South Australia. I don't know what you can derive from what I've just said that's helpful, but I'm imagining, since the state owns the resource, if a farmer in South Australia finds that his livestock or his livelihood on that farm is being impacted negatively, then I would think the state would reimburse him for that. That's part of the cost. This isn't pure profit for the state. There are negatives here.

977 The Hon. J.S.L. DAWKINS: Thank you very much for that answer.

Prof. INGRAFFEA: Was that close?

978 The Hon. J.S.L. DAWKINS: Thank you, yes.

979 The Hon. G.A. KANDELAARS: What has been the impact in terms of US energy markets in relation to shale gas? Hasn't it given the US independence in terms of energy sources?

Prof. INGRAFFEA: Again, I can't hear you. I think the clue here is you have to get that microphone right up next to your mouth and shout.

980 The Hon. G.A. KANDELAARS: What has been the impact in the US in terms of energy independence as a result of shale gas?

Prof. INGRAFFEA: What is the impact on energy independence from shale gas? Excellent question. Let me back up a step and say that the US currently consumes 20 million barrels of oil per day. Last year, the US produced nine million barrels of oil, mostly from its shale deposits. That's the new thing: shale oil, not shale gas. I will get to gas in a minute. The huge shale oil deposits in North Dakota and Texas allowed the US to go from roughly six million barrels of production per day to almost 10 million and then it peaked and dropped. It peaked in 2014 and it's on its way down. So,

the US will never be oil energy independent. It never was, it never will be. It can't be. We consume too much and we can't produce enough.

Let's turn to shale gas. Six years ago the US was producing and consuming 23 trillion cubic feet of gas per year. We're now producing and consuming almost 26 trillion cubic feet of gas. We are gas energy independent.

Before the shale gas we were on our way to becoming gas energy dependent. We were starting to import natural gas from the Middle East and from Canada. We no longer do that. So shale gas has made the US gas independent. The US is not energy independent. We are not fossil fuel independent because we will never produce enough oil, but we are gas independent. But, as I pointed out before, the shale gas boom has bust.

We produced 26 trillion cubic feet in 2014. Our Energy Information Administration is predicting that by 2016-17 total production of shale gas will start to decline. Most industry analysts are expecting that we will run out of shale gas at the current rate at which we are producing it, without exporting any of it, in about 10 to 12 years. If we start exporting it, we will be out of it in a much shorter period of time. It's a flash in the pan. I don't know if you use that phrase down there, but here today, gone tomorrow.

981 The PRESIDING MEMBER: We do, mainly to do with gold production. You're talking about the industry having gone bust. Where is shale gas being produced at the moment in the US?

Prof. INGRAFFEA: I mentioned that there is one shale gas play that is increasing, and I'm going to go back and show you where that is. You can see my screen again?

982 The PRESIDING MEMBER: Yes.

Prof. INGRAFFEA: Remember this is Pennsylvania, and this is a colour map which shows the density of gas in place per square mile. This is a billion cubic feet per section, that's a billion cubic feet per square mile surface. You will notice that here we're talking about the Marcellus gas in place, and here we're talking about Devonian and Marcellus and Utica gas in place. So, beneath the Marcellus shale in Pennsylvania, Ohio and West Virginia, there is a Utica shale; it is about another thousand metres down.

Production from the Utica shale is continuing to increase, but it is a small percentage of all the shale gas produced in the US. All of the major shale gas plays—the Marcellus, the Fayetteville, the Haynesville, the Barnett—they're all in decline as of this year. So most of the shale gas is now coming out of the Marcellus, but it's no longer growing: it's now decreasing.

983 The PRESIDING MEMBER: Thank you very much. I think we are going to have to leave it there.

Prof. INGRAFFEA: This picture says a lot more than I talked about. These colours mean everything. The industry talks about 'hot spots', not hot in terms of temperature but hot in terms of the gas in place. This is all the Marcellus, all this blue is Marcellus, but most of Marcellus is useless— 50 billion cubic feet per square mile is nothing, it's uneconomic. Yes, we have a huge play in terms of 20,000 square miles, but only a relatively small section of it is going to produce a lot of gas, and that's characteristic of shale gas.

If you go ahead and start doing exploration wells in the South-East, they will find the same thing. They will find an exploration well where there might be a lot of gas, and they will move one kilometre away and they won't find any or that it will not be economic to produce. Not all shale plays produced are born the same, and there is no such thing as uniform production across a play.

That's what we learned in the US and that's what you should be aware of. It could be that in the South-East you have a few wells that will be gushers, and you will have dozens that won't be economic, or it could be just the opposite; you don't know. You don't know until you drill a lot of wells, but if you drill a lot of wells you had better be prepared for the consequences.

984 The PRESIDING MEMBER: Can I thank you very much for your evidence today. We really appreciate your time. Despite the technical problems, we've really learnt a lot from you today. Thank you very much.

Prof. INGRAFFEA: We got over it. We're good, we got over it. Thank you very much for the opportunity.

[Skype videoconference concluded]



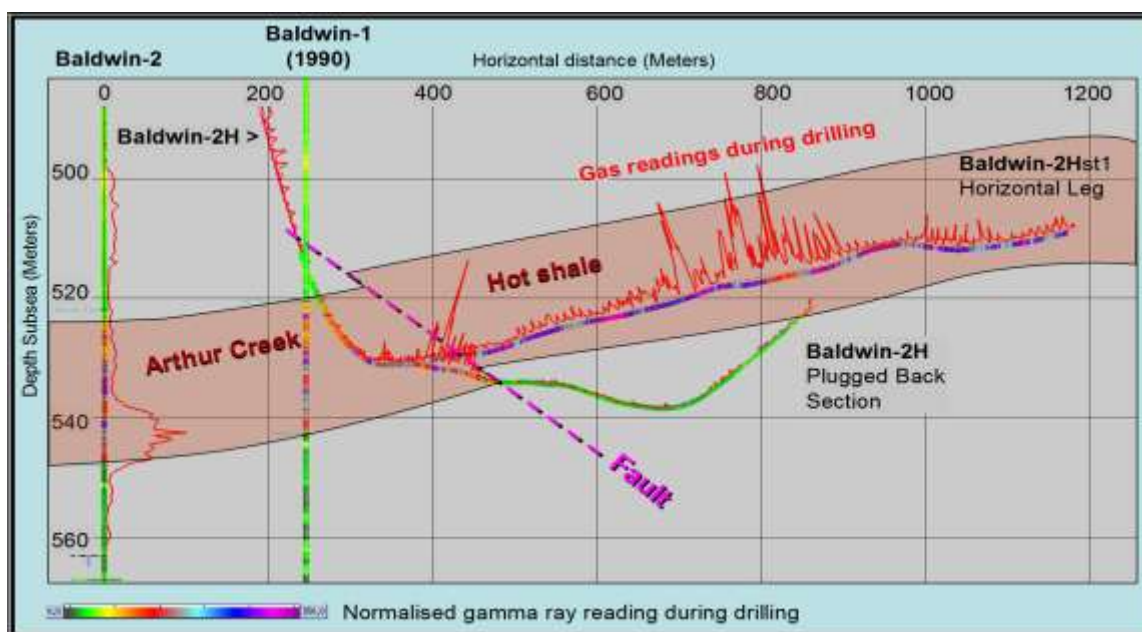
PETROFRONTIER CORP. ANNOUNCES SUCCESSFUL DRILLING OF BALDWIN-2Hst1 HORIZONTAL WELL IN THE GEORGINA BASIN, AUSTRALIA

Calgary, Alberta – October 11, 2011 (TSX-V: PFC) - PetroFrontier Corp. ("PetroFrontier") is pleased to announce that it has successfully drilled Baldwin-2Hst1, Australia's first horizontal well in the Lower Arthur Creek "Hot Shale" Formation in the southern Georgina Basin in the Northern Territory, Australia. Baldwin-2Hst1 is located in the southwestern part of EP 103 in the Southern Georgina Basin. PetroFrontier has a 100% working interest in EP 103 and is the operator. EP 103 covers 3.16 million gross acres and accounts for approximately 27.2% of PetroFrontier's net acreage in the Northern Territory, Australia.

The "Hot Shale" formation is comprised of interbeds of shale, silt, sand and carbonate, is slightly radioactive and is easily identified on gamma ray logging tools. The "Hot Shale" is petroliferous, up to 40 metres thick and extensive in area. The "Hot Shale" is geologically and mechanically analogous to major unconventional oil plays in North America such as the Bakken and Eagleford. These unconventional oil plays require the use of advanced horizontal drilling and completion techniques to be economic.

Baldwin-2Hst1 reached a total measured depth ("MD") of 1,948 metres and remained within the main target zone in the Lower Arthur Creek "Hot Shale" for 875 metres while directionally drilling up a regional dip of 1.7 degrees. Positive hydrocarbon indications were recorded along the entire length of the horizontal section, with elevated gas readings and evidence of heavier hydrocarbons present.

The following diagram is a vertical cross section showing Baldwin-1 (drilled in 1990), Baldwin-2, the successful horizontal leg (Baldwin-2Hst1) and the plugged back horizontal section. Baldwin-2Hst1 was kicked off from Baldwin-2 above the field of view in the plot. The color variation along the well path shows the recorded gamma ray log with green indicating low gamma values (sands or carbonates) and blue indicating high gamma ray values (shale). The red values along the well paths show the variation in total gas values.



Delays in drilling occurred when the bit tracked into the underlying Thorntonian Limestone Formation after encountering an unexpected fault. Every effort was made to redirect the bit upwards back into the Lower Arthur Creek "Hot Shale", but the bends in the hole became too severe for an effective future well completion. The new horizontal section kicked off along the regional dip established by the plugged back portion of the well and was successfully steered through the Lower Arthur Creek "Hot Shale". Total gas recorded in Baldwin-2Hst1 averaged 240 units over the entire horizontal section, commonly peaking above 1,000 units, with maximum recorded values over 2,500 units. The gas recorded contained heavier hydrocarbon fractions up to pentane ("C5") over much of the horizontal section. Conventional gas ratio analysis indicates very wet gas to oil for the most of the well with occasional definite oil signatures in places. However, this interpretation may be biased towards gas due to the nature of the reservoir being intersected.

Following the interpretation of the full suite of logs acquired in the pilot hole, a mechanical earth model was constructed with very positive indications for the ability to fracture stimulate Baldwin-2Hst1. Fractures developed in the vertical plane of the well, transverse to the horizontal well path, are predicted by the model, with excellent containment indicated from the bounding layers both above and below the possible pay zone. In addition, natural fractures were observed. These will assist in the initiation of the stimulation fractures and aid in growing the complexity of the fracture treatment. This should have a positive impact on flow rates.

X-ray diffraction ("XRD") analysis has shown little presence in samples of clay minerals often associated with sensitivity to water-based frac fluids. The XRD results, combined with further confirmation in laboratory sensitivity tests, have given PetroFrontier the confidence to fracture stimulate with water, which is an important factor in keeping the stimulation costs as low as possible.

Although these findings are encouraging, this well remains a high-risk exploration venture and yet to be proven. Readers are cautioned that no reserves or production has been proven by this well.

PetroFrontier plans to suspend Baldwin-2Hst1 and then move Major's TXD-SS2018 rig to the second location in the current program, MacIntyre-2, located in the northeastern corner of EP 127, approximately 60 km to the northwest of the Baldwin location. Once released from Baldwin-2Hst1, the rig is expected to commence drilling MacIntyre-2 in approximately three weeks following minor rig modifications. PetroFrontier has redesigned and re-engineered the MacIntyre-2 well to be drilled as a deviated pilot hole kicking off to a horizontal in the Lower Arthur Creek "Hot Shale". This new well design is expected to result in greater drilling efficiencies and substantial cost savings.

Once MacIntyre-2 has been drilled, PetroFrontier intends to frac and complete the well using multi-stage open hole techniques. Final results will then be released from MacIntyre-2 and the completions crew will return to Baldwin-2Hst1 to conduct a similar completion program there. It has always been PetroFrontier's strategy to frac MacIntyre-2 first and Baldwin-2Hst1 second in to order minimize costs.

PetroFrontier is using Schlumberger, the Australian representative of Packers Plus, to run the multistage open hole completion string and conduct the fracture stimulation program. PetroFrontier is the first company to introduce to Australia these open hole horizontal and multi-stage fracing technologies to unlock unconventional oil potential. These technologies have been widely successful in unlocking North American unconventional oil reservoirs such as the Bakken formation. The use of these technologies is expected to give PetroFrontier every chance of establishing commercial production.

"PetroFrontier's long range exploration planning includes accurately defining the regions of oil and gas maturity within the basin to help target our exploration efforts," stated Paul Bennett, CEO of PetroFrontier. "We believe that within our lands the full range of hydrocarbon

maturation is present and this will allow PetroFrontier the flexibility to chase the best economics for the play, whether it is pure oil or various mixtures of oil and gas.”

About PetroFrontier Corp.

PetroFrontier is an international oil and gas company engaged in the exploration, acquisition and development of both conventional and unconventional petroleum assets in Australia’s Southern Georgina Basin. PetroFrontier’s common shares are listed on the TSX Venture Exchange under the symbol “PFC”. Founded in 2009, PetroFrontier is one of the first companies to undertake exploration in the Southern Georgina Basin in Australia’s Northern Territory. PetroFrontier’s head office is based in Calgary, Alberta and operations office is in Adelaide, South Australia.

Forward-Looking Statements

This press release may contain forward-looking information that involves substantial known and unknown risks and uncertainties, most of which are beyond the control of PetroFrontier, including, without limitation, statements pertaining to management’s future plans, drilling program and operations. All statements included herein, other than statements of historical fact, are forward-looking information and such information involves various risks and uncertainties. There are no reserves, economics or results associated with the well. There can be no assurance that such information will prove to be accurate, and actual results and future events could differ materially from those anticipated in such information. A description of assumptions used to develop such forward-looking information and a description of risk factors that may cause actual results to differ materially from forward-looking information can be found in PetroFrontier’s disclosure documents on the SEDAR website at www.sedar.com. Any forward-looking statements are made as of the date of this release and, other than as required by applicable securities laws, PetroFrontier does not assume any obligation to update or revise them to reflect new events or circumstances. Neither the TSX Venture Exchange nor its Regulation Services Provider (as that term is defined in the policies of the TSX Venture Exchange) accepts responsibility for the adequacy or accuracy of this release.

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