Alice Springs – Dr Matthew Currell

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4 August 2017

Alice Springs Convention Centre, Alice Springs

Speakers: Dr Matthew Currell

Dr Matthew Currell: Yes. My name is Matthew Currell. I'm a lecturer at RMIT University in Melbourne and today I'm appearing at the request of the Environment Defenders Office Northern Territory however all the opinions that I'm expressing here are my own as an independent academic.

Thank you very much for having me here today. It's a pleasure to be able to talk to you about this very important topic of hydraulic fracturing for shale gas and in particular the interactions between shale gas, fracking and ground water. I'm a hydrogeologist by training and I currently work in the environmental engineering department, teaching and researching in that field.

Today I'd like to talk primarily about scientific and technical issues with respect to potential impacts that may occur on ground water systems as a result of hydraulic fracturing and more specifically talk about requirements for baseline data, what a effective baseline data collection and reporting regime might actually look like, talk about a couple of issues that came up in the inquiry's interim report and them also talk about a few new advances in the research world that may be relevant to this inquiry.

I'd just like to quickly pay my respects to the elders past and present of the Uranda people on whose land we make today before getting underway.

First topic today of three topics, the need for baseline data. This was identified by a number of the submissions and community groups that spoke to this inquiry. That's made clear in the interim report and it's good to say that the I guess debate about hydraulic fracturing in everyone's mind is at the forefront there seems to be this discussion of baseline data and that being really an important requirement for any future gas industry.

What is baseline data for unconventional gas development? When you're thinking about protection of land and water resources, particularly aquifers, here is my take on it. Number one, it is preexisting data sets, so for example historic time series of groundwater levels, ground water quality data in aquifers that are above or adjacent to gas deposits. That's one thing. However it is also an understanding of those groundwater systems which allows observe changes in water quality or quantity to be clearly detected ...

firstly, secondly to be clearly explained what is the mechanism, what is the activity that actually caused the observed changed, that caused water quality or quantity to deviate from an established baseline.

Without all of these requirements, a baseline monitoring programme does not meet its objective. You can have historic data, you can have a couple of data points, you can have a time series that's quite extensive. That doesn't necessarily tell you that that data set will allow you to achieve this purpose of determining what exactly has happened in this case, what is the cause of the change in groundwater quality.

I just need to ... Well, I hope that this is the first take home point from me coming here today is that a baseline monitoring programme is more than just collecting some numbers. It's scientific understanding of groundwater systems and their relationship to gas deposits and it's understanding of the water quality changes that may occur as a result of gas development, quality and quantity changes and it's having enough understanding and data to be able to go forward and actually clearly explain observed changes in groundwater conditions in a given aquifer.

Why is that important? Without this proper baseline, it's basically impossible to either detect or resolve the cause of changes to groundwater systems that you see due to gas development and it's likely that should there be some kind of impact or some kind of dispute, for example a bore owner and a gas company begin to argue about a particular impact, it's going to end up in very costly litigation, neither party is probably going to be able to conclusively demonstrate or resolve the matter and that's not a good outcome for any party involved, bad for communities, bad for gas companies.

Everyone's seen news stories about the Condamine River and its bubbling. This is an issue that was in the media for years and years. I think I first saw it maybe in 2011 or 2010 so it's an issue that's been raging in the media, lots of stories that have various levels of scientific information actually informing that debate but very passionate views on both sides about what's causing the bubbling in the Condamine and so on. The inquiry, I'm sure, is aware that the CSIRO's produced a report saying that on the best scientific evidence they have, it's unlikely that this is caused or exacerbated by coal seam gas development. However we had to wait six years to get to that point and some people are still unsatisfied with that finding.

The point of raising this issue is that with a proper baseline data set, with a proper understanding of the Condamine system and its relationship to the underlying coal measures, proper understanding of natural … generation of methane in those aquifers, you don't have to go through that six years of debate, of media, of arguments that are informed by emotion instead of being informed by data, which is what they should be informed by.

Types of baseline data that could be really important in areas of potential shale gas development. This largely comes from the US experience, as the inquiry's identified there's a number of studies and reports that have gone on in the US in shale gas regions to look at issues with surface water and groundwater contamination, so for what a quality key constituents include dissolved or free phase methane and other hydrocarbons. Another thing to look out for is salinity, so basically saline waste water getting into aquifers due to surface spills or lakes of waste water, heavy metals and radionuclides, chemicals used in hydraulic fracturing. Also another one is foreign bacterial communities. Because of the very different microbial communities present deep in shale formations with what we find under the surface, if those are introduced into new aquifers, that can catalyse other biogeochemical changes and affect groundwater quality in indirect ways.

Baseline data sets need to include these analytes and they need to capture existing levels of natural variability in these analytes and they also need to have, as I say, a good understanding of water quality and its relationship to geochemical and hydrological processes in those systems.

Why do we need to monitor for dissolved and free phase methane in aquifers where we're conducting shale gas development? Well, stray gas contamination happens. It's been documented in the US. It is a contaminant that's impacted shallow aquifers. The most likely cause of this is well integrity failures. These studies are very high profile ones in the Marcellus, which have documented stray gas contamination of a number of systems. There's another, we just looked at the Barnett Shale in Texas.

A comprehensive baseline data set for groundwater methane and other hydrocarbons prior to gas development is needed and there's also a need for understanding sources and behaviour of methane in aquifers. Methane's a natural component of many groundwater systems and so there needs to be that understanding of preexisting sources, transport pathways and interaction with water quality generally in those aquifers.

In part this can be achieved by analysing isotopes of methane as well as other isotopic compositions of the water in organic carbon and this can allow for fingerprinting of particular methane sources far more valuable than something like a raw concentration time series which just says methane level but doesn't give you any discrimination as to source of methane, type of methane that you're seeing in the monitoring wells.

Here's an example, sources of methane in groundwater. Methane can be produced by these three predominant mechanisms. Two of them are biogenic or bacterial. Carbonite reduction or acetate fermentation. The other is thermogenic methane, so catalytic breakdown of organic matter under high temperature in gas deposits, natural gas. Each of these different pathways produces isotopes of methane. That's what this ... Just going to ... see if we can try and point those out. That's what these symbols mean here, so they're isotopes of carbon and deuterium within the methane molecule and there are distinctive ranges for these different methanogenesis mechanisms. I distinguish the different methane sources.

For example, a baseline study could look something like this, it could be a collection of groundwater samples in and around aquifers at different depths and locations around the potential targets for gas development and sampling for pre-existing methane, looking at the characterization of existing methane isotopes in that methane to help you get a feel for what are the different sources within those different aquifers and this is data from Victoria. A baseline study in the Gippsland Basin as part of the Biregional Assessment Programme that happened in Victoria.

Here we found three predominant groups of methane in the groundwater. Number one had very depleted, unusually depleted isotopes of carbon and hydrogen. There was a second group that fitted more within the classic biogenic bacterial methane range, isotopically speaking. And then there was one sample that was an outlier that plotted well outside the range for bacterial methane and which we put down to potentially being related to a stray gas source, there's a lot of natural gas distribution in transport infrastructure at the surface in Gippsland due to the offshore gas operations there and so this may have represented a minor leakage from one of those distribution structures.

And these are the types of outputs you can produce with collecting baseline data of this kind. This is just a map of the Gippsland Basin. Each point on there is a measurement of methane in groundwater ranging from almost below detection right up to maximum solubility of 30 milligrammes per litre in groundwater. Where there are two symbols that means we looked at nested monitoring sites. A very important aspect of characterising an aquifer system is looking at different depths as well as just lateral distribution of concentrations and so we were able to come up with some nice data such as the relationship between depth in the aquifer system and dissolved methane concentrations, depth also and methane isotopes in the groundwater and then a nice map showing different regions. We can almost colour code where the classic bacterial methane seems to predominate versus this more unusual source that's in the blue which seems to be associated with a shallower lignite and coal deposits in the Latrobe Valley region in Gippsland. Just as an illustrative example of how a baseline data set that's well-planned and uses good indicators like this can actually give you real value.

Okay, so as I said, time series of methane alone in groundwater may be inconclusive. Methane levels tend to vary naturally in groundwater regardless of the mechanism or the source in the aquifer. It's quite a dynamic and sensitive parameter. Mists of sampling and measuring for methane and groundwater are not straightforward. It's quite difficult to sample for effectively in the field and there are a number of competing methods that can be used to actually get a methane measurement for groundwater and so additional data is needed. I think the isotopic data is valuable as well as that sound understanding of what's actually happening geochemically, biogenically within your aquifers.

Here's just an example from the Groundwater Protection Council in the US. This is their paper on stray gas from a few years back. These are all data from the same well which show measurements of methane level. You can see that they've used three different methods and compared all three at each time step and you can see that depending which method you use, you get a very different results and even regardless, if you're using one consistent method, you'll get quite significant variation from almost non-detected in some case right up to high levels, 10 milligrammes per litre just in one well. Again, underscoring, baseline data sets need to be pretty comprehensive and a lot of thought and a lot of work needs to go into them to make sure they actually can do their job down the track. If someone asks, "Why am I seeing this particular water quality characteristic in my well?", you're going to have to be able to explain the geochemical changes in that groundwater in the context of significant existing natural variability.

Baseline data in areas of gas development, there are precedents, there are examples of this being done, there's the work that Southern Cross University did up in the Northern Rivers in New South Wales, there's the CSIRO's Biregional Assessment Programme, there's the Victoria Water Science studies, which is what I was partnering with when doing that work that I've just presented, the isotopic work in the Gippsland Basin. It's not something that you have to sort of plan from scratch, reinvent the wheel. It can be done. It does cost money and it does take time and it's an upfront cost and it's an upfront delay to development projects.

However it's my view that this sort of work can have a huge saving in terms of time and money in the future. If you end up having disputes, if communities feel like they think there's an impact, something's happening to the groundwater system but it can't be conclusively proven because the baseline data set wasn't done properly, you just end up with conflict, endless argument, outcomes that are based on emotion, not based on data, not based on science.

Topic number two. Just want to quickly talk about well integrity failures. This is a topic that was in the interim report that was addressed and I thought it would be worth talking about reconciling the different rates of well failure that seem to be coming out from different sources. We go across orders of magnitude in terms of the rights of well failures that seem to be reported by different sources, different studies. APPEA in their submission to this inquiry have argued that well failures resulting in serious leaks, fluid and gas migration are a rare event. A tenth of percent of wells or something like that and with best practises as low as much lower than a tenth of a percent. That's largely based on a paper by King and King that's what they refer to in their submission, and they define different types of failure, so single barrier failure being one part of the well failing versus a total well failure where all barriers fail within the well.

Now, something I didn't see in the inquiry's interim report, which would've been nice to see, was some follow up studies, further studies have been done in the academic literature. …..have considered this difference in definition. They looked at barrier versus integrity failure, they looked at all different types of failure and they reviewed a huge number of data points in a large number of data sets from around the world, all within the category of being onshore gas, so including conventional and unconventional. Got some hard copies here if we need to revert to that.

Hon. Justice Rachel Pepper: That's all right. If we need to take a short break while we fix this out, we will do so.

Dr Matthew Currell: Yeah, great, yep, I've got copies, enough copies for everyone.

Hon. Justice Rachel Pepper: Great, excellent. Please continue, thank you.

Dr Matthew Currell: Great. The Davies et al study ... It seemed to me reading, my interpretation of the inquiry's report was that perhaps this difference in definition of a total failure versus a barrier failure might in itself explain why you get such different rates of failure reported in different sources. I'm not sure that that's the case. The Davies et al study looked at this definitional difference and it looked at a large data set of wells, much larger than what was examined in the King and King study.

They found that the failure rate for unconventional gas wells, where there's reasonable data, which still is basically confined to Pennsylvania, Marcellus Shale, where we've got enough wells to actually say something concrete, failure rate involving detected leakage of gas at the surface on the order of 1% to 5% of wells. These rates seem to be pretty typical for most onshore oil and gas operations. There are a number of factors that make it more or less likely that wells will fail.

A key issue perhaps irrespective of those definitional nuances is really whether a well failure actually leads to leakage of gas or other fluids between aquifers or to the surface. The Davies et al data had this to say on that, basically a bunch of different figures derived from the database of wells in Pennsylvania for the Marcellus Shale, a few different authors reporting different rates of failure but ultimately they concluded something like 2.5% of wells had some sort of problem and that this was either a cementing or casing failure and that measurable concentrations of gas were present at the surface for most wells with those failures or violations.

To my mind that's probably the most up to date study of well integrity as an issue. Probably something the inquiry might want to look at. They produced an inventory just looking worldwide at failure rates from different types of operations so ranging from on the order of about 2% of wells up to 75% of wells depending on the type. Note that this includes any type of failure, a barrier or an integrity failure. Doesn't necessarily mean the whole well has failed entirely but there does seem to be an age-failure rate correlation here. These wells up here, the oldest onshore oil and gas wells in the world in California up to 100 years old, failure rate's much higher than for say Pennsylvania's shale gas wells which are at this end of the scale and there's an argument that the relatively low failure rates in those unconventional gas wells may in fact be a function of well age, or at least that age is not an unimportant factor in determining how many of these wells are going to fail over the long term.

Looking at abandoned and legacy wells as well as wells that have been in the system for a long time and looking at the full lifecycle of a well is obviously an extremely important consideration I think.

Implications of this, I'm just quoting from the inquiry's own interim report here, I've seen in chapter seven, it said that it's possible for fluid, liquid or gas to move into an aquifer through defects or deficiencies in the production well casing or the cement however as discussed in chapter five, the likelihood of this occurring is low, assuming wells are constructed to current best practise standards.

My interpretation of that is that the inquiry may have formed a somewhat premature view on that issue. I think it's worth looking at a range of sources before making a clear judgement that that risk is something that's going to be low in the future. I think it's worth knowing that an oil and gas operation never wants its wells to fail. It's always going to construct them to high standards with a high level of care and integrity. While it's great that there may be aspiration on the part of the industry to do things better and better and improve and reduce those rates of well integrity, as a scientist who worked with data and the best data that we have at the moment tells us that we have failure rates that are on the orders of percentages of wells rather than sub tenth of percent of wells.

The other issue here is that fugitive gas contamination due to well integrity failures isn't actually listed as one of the primary risks to water quality, in chapter 7.4 of the inquiry's report. My view would be that the inquiry should look at this and that baseline data collection should actually focus on that issue as well as looking at the other stuff, surface spills, waste water and so forth.

And implications, downplaying the incidents or risk of well integrity issues could have a lot of future implication. It could end up with similar situations to some of the early developments in the US where you had stray gas impacts that went unnoticed for a long time, got to the stage where they caused significant issues with landowners, pumps and bores and so forth. Again, it's not necessarily very easy to detect stray gas contamination incidents and even more difficult to conclusively link them to a source or a mechanism. Without a really robust monitoring programme and baseline data sets it's not going to be possible here either and we're going to end up in that vacuum of uncertainty where people get hot around the collar, they get passionate, they don't have the data to actually resolve the issue properly.

Another thing that came out of that Davies paper which may be worth bringing to the inquiry's attention is just looking at the data base of environmental violations in the Marcellus Shale, it appears from that study that in Pennsylvania there's a fairly robust regime for actually checking compliance and looking for environmental violations. That would seem to be the case based on the data we have that's sorted in Davies so there they found that there have been over 1000 environmental violations between that period, 2008 and 2011, something on the order of about 20% of wells. Some of these thousand were repeat violations at the same site, the same well.

It should be noted, most of those are minor environmental impacts. There haven't been, in the majority of cases, not a huge impact that causes irreversible contamination or damage to an aquifer but I think it's a good contextual number, just to give an idea of the fact that when you're starting developing shale gas intensively in a region, there are many things that can go wrong and they do go wrong. Things spill, they malfunction, they fail in the field and without a really good compliance and monitoring regime to actually look at that, this sort of number of incidents may happen and they may go unnoticed and undetected, and it's usually when incidents are unnoticed and undetected that they start having a bad impact on the environment. If they're picked up quickly, usually that could be resolved quickly.

The pie chart here just shows what mechanism those environmental violations relate to. About 10% are related to well integrity. The biggest categories, perhaps as the inquiry may have already picked up, are related to waste water, so surface water spills, land contamination with fluids stored inappropriately onsite and so forth.

It does underscore how common environmental contamination incidents are in areas of shale gas development. We shouldn't go in with our head in the sand thinking that yeah, stuff's just not going to happen, it's going to be a perfectly clean industry. It's more about preparing for the industry so that its impact, which is inevitable, is minimised and it's not going to lead to really negative impacts that people don't want to see happen.

Last topic today, behaviour of methane in groundwater. I just thought I'd draw the inquiry's attention to some really interesting new research that's come out. This is a Canadian group in the US, one of the leading groups on contaminant transport. You can see John Terry's name in there, sort of the grandfather of contaminant transport research. This came out in Nature Geosciences earlier in this year and it is the results of some experimental work looking at the behaviour of methane in groundwater. Basically the impacts, I think the inquiry's probably on top of this but methane can cause explosions, pump failures and can also cause associated geochemical and microbiological changes to water if it's released into an aquifer. It's also a potent greenhouse gas.

Understanding methane occurrence, its transport and its movement in sedimentary basins that contain groundwater and contain hydrocarbons, is really important regardless of unconventional gas activity but even more so when you're starting to drill gas wells and bring gas to the surface.

I think this is the best insight yet into methane's behaviour in groundwater due to potential natural gas related leakage. It was an experimental piece of work that was done on the Borden site, so again, that's a really well-characterized hydrogeological site that all hydrogeology experts are comfortable with, familiar with, they know the results that have come out of Borden over the years and so it's a fairly heavily instrumented site. They've got a huge number of wells, very tightly spaced, many, many different depths are monitored within the groundwater system.

Basically what this group did, they injected methane under very carefully controlled experimental conditions, it was a 72 day experiment and it was designed to replicate reported surface casing vent flows, so leakage out of a failing well, into a gas well if it hand casing problems. Hypothetical, if we've got a gas well that's leaking into a shallow aquifer, if it puts out this much methane, based on reported rights of leakage, how is that methane going to behave in the aquifer?

What they found, even in quite well-constrained settings, they've a very good handle on the hydrogeology of the site, however the methane behaved in somewhat unpredictable ways and was somewhat unexpected ways in the aquifer. In particular was switching between being a free phase gas, so bubbling gas within a separate phase from the water and dissolved methane, actually dissolved within the water itself, and it would periodically switch between those two and it became quite difficult to explain why and when this would occur, so underscoring the need, if we're looking at methane in groundwater as a baseline monitoring criteria, look at both the dissolved gas and the free phase gas because there's a relationship between the two that's important.

They found that the highest concentrations and highest extent of dissolved methane was actually many days after the gas injection ceased, so more than 100 days and that significant concentrations were still in there after nearly ... getting on the best part of a year and the presence of methane in the ground water also led to a range of indirect water quality changes, in particular increasing the concentrations of trace metals in the ground water and other cations near the injection zone. That's just a ground probing radar image of the methane plume at a particular time step as it's making its way through the aquifer during the experiment.

Some data from the study itself, just looking at levels of methane at different depths in the aquifer, at different times and sort of having the pre-injection period and then the injection and then post-injection period, so show how things behaved. The methane behaved in some predictable ways and that could explain some of the observations but it was tricky and this is a very well-characterized site. For sites where we may be developing shale gas, say in the Northern Territory, and would want to get a handle on whether methane's behaving a certain way in the groundwater. There's no way you're going to have a monitoring network that's anywhere near as dense or as comprehensive as this site, so being mindful that your baseline data set really needs to include also that understanding of the system is what's going to give you a chance of actually being able to explain and firstly detect and then characterise what's going on in a setting like this that's relatively unconstrained.

They looked at flux to the atmosphere as well. They found significant surface flux. This was an unconfined aquifer, you had methane coming out of the ground throughout the experiment and it was also venting off the groundwater, so coming out of the groundwater basically volatilizing as a free phase and coming off at various stages through the trial. Last thing they looked at was microbial community changes. They looked at bacterial DNA and how that might have changed during those days of experiment. They found that the bacterial communities, as they were injecting methane into the aquifer, were significantly changing in their composition and certain communities were outcompeting others throughout the experiment. All important implications.

Release of methane into an aquifer can have significant impacts on water quality and biogeochemistry of the groundwater not just in terms of giving methane, which is an explosion and pump failure risk. It can also cause changes to the dissolved water constituents in the aquifer. The impact of an episodic methane leakage, so if something happens for a while then they plug the leak on a well and the well integrity is restored, for example, there can still be residual impacts that occur for many many days and months after the fact, and characterization of the changes that might occur does require pretty extensive monitoring networks and a range of complementary parameters to monitor. As with all good hydrogeology, exploring multiple lines of evidence.

Again, just the last point reiterating the first point, rigorous baseline monitoring, comprehensive monitoring programmes are going to be needed in areas of gas development in case of these toxic impacts materialising and it's all about trying to explain and resolve the causes of things. Ideally we minimise conflict and we stop people going to court and all that sort of stuff, arguing about things in the absence of knowledge and information and good data. References from the presentation here, so everything I've cited there's in the references here. Happy to share that presentation. You've got it now obviously.

Hon. Justice Rachel Pepper: Please do. That was a most excellent presentation. Thank you very, very much.

Dr Matthew Currell: Our pleasure.

Hon. Justice

Rachel Pepper: We're very, very grateful. Yes, have a copy of that would be very appreciated. Electronically.

Dr Matthew Currell: Yeah, no worries. I'll leave some hard copies too.

Hon. Justice Rachel Pepper: Excellent, no, thank you. We all already had requests, see the side of me, for hard copies. That's fantastic. Just a question, and I'm not a scientist so just bare that in mind when I ask this, but the baseline data that you have quite rightly identified needs to be obtained. Can that be obtained between exploration and production, assuming that gap might be somewhere between three to five years?

Dr Matthew Currell: Look, the scientific answer is it doesn't matter when it's collected. It needs to be collected well before you engage in any activity that might cause a change in the chemistry of the groundwater. In terms of regulatory regime that might apply in the Northern Territory-

Hon. Justice Rachel Pepper: No, I'm not so much asking of that because of course one of things that the gas companies have told us and will continue to tell us is, "We can get all this data, we can start exploration now, we can get all this data and then assuming we're satisfied with the data then we can start product."

Dr Matthew Currell: Well, the only issue with that argument is that impacts can also occur during exploration and often, in fact, in that early stage when those first wells are being sent down and nobody's got any experience drilling in the aquifer, it's probably the highest risk phase, so it'd be, probably to me as the scientist, I'd be saying, "Well, let's get some baseline data before we start drilling any wells, whether they be exploration or production wells because we need to be able to get a handle on what happens in the first instance." Yeah.

Hon. Justice Rachel Pepper: Oh, thank you, yes, I'm sure there are other questions. Yes, Dr. Jones.

Dr David Jones: Well, certainly, yes, we can't underemphasize enough the issue of monitoring wells and this, I guess, came up last week as well when you visited the CSG fields in Queensland.

Dr Matthew Currell: Right, yeah.

Dr David Jones: You'd be very much aware of the lateral extensions of those fields, the lateral extent of the groundwater model and how it's being used there.

Dr Matthew Currell: Yeah.

Dr David Jones: I guess one of the key issues there was that they have something like 600 wells they use to monitor pressure levels but if you're talking about geochemical type of changes then in my impression that was nowhere near enough the density of monitoring wells there to actually pick up any developing groundwater plumes. In the case of the industry we're talking about here, it is different in many respects in the sense that you're proposing multi-well pads with say an array of I think up to 16 well heads and one pad with multiple laterals.

Dr Matthew Currell: Sure.

Dr David Jones: Now, in my mind that kind of array lends itself much better to the kind of implementation of monitoring systems that you're talking about.

Dr Matthew Currell: Yes, I think so. Obviously the gas industry can speak best to the density and the layout of a gas field for different settings. Certainly there's been an issue in Queensland with the coal seam gas fields with the extent and the number of wells and the footprint and just being very difficult to get enough monitoring wells to actually cover all potential.

Dr David Jones: Of course baseline there wasn't got before they started.

Dr Matthew Currell: No, that's right. And you see it in terms of court cases. I get lawyers calling me up on the phone, "Can you be an expert witness because we've got a landowner that is in dispute with a gas company?" I always ask them, "Is there any data?" I mean what am I going to do other than stand up there and say, "Yes, mechanism A, B and C are all plausible. If we don't have the data, we can't say which."

Hon. Justice Rachel Pepper: Is this where a reversal of the onus of proof would assist? If a land owner does come along and say, "Oh, look, I've noticed some changes in both quantity and quality of the groundwater" and provided there's a reasonable basis for that belief then the onus is then placed on the particular company in question to prove otherwise. Or disprove.

Dr Matthew Currell: I think that would be a strong incentive for companies to really invest upfront and strongly based on monitoring.

Hon. Justice Rachel Pepper: Yeah, it does have that effect. Quite right.

Dr David Jones: Just the other thing about well integrity, it's quite a vexatious issue and just trying to get our heads around what these different analyses mean is important and I think one of the metrics you used there was monitoring surface methane. Now, yes, that is one metric but in terms of a well failure, that could be an internal pressure issue rather than it being a lateral barrier failure into an aquifer.

Dr Matthew Currell: Could be, yeah.

Dr David Jones: For us trying to tease out the analyses from these reports without going through the entire data set ourselves is quite difficult.

Dr Matthew Currell: Yeah. The only advice I could offer to the inquiry would be to check the sources themselves. If AP had put forward in a submission that this is a rate, I went straight to the sources they used to get those rates. We found it. One of them was a conference paper in the Society of Petroleum Engineers-

Dr David Jones: I've seen both of those papers.

Dr Matthew Currell: There's a range of references out there and I know you've got a huge job as an inquiry to try and get your head around a huge amount of data and information but it is worth digging into the literature on well failure.

Dr David Jones: I'm a water person, work quality water management, not a hydrogeologist but I know probably enough about it to be dangerous.

Dr Matthew Currell: Sure.

Dr David Jones: The issue that most people are concerned about is our groundwater resource going to be contaminated, and I think that's where this issue of well integrity can, despite the best intents of some studies that are done, it can actually give a bit of a misleading picture either way, in terms of us trying to assess the risk.

Dr Matthew Currell: Yeah, look, as I talked about it in the presentation, primarily the risk I was talking to is that of stray gas. Stray gas can go to the surface, it can also go into an aquifer. There's enough cases in the US where shale gas has lead to stray gas.

Dr David Jones: I think in this particular environment, which is one thing actually …. on our side for having a true baseline is that so many of these fields would've been so compromised by in the past by a whole host of other petroleum extraction activity so trying to establish cause and effect with methane and .. can be really difficult because it's really been difficult whereas at least here we do have what's truly a Greenfield sign.

Dr Matthew Currell: Yeah.

Hon. Justice Rachel Pepper: Look, we're certainly aware that much more work needs to be done on well integrity and demystifying and unpacking what is meant by failure, what is meant by ... It's not, as you've quite rightly pointed out, there are different definitions, there are different conceptions, there are different studies, there are different rates. I mean even in the one instances of a well blow out in the Northern Territory can the causes of that are a dispute and indeed I think we've described it as a well blow out at page 27 in the interim report. We've had a submission from the particular department involved that said, "No no, it wasn't a well blow out at all. In fact you've mischaracterized it."

Dr David Jones: It's a casing failure under pressure.

Hon. Justice Rachel Pepper: Yeah, quite. Sorry, Dr. Andersen.

Dr Alan Andersen: Yeah, thanks, Dr. Currell. It was a fabulous presentation and I just want to ask a couple of followup questions about the issue of likelihood of well integrity failure. One of them was touched on in the sense of you provided some figures on proportion of wells that had some sort of surface gas leakage. I forget, under 5% or something like that. I'm sorry, my question is, and obviously I appreciate you can't give me quantitative answer but just your thoughts. What proportion of those wells where there is a gas leakage would represent a substantial contamination risk to the aquifer? Can you comment on ... And then I've got a followup question from there.

Dr Matthew Currell: Yeah. I really don't think that the data, even in that review, the Davies review, which is the best source I could find, that it would give you a breakdown. All that it's saying that when there's a cementing failure or a casing failure generally you're going to get leakage at the surface but how many of those lead to a leakage somewhere along the-

Dr Alan Andersen: Obviously something we're grappling with is distinguishing between a ... you can detect a leak from a significant issue.

Dr Matthew Currell: If it's a cementing failure and it's related to the annular space between the bore hull and the rock itself then there is a significant likelihood that you could have gas going up the walls and getting cross-contaminating aquifers. The annular seal's very important there.

Dr Alan Andersen: Followup question is what are your thoughts on what could be deemed a low likelihood? What figure would you be comfortable with and say, "Well, that likelihood is low" or not?

Dr Matthew Currell: Well, to me, if you're looking at size of gas developments, a number of shale gas wells, and you're saying that the chances are you're going to have one or less of those wells causing a problem in a gas field then I'd call that a low likelihood. If you're looking at a shale gas field and it's got X number of wells and you're saying, "Probably more than one of those wells is going to have a problem based on best estimates" then I'd say that's not a low risk anymore.

Dr Alan Andersen: So it's more an absolute number than a likelihood or relative number, is what you're saying.

Dr Matthew Currell: Well, no. As I say, based on the size of the gas field. If you're only drilling three wells, it's a very different proposition to if you're drilling 300.

Hon. Justice Rachel Pepper: If you're only drilling three wells and one of them fails, it's a 30% failure rate. That's pretty high. You're effectively saying that the larger the gas field, the smaller the number of wells. Again, I emphasise, I'm no scientist. I'm about to venture into territory that's probably dangerous for me but the larger the gas field, the lower number of the wells that failed, that risk is going to decrease.

Dr Matthew Currell: Yeah, it's the multiplication of the rate. How many wells generally might fail times the number of wells you're going to drill will give you ...

Dr Alan Andersen: Which is the absolute number

Dr Matthew Currell: An absolute number as you say.

Hon. Justice Rachel Pepper: Yes, Dr. Beck.

Dr Vaughan Beck AM: Dr. Currell, thank you very much for your very comprehensive presentation. It's excellent to see all the data presented that you have there. Just following on from the previous question which was from beyond the issue of incidents to consequences and I think you indicated, it is difficult from the Davies paper to try to get any indication of consequences. A question, are you aware of any papers that do try to articulate consequences? Is the first question. The second question is that consequences are a function of time and it's also important to realise that if there is a failure, how quickly is it detected and remedial action taken because that is a major factor in determining the consequence?

There's some important pieces of information that we would like to have, we don't have and if you can provide any insights then that would be particularly helpful because quoting failure rates is one thing but trying to articulate consequences or remedial action is a very important further action because if we're talking about risk then we need to be able to quantify that second phase, not only the first phase. Which is the incidents.

Dr Matthew Currell: Yeah. Look, I can't enlighten the inquiry too much more on that issue. The only thing I can say is that obviously the chances that you're going to detect incidents and therefore lower the consequences are going to be entirely dependent on the monitoring and compliance regime. If it's a really robust regime, and there are different examples. The US is a good case study because every state does things differently, and they like that. There are states that do things one way and states that do it other way.

Dr Matthew Currell: It can somewhat, yeah.

Dr Vaughan Beck AM: You continue to answer the followup question.

Dr Matthew Currell: Yeah, I think just looking at some of that literature coming out of the Groundwater Protection Council, the US EPA, various regulatory bodies that have looked at different states in the US, there's a factor there which is how much compliance checking is there, how much monitoring is there, which can then be an important input into thinking about how can we lower consequence by quickly detecting ...

Dr Vaughan Beck AM: I've got a number of questions. I'll try and get through them quickly.

Dr Matthew Currell: Sure.

Dr Vaughan Beck AM: Are you able to articulate any of those regulatory regimes that you consider to be leading practise?

Hon. Justice Rachel Pepper: You stole my question.

Dr Vaughan Beck AM: Okay. And a second question is that there's been a major study recently completed by the US EPA on groundwater contamination. I didn't see that being quoted there and I'd just like to get your observations on that particular reference given that it was a very major study.

Dr Matthew Currell: Yes. In terms of best practise monitoring regimes, again, I'm stretching my field, I'm a hydrogeologist, technical person, science, engineering. I've heard people say that Alberta, Canada's a good example to look at. I don't know how true those claims are but certainly worth the inquiry looking into it if you haven't.

Dr Vaughan Beck AM: Mm-hmm (affirmative). We are.

Dr Matthew Currell: Yeah, good. I think for unconventional gas it's probably important to look at what's being done in Pennsylvania because that's where shale gas has been happening most intensively and for the period of time in the US and there are a couple of references looking into that Davies study and other work that's related, that actually look at how often do things go wrong in unconventional gas and shale gas and how do they get detected and what's the reporting requirements and so on. I think Pennsylvania and Alberta are good starting points.

Dr Vaughan Beck AM: Thank you for that.

Dr Matthew Currell: In terms of the US EPA study, the five year study, yes, I certainly refer to that in my written submission to the inquiry. It had a lot to say about waste water spills, which I didn't have time to talk about today but I talk about that a fair bit in my submission. There's a spills database that's being compiled now in the US which has got a record of something like 10,000 or more incidents across the country, so starting to get a handle on how frequent a spill of waste water is when you're hydraulically fracturing wells.

I think the US EPA's initial figure was something like between 1% and 10% of all unconventional gas wells have some kind of spill, be it from a tiny spill to a major one. I think it's a pretty comprehensive review, looks at water quantity issues as well as quality. It's balanced. I sort of laughed when the media stories about it started coming out, how anti-gas groups were saying, "Yes, this report indicates everything we've said" and then-

Dr David Jones: Selective quoting.

Dr Matthew Currell: ... so did the gas industry, they came out and said, "It indicates everything we've said" and if you read the report you can kind of cherry pick the part that suits your view. That's just because it's looked at all angles.

Dr Vaughan Beck AM: Okay. You're then saying that's a very good report and should be considered and it's in your written submission which is excellent, thank you for that. I got two I think fairly minor questions. One is that you've had a graph of, I think it was effectively failure rate against age and you said you could conclude from that the age of the well is a particularly important factor. I don't know whether you also mentioned that there's been an evolution of standards over that time period and-

Dr Matthew Currell: That's true.

Dr Vaughan Beck AM: ... standards would be a perhaps equally if not more important factor than simply age.

Dr Matthew Currell: Yeah, entirely true. Yeah, there are two factors. It's not a simple linear relationship but yeah, I'd agree with that.

Dr Vaughan Beck AM: Good, thank you. You also made reference to Atkinson 2015. I think that was the University of Southern Cross study, is that right?

Dr Matthew Currell: That's right, yeah.

Dr Vaughan Beck AM: You did reference, I don't know whether it was that one but earlier one that the University of Southern Cross conducted was highly contentious study because it was drive-by study and found it difficult to really make any definitive conclusions and I just want to get your response to that because there's a large amount of contention around that particular study.

Dr Matthew Currell: Yes, so the study you're referring to was by Damien…. and colleagues which came out a little bit earlier.

Dr Vaughan Beck AM: Right.

Dr Matthew Currell: You're right. They were using a portable isotope mass spectrometer to look at methane around gas fields. They did actually publish that work a couple of years ago in a journal and it was all peer-reviewed and got through. I think that the controversy of that work is perhaps a little bit overstated. I think it's a useful data set. I don't think anyone can argue that it's not useful data in terms of whether it represents a certain level of impact or not. That debate's ongoing.

The Atkins study that I mentioned was actually at the same university department, that's a Ph.D study. I was lucky enough to examine that Ph.D recently so I just saw that it was a really nice study where they've gone through over three years and sampled as many surface and groundwater sites as they could, characterised the geochemistry and the methane in groundwater and surface water and then tried to explain that in terms of geological and natural anthropogenic factors.

Dr Vaughan Beck AM: Thank you for clarifying. That's good. Okay, thank you.

Hon. Justice Rachel Pepper: Yes, Dr. Andersen.

Dr Alan Andersen: Discussion of well integrity is focused on issues during the operation phase. I just wanted to ask a question about longer term because people will be concerned, obviously, that yes, one can guarantee that things are safe within the 20 or 40 or 50 year time frame but what happens in 500 years, 1,000 years. My question to you is if there were a breach of well integrity in 500 years' time, after well's been decommissioned, what would the consequences in the worst case scenario? What would be the consequences for an aquifer?

Dr Matthew Currell: That's a good question. That would largely depend upon what was the residual pressure in the gas reservoir. If there's not much residual pressure, not much residual gas there then your impact is going to be relatively minor. If there is residual pressure, residual fluid and gas that is able to come up the well and there's a conduit there then it could be a serious impact. That's a question probably a petroleum engineer needs to speak to that one to talk about what sorts of pressures are you normally left with when you shut off a gas well and walk away and are those pressures still something that's a risk of making it up the well annulus if it fails.

Dr Alan Andersen: And presumably that can be quantified that pressure's necessary to pose a risk?

Dr David Jones: The other thing in terms of residual pressure is that, and this could be a bit of a worry that rather than letting a well go to its lifetime completion completely depressurized that the economics changes and these wells are so-called shut in because there you could actually have a significant residual pressure. That's what actually just occurred to me.

Dr Matthew Currell: Yeah. The other thing, I mean any abandoned bore, whether it's a gas bore or any sort of bore, it is a groundwater contamination risk from the other direction. If it's a direct conduit down to the subsurface and there's a break in the annulus space or the casing, contaminants can go down the side of the well and into an aquifer as well as coming up from a deeper reservoir. It's a big issue.

The other big area that I work in, and forgive me for going on a slight tangent, but I do a lot of work in China and in the North China Plane on groundwater sustainability there and the recent data we've been finding is that they've got a huge, huge issue now with well integrity. They've drilled over four million wells for groundwater production. Most of those wells are not properly sealed or cemented and now they're finding that nitrates from the agriculture at the surface appearing in these supposedly pristine deep aquifers with otherwise very fresh water, and it must be because of this well integrity issue that it's starting to have all this bypass flow of surface material down to deeper aquifers. It's not a trivial issue.

Dr Vaughan Beck AM: Can I just ask, is there a paper written on that particular mechanism?

Dr Matthew Currell: There is, yeah.

Dr Vaughan Beck AM: Can you provide that reference then as well?

Dr Matthew Currell: Yes, be happy to. Yeah.

Hon. Justice Rachel Pepper: Thank you.

Dr Vaughan Beck AM: And I suspect, the implications of what you've been talking about is there might be a lifetime work for people like yourself in terms of continual monitoring.

Dr Matthew Currell: That's true but the challenge is getting people to pay enough attention to the issue to actually fund programmes to go and find the wells and plug them up because it's no simple way other than actually going to the well and trying to fix it. That takes manpower, it takes money.

Hon. Justice Rachel Pepper: Can they be fixed with manpower and money?

Dr Matthew Currell: It's another good question. It's always a transient phenomenon, isn't it? A well can have integrity for a period of time. That doesn't guarantee its integrity for all time I guess. Yeah.

Hon. Justice Rachel Pepper: But is, again, I'm just trying to explore this, is one way of mitigating that or dealing with that the then have this robust monitoring regime and manpower and money effectively, to make sure you're going around and checking these wells and if there are problems, dealing with them?

Dr Matthew Currell: Yeah, I think so. Yeah. It's often an overlooked part of environmental regulation, groundwater regulation generally.

Hon. Justice Rachel Pepper: Yes. No, go ahead. You are presenting to a panel of scientists. And look, we have gone over it but yeah, it might be worthwhile for doing so, so please. If you're happy to continue, we're happy to continue.

Dr Matthew Currell: Absolutely, yeah.

Hon. Justice Rachel Pepper: Great, yeah.

Dr Vaughan Beck AM: You don't have a plane to catch in five minutes?

Dr Matthew Currell: No.

Dr Vaughan Beck AM: Oh, okay. You've just spoken about the possible contaminant route from surface down to the aquifer via the conduit provided by the bore but do you have any information on failures of abandoned wells that we could access? For either route, from bottom up or top down. If you could point us into some of the literature, that would be very helpful to us, thank you.

Dr Matthew Currell: Yeah, I could certainly try. I just need to double check as to whether I, I'm not sure if the interim report cited that review done by the IECS on bore integrity. There's a review in 2014. I have a feeling that-

Dr David Jones: I think it might be in here. I've seen that review.

Dr Matthew Currell: Yeah. I have a feeling abandoned and legacy bores is within the scope of their review. Or was within it. I don't know how much detail it put on it though.

Dr Vaughan Beck AM: Would you classify that as the gold standard reference or are there other references that could be useful for our deliberations?

Dr Matthew Currell: I think it's one of the good references.

Dr Vaughan Beck AM: Right, thank you. If you could provide us…

Dr Matthew Currell: Yeah, sure.

Dr Vaughan Beck AM: That'd be very helpful, thank you.

Dr Matthew Currell: Yeah, no worries.

Hon. Justice Rachel Pepper: I'm almost hesitant to ask whether there's anything further. Again, thank you so much for your very excellent presentation. Considerable amount of effort's gone into it but it's been very, very useful. Very useful and will lead to a number of lines of inquiry and you've provided some very beneficial references and sources of evidence.

Dr Matthew Currell: Fantastic.

Hon. Justice Rachel Pepper: Again, I know you've flown all this way to present to the inquiry. The inquiry's very, very grateful for your time and effort. Thank you very much.

Dr Matthew Currell: It's a pleasure, yeah.

Hon. Justice Rachel Pepper: Thank you.

Dr Matthew Currell: Thanks all of you. Good luck.

Hon. Justice Rachel Pepper: That concludes the hearing, the public hearing's in Alice Springs, thank you.