Reference document

Coal seam gas and groundwater quality

- Conservation and protection of groundwater is a top priority in all oil and gas activities.
- Use of chemicals during drilling, cementation and hydraulic fracture stimulation of wells is strictly regulated and carefully managed to minimise environmental risk.
- Studies and decades of operational experience show the risk of groundwater contamination is low.
- The industry continues to monitor critical aquifers and study the impact of drilling activities. Research is continually updated.

1. Introduction

The oil and gas industry focuses on conducting all aspects of its activities safely and sustainably. Conservation and protection of ground water is a top priority. Environmental protection during oil and gas production is achieved by:

- Designing wells to standards that protect aquifers by ensuring multiple failsafe levels of protection;
- Isolating all fluids that might have a detrimental impact; and
- Being transparent and consulting with communities and government agencies before, during and after activities.

2. Chemicals used in drilling

Oil and gas drilling is regulated by legislation in all Australian jurisdictions – the states, the Northern Territory and federal waters. To ensure strict guidance on drilling and constructing wells, several states have published Codes of Practice detailing minimum acceptable standards to ensure long-term well integrity, containment of oil and gas, and the protection of groundwater resources.

2.1 Drilling Fluids are used to lubricate the drill bit, return rock cuttings to the surface, and to provide pressure control in the well. The fluids must meet the requirements of the associated environmental licence. The fluids are typically water-based and contain:

- **Water** – often from surface catchments or produced formation water sourced from other drilling operations.
- **Highly absorbent clays** such as bentonite, which is a natural product formed from the breakdown of volcanic ash, and is commonly used to line dams to prevent leakage.
- **Density control additives** such as barite, which is used to control the weight of the drilling muds to prevent well blowouts. Barite is also the primary component of barium meals used in the medical profession and given to patients before CAT scans.
- **Organic based polymer additives** such as xanthan gum or guar gum, used to control the viscosity of the fluids. Guar gum is commonly used in making ice-cream.
- **Loss control materials** such as sawdust or cellulose material are sometimes necessary to prevent the loss of drilling fluid into highly permeable rock formations.

2.2 Cementation is a part of the well construction phase. Steel casing is positioned in the well. The cement is injected down the centre of the casing and returns to the surface between the outside of the casing and the adjoining rock. The cement sets and holds the casing in place. It also forms a barrier between the outside of the casing and the rock.

The cement is typically a Portland cement (the most common cement worldwide, which is primarily hydraulic lime). It seals potential pathways that could allow gas and formation fluids to move between the target gas reservoir and any adjoining aquifers. The cement also helps prevent corrosion of the well casing by blocking off intersected aquifers.

2.3 Hydraulic fracturing is used to increase well productivity. Fracture stimulation (fraccing) was first undertaken in 1947 and has since been performed more than 2.5 million times worldwide.[1]

Stimulation is a method for increasing the permeability of the source rock or reservoir from which the oil or gas will be produced. Permeable rocks allow easier flow of oil and gas.

A fluid mix of primarily sand and water with some chemicals is pumped into the well under high pressure. The hydraulic pressure of the fluid creates fractures that allow the sand and water mixture to be pushed deep (tens of meters) into the rock. The sand acts as prop to hold open the created fractures, through which the oil and gas can then more easily flow.

About 99% of fracture stimulation fluid is sand and water[2]. In fact the US Environment Protection Agency (EPA) found that the median maximum hydraulic fracturing fluid concentration was 0.43% by mass[3]. The remainder comprises guar and xanthan gum gels to thicken the fluids and hold the sand in suspension (without the thickeners the sand will settle out of the water too quickly); acids to correct the pH of the water; and biocides to control bacteria. Bacterial growth in the rock formation can block the pores, reducing permeability, and can also generate unwanted hydrogen sulphide gas.

Most fraccing chemicals are also used in everyday household applications or food in additives. These include sodium bicarbonate (bicarb of soda), sodium hydroxide (used in toothpaste), calcium chloride (used in sports drinks), sodium hypochlorite (pool chlorine), acetic acid (vinegar), and guar gum or xanthan gum, thickening agents used in ice cream.

Before hydraulic fracturing, companies undertake comprehensive risk assessments of the chemicals to be used. A list of chemicals that may be used in a fracture stimulation is included in **Appendix 1**.

3. The risks of aquifer contamination

The risks of aquifer contamination can be assessed on three levels:

1. Concentration and toxicity

The list of chemicals that can be used is long and complex, but the actual nature of the chemicals and the concentrations are well known. The US EPA noted that the median number of chemicals used in a frac is 14[3]. The chemicals placed hundreds of meters beneath the surface are used in similar concentration to those used in swimming pools. Higher risks exist at the surface where the transportation, storage, and handling of chemicals must meet prescribed regulatory standards.

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[1] King, G.E., 2012: *Hydraulic fracturing 101: What every representative, environmentalist, regulator, reporter, investor university research, neighbour and engineer should know about estimating frac risk and improving frac performance in unconventional gas and oil wells*. SPE Paper 152596, (cited with Cooke, 2012 and Trydal, H., Lund, E., & Kleiven, M. (2014) *Production of Natural Gas from Tight Sandstone*, Norwegian University of Science and Technology)

[2] Government of Western Australia, Department of Mines and Energy (2014) *Natural Gas from Shale and Tight Rocks Fact Sheet,* http://www.dmp.wa.gov.au/documents/Petroleum-Hydraulic-Fracture-Stimulation.pdf

[3] http://www2.epa.gov/sites/production/files/2015-03/documents/fracfocus_analysis_report_and_appendices_final_032015_508_0.pdf

2. Likelihood that the chemicals remain in the ground

Drilling fluids are mostly returned to surface for proper disposal or recycling for reuse in the next well. Cementation chemicals are contained in the cement.

For fracture stimulation operations, 40% to 60% of the stimulation fluids return to surface as the well is flushed and cleaned out in the following weeks, and are then either properly disposed of, or recycled. Over the life of the CSG well – which may be decades – the pressure gradient towards the well ensures that any chemicals that may be freed up over time are swept to the well and up to the surface for proper processing.

3. Likelihood the chemicals will migrate to uncontrolled areas

Drillers are very alert to drilling fluids that are not returning to surface. This presents a risk to the safety of the well drilling operation if it is not fixed promptly. This can be addressed with specialised 'lost circulation materials' such as sawdust or cellulose which blocks cracks and prevents drilling fluid escaping into the surrounding rocks. If the problem persists, cement or steel casing may be used for a more comprehensive solution.

For fracture stimulation operations, the volume of stimulation fluid is carefully calculated and monitored to ensure it cannot travel material distances from the well. Typically there are hundreds if not thousands of meters of rock between a fracture stimulation and any sensitive aquifers such as those used for domestic or agricultural purposes. This can be monitored with seismic or tracer technologies to verify the models for fluid travel.

The Australian Council of Learned Academies (ACOLA) has published a summary review of the risks associated with fracture stimulation[4] and concluded that there is no evidence of hydraulic fracturing fluids moving up in the earth from a fraccing operation to a surface aquifer.

ACOLA also noted research (Fisher and Warpinski[5] and Davies[6]) that showed the fracture stimulation treatments that travel the greatest vertical distance are those that break into natural faults. Davies cites a maximum fracture stimulation height of 588m for this type of stimulation treatment.

However, ACOLA notes that there are several effective ways to prevent this from occurring or mitigate the effects, including:

- using 3D seismic measurements to map locations where fault risks exist and avoid fracture stimulation in the immediate vicinity; or
- geomechanical modelling to predict the susceptibility of different fault orientations to conduct fluids; or
- using microseismic technology to map in real time the growth of a fracture stimulation treatment and shut down the treatment if unwanted height growth is observed.

The ACOLA report also addresses concerns about contamination of the Great Artesian Basin by pointing out that those aquifers already contain numerous oil fields. For example, the Cooper Basin has more than 500 oil wells and has produced more than 160 million barrels of oil since 1982.[7]

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[4] Cooke. D. 2012, A Brief Review of GeoScience Issues associated with Shale Gas development in Australia published by the Australian Council of Learned Academies. http://www.acola.org.au/

[5] Fisher, K and Warpinski, N, 2011 Hydraulic Fracture-Height Growth: Real Data, Paper SPE Paper 145949 Presented at the Annual Technical Conference and Exhibition, Denver Colorado, USA. (cited with Cooke, 2012)

[6] Davies J.D., Mathias S.A., Moss J., Hustoff S., Newport L., 2012: Hydraulic fractures: How far can they go?, published in Marine and Petroleum Geology, Elsevier Press (cited with Cooke, 2012)

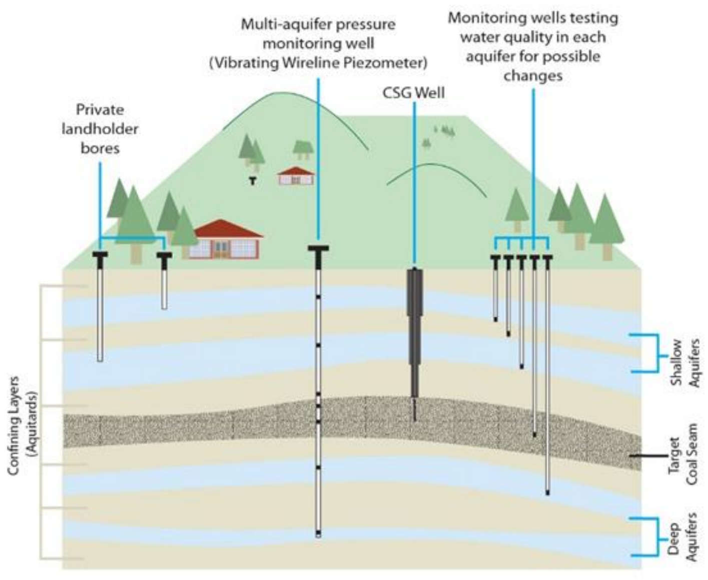
[7] DMITRE PEPs database, 2012: The South Australian government's Department for Manufacturing, Innovation, Trade and Resource (DMITRE) maintains a publicly accessible database (PEPs) on oil and gas production that can be downloaded at: http://www.petroleum.dmitre.sa.gov.au/access_to_data/peps-sa_database (cited with Cooke, 2012)

4. Case Study: How is the water quality in aquifers monitored and protected?

Wells are monitored to ensure they have been correctly designed and constructed. During and after the completion of any well, its production of water and gas is monitored.

In Queensland, Regional aquifers that could be affected by CSG wells are carefully monitored (see Figure 1). The government holds historical data from the monitored water pressure in more than 300 wells, and the major CSG companies have also been required to establish a further network of 498 monitoring points over 142 monitoring sites.[8]

Figure 1 – Domestic bores, CSG wells and monitoring



Source: Capital Energy Group, 2015

Landholders can search the results of the groundwater modelling and the potential impact on their registered bores. The Queensland Government's Office of Groundwater Impact Assessment (OGIA) has established an online search tool (links are available on the OGIA website and through *Queensland Globe*) where a *registered bore number* can be entered, and the results of the predicted impacts are made immediately available. [8]

Landholders can raise any concerns about the impact of CSG operations on their bores directly with the OGIA via the Queensland CSG-LNG Hotline (13 25 23). In the event that there is found to be an impact on the landholder bore, then the CSG companies must "make good" the impact, by repairing or deepening the bore, or by providing a new bore or an alternative source of good quality water.

Ultimately, landholders and the environment are protected through the extensive knowledge that is held on the geology, Codes of Practice for the drilling and completion of wells, and from the extensive ongoing research on aquifer protection.

[8] OGIA – Bore Search https://www.dnrm.qld.gov.au/ogia/surat-underground-water-impact-report/bore-search

Appendix 1. Chemicals that may be used in hydraulic fracture stimulation

Component	% Volume	Purpose	Other Example Uses
Water	>90%	Applies pressure to the rocks, and carries proppant into the fractures	Ground, surface, or recycled water
Clay Management (eg Sodium and Potassium salts)	< 1%	Minimises clay swelling or fluid interaction with the rock surrounding the fracture	Swimming pool salt, food additives, soil treatments
Gelling agents (e.g., Guar or Cellulose gums)	< 1%	Increases viscosity of fluid to carry more sand into the fractures	Cosmetics, personal products, ice cream, food thickeners, litter box clumping
Breakers	< 1%	Breaks down the gelling agents after the proppant is carried into the rock fractures, enhancing gas flow and frac fluid recovery into the well	Hair bleach, food additive, washing powder, enzyme products
Friction reducer	< 1%	Reduces friction or 'slickens' fluid flowing through pipes, decreasing need for high pumping horsepower	Cosmetics, drinking water flocculants
Surfactants (eg alcohols, turpenes)	< 1%	Reduces fluid surface tension aiding fluid recovery, prevent formation of emulsions	Soaps, laundry and dishwashing detergents, household cleaners
Biocides	< 1%	Inhibits the growth of unwanted bio-organisms which may contaminate the rock or frac fluid, rock, or wellbore.	Disinfectants, bleach, swimming pool chemicals
Corrosion and scale inhibitors	< 1%	Reduces corrosion of steel casing and the build-up of mineral precipitates in the well	Gelatine, instant coffee, detergents, swimming pool scale preventatives
Cross linkers (eg Borate salts)	<1%	Links the guar or cellulose polymers to enhance viscosity	Borax, laundry detergents, cleaners
Other acids, buffers and stabilisers (eg hydrochloric acid, acetic acid, sodium hydroxide, sodium carbonate, sodium bicarbonate, sodium thiosulfate)	< 1%	Maintains stability of the frac fluid by managing pH, iron control and reducing chlorine and other free radicals that could affect the crosslinking of the polymers	Household cleaners, aquarium chlorine remover, swimming pool pH and chlorine adjustors, vinegar, baking soda