CASE STUDY

CSG EXTRACTION IN THE SURAT BASIN, QLD

KEY TERMS

Porosity:
The volume of "space" between solid grains or particles of soil or rock as a percentage of the total volume of the soil or rock.

Permeability:
Permeability is a measure of how well connected the pores in soil and rock are. Generally groundwater flows through gaps between particles of soil and rock. How well it flows depends on how many gaps there are (porosity) and how well connected the gaps are (permeability).

Aquifer:
A layer of soil or rock that has relatively higher porosity and permeability than the surrounding layers, enabling usable quantities of water to be extracted.

Aquitard:
A layer of soil or rock that has relatively lower porosity and/or permeability than the surrounding layers, limiting the movement of groundwater through it and the capacity to extract useable quantities of water.

Gas Well:
A hole is drilled into the ground to the gas reservoir. A thick steel pipe is then put into the hole and the gap between the rock and the steel is filled with cement. The pipe is then pressure tested to make sure that it does not leak.

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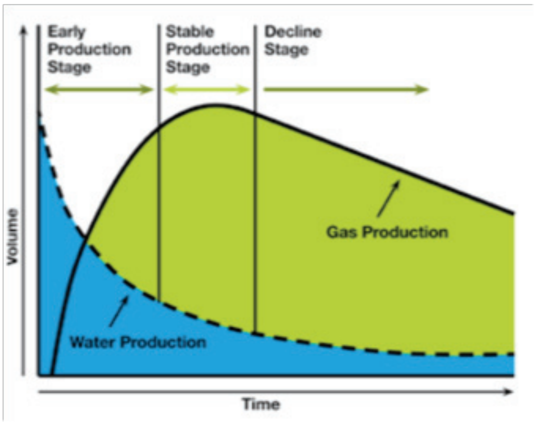
What is Coal Seam Gas

Coal is formed when plants are buried deeply underground. The pressure and temperature that forms the coal also forms natural gas within the coal. Coal seam gas (CSG) is a form of natural gas found in coal seams, rather than in the sandstone reservoirs that hold conventional natural gas. CSG is almost pure methane. It can be used for generating electricity and in gas appliances such as heaters and stoves. In Queensland over 90% of the gas used is CSG.

Methane is the same gas that causes underground explosions in coal mines. Scientists in the 1970s were looking for a way to make underground coal mines safer and discovered that the methane could be extracted from the coal before it was mined. CSG uses this technology to extract the natural gas from deeply buried coal seams that cannot be mined.

CSG is held in tiny cracks in the coal by the water pressure. Gas wells are drilled into the coal seams and pumps are used to pump out the groundwater to lower the pressure. When pumping starts, more water is pumped than gas, but once the pressure of the water in the coal reduces beyond a certain point, the gas will begin to flow. Over time, the amount water being pumped will reduce and the amount of gas coming out of the well will increase. This is shown in Figure 1.

FIGURE 1. TYPICAL CSG WATER AND GAS PRODUCTION PROFILE



The gas and the water are separated at where the bore comes to the surface (the wellhead). They flow down separate pipes to a gas plant and a water treatment plant. The gas plant dries and compresses the gas before piping it to where it is needed.

The spacing of the gas wells depends on the drainage area that each well affects. In the Surat Basin the usual well spacing is approximately every 750m. This is distance is a balance of how much of the gas in the reservoir is removed and the cost of installing and operating each well. In low permeability areas, where the drainage area of a well is small, the gas company may increase the permeability of the coal by hydraulic fracturing (fraccing). By fraccing, fewer wells need to be installed to drain the same area.

In southern Queensland there is more CSG than can be used locally. Four very big projects plan to extract CSG, compress it into a liquid and export it overseas.

The Surat Basin

The Great Artesian Basin (GAB) is one of the largest groundwater systems in the world. It is underneath about one fifth of Australia across Queensland, New South Wales and the Northern Territory. It is an important source of water to farmers because if provides a reliable water supply for their stock in areas where there may be little rainfall a few permanently flowing rivers.

The GAB is made up of three main geological basins: the Eromanga, Surat and Carpentaria Basins. It is Jurassic to Cretaceous in age.

In Queensland, CSG is extracted from the Surat Basin. Conventional gas is also extracted from the Surat Basin and was discovered during the drilling of a town water supply bore in Roma in 1906. It has been commercially extracted from the basin since the 1960s. Commercial CSG extraction started in approximately 1997 in Queensland.

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Hydrostratigraphic Unit:
A term used for a group of vertically adjacent geological layers that have similar hydraulic properties.

Drawdown:
A lowering of groundwater level due to pumping.

FIGURE 2 THE GREAT ARTESIAN BASIN

The approximate extent of the Queensland CSG industry is outlined in red. Blue arrows show the groundwater flow directions in the Guberamunda Sandstone and its equivalents. (Radke et al. 2000)

The Surat Basin is an elongated basin that contains layers of alternating river sands, coal from swamps and shallow ocean silts, muds and clays. These deposits reach a maximum thickness of approximately 2,500m. The river sands are generally the aquifers, and the ocean silts and muds are aquitards. The names of the hydrostratigraphic units are shown in Figure 3. The formations shown in Figure 3 are not uniform through their entire thickness and each hydrostratigraphic unit contains both coarser grained and finer grained rocks, displaying a mix of hydrogeologic characteristics.

CSG is extracted from the Walloon Coal Measures, which lies about halfway through the Surat Basin. The coal measures (layers of coal, silts and clays) are about 350 meters thick, but less than 10% (35m) is actually coal. The coal seams themselves are very thin (mostly less than 0.5m and up to about 2m), and the remaining material is mostly aquitard. The individual coal seams rarely extend for more than 2 kilometers.

Because it is bowl shaped, all of the formations outcrop along the northern edge of the basin. This area is known as the intake beds and is where most of the water gets into (recharges) the GAB. Recharge is predominantly by summer rainfall, either by direct infiltration into the outcropping areas, or indirectly via leakage from streams and/or from overlying aquifers.

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Groundwater flow tends to be to the southwest away from the intake beds. Groundwater movement is slow and in the order of 0.35 to 5m per year.

Groundwater naturally discharges from the GAB through springs. In the Surat Basin, most of the springs are in the recharge areas around the northern margin of the basin. Flow from some of the springs support protected plants and animals.

Farmers usually use the shallowest aquifer for their water supply. Because of this, the Mooga Sandstone and Gubberamunda Sandstone are the most used aquifers in the Surat Basin, however where an aquifer is shallow or in the recharge area, it will be used. Historical use has exceeded the recharge into the shallow aquifers and as a result declining water levels have been observed in some places.

Sometimes bores will be installed to tap deeper aquifers (Hutton Sandstone or Precipice Sandstone), but this is usually only when a larger water supply is required, such as for a power station, mine, town water supply or feedlot.

Going further

What are some of the ways we find out about what's below the ground?

Where the Walloons Coal Measures outcropped, the Condamine River carved a valley and deposited alluvium up to 100m thick. The Condamine Alluvium is one of the most used groundwater resources in Australia, and groundwater level declines of up to 25m have been observed. Through comparison of groundwater pressures and water qualities, there is some evidence for hydraulic connection between the Condamine Alluvium and the underlying Walloon Coal Measures, however the degree of this

Going further

Find out more information on the groundwater resources of the Great Artesian Basin.

Hydrostratigraphic unit	Hydrogeologic Character
Cainozoic Units (incl Condamine Alluvium)	Aquifer
Rolling Downs Group	Aquitard
Bungil Formation	Aquitard
Mooga Sandstone	Aquifer
Orallo Formation	Aquitard
Gubberamunda Sandstone	Aquifer
Westbourne Formation	Aquitard
Springbok Sandstone	Aquifer
Walloon Coal Measures	Aquifer (coal seams)/ aquitard (siltstones, mudstones)
	Aquitard
	Aquifer (coal seams)/ aquitard (siltstones, mudstones)
	Aquitard
	Aquifer (coal seams)/ aquitard(siltstones, mudstones)
Eurombah Formation	Aquitard
Hutton Sandstone	Aquifer
Evergreen Formation	Aquitard
Precipice Sandstone	Aquifer
Bowen Basin Sequence	Aquitard

FIGURE 3 HYDROSTRATIGRAPHIC COLUMN OF THE SURAT BASIN

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Potential Impacts of CSG Extraction

In the gas fields, the Walloon Coal Measures are between about 200m and 800m deep. To extract the gas, the groundwater level will be pumped down (depressurized) to approximately 35m above the top layer of coal. The amount of depressurization has the potential to suck groundwater from the overlying and underlying aquifers. The depressurization in the reservoir and associated leakage from other units has the potential to:

- Reduce groundwater supplies to landholders or other users in the GAB aquifers and in the Condamine Alluvium
- Reduce flows to springs and other natural groundwater discharge
- Cause compaction of the geological layers which may result in subsidence at the surface.

However, the fact that the coals are layered between siltstones and mudstones (aquitards) which separate them from the aquifers above and below limits how much water can be sucked from them. It also delays the sucking of water – in fact the greatest impact on shallower and deeper aquifers will be much later than the maximum depressurization of the coal seams.

Recovery of pressures to pre-CSG extraction levels may take decades to centuries. Extensive computer modelling of groundwater flows has been undertaken to assess the possible changes in waterlevels associated with CSG extraction to help understand impacts and plan to minimize them.

Because the water qualities of the aquifers are so similar, interaquifer waterflow due to changes in pressure are not expected to change the overall water qualities of the aquifers.

Monitoring

The State and Federal Governments have imposed a large number conditions on CSG projects to ensure that the potential impacts are minimised. These conditions include a development of extensive programs to monitor pressures and water qualities within the Walloon Coal Measures and the aquifers above and below. Between all of the companies operating in the Surat Basin, there will be over 400 dedicated monitoring points throughout the aquifers within and immediately surrounding the gas fields. Most of the companies will also be monitoring a number of private landholder bores on an ongoing basis.

The Queensland **Water Act 2000**, requires the gas companies to survey all registered bores on their leases before gas production starts. These surveys are called baseline surveys and provide waterlevel and water quality data against which potential impacts can be compared.

The gas companies have formed a consortium to monitor potential subsidence using InSAR, a satellite based technique that can measure ground movement of only a few millimeters every year. This will be augmented by geotechnical monitoring and regular elevation surveys of the same locations.

The project approvals require the companies to report their monitoring results on the internet. They also have to provide the findings of the baseline surveys and their groundwater monitoring to the CSG Unit of the Queensland Water Commission.

Management and Mitigation

The Queensland Water Commission (QWC) has defined an area that encompasses all petroleum production in the Surat Basin and a 50 kilometre buffer around the production areas (Surat Cumulative Management Area). The QWC has built a groundwater flow model to predict potential impacts to the aquifers with the Surat CMA. This model is used to inform an Underground Water Impact Report (UWIR) which identifies which bores and springs are predicted to be impacted within the coming three year period. The modelling and the UWIR will be updated every three years.

The gas companies will have to undertake detailed assessments of the bores identified in the UWIR, and will have to enter agreements with the bore owner as to how the water supplied will be maintained (made good) if impacts do occur. The triggers for "make good" are:

- 5m of drawdown in a consolidated aquifer
- 2m of drawdown in an unconsolidated aquifer, e.g. the Condamine Alluvium
- 0.2m of drawdown at a spring.

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Although an agreement will be in place between the gas company and the bore owner, the requirement to make good will is based on a change in the waterlevel measured during the baseline assessment or the follow-up detailed assessment. Ways that the gas companies could make good include:

- Setting the pump deeper in the bore
- Making the bore deeper
- Replacing the bore into a different aquifer or at a different location
- Providing an alternative supply of water

Should the waterlevel at a spring draw down by 0.2m, the gas companies will have to minimize and repair (mitigate) potential impacts. This is more complicated than ensuring a water supply to a water user. It may need the company to inject water to increase the pressure in the source aquifer of the spring or stop or change the way the company extracts the gas in the area closest to the spring.

Although aquifer injection, or managed aquifer recharge (MAR), has been done in many places around the world including Australia, it has never been done in the GAB. The gas companies are required by their approvals to undertake studies to assess whether aquifer injection is feasible. If feasible, aquifer injection may:

- Reduce the potential drawdowns associated with CSG production
- Improve the balance in the amount of water that is extracted from the Surat Basin compared with the natural recharge. This will reduce the amount of time that it takes for the waterlevels in the aquifers to return to pre-CSG production pressures
- Improve access to groundwater supplies by locally increasing waterlevels
- Improving the water quality in the GAB by injection of better water quality than that extracted from the Walloon Coal Measures because it has been treated by reverse osmosis and injected water will be of equal or better quality to that in the aquifer where it is injected.

Aquifer injection is regulated by the Department of Resource Management. In order to get a license to inject the gas company has to undertake studies to prove that there will not be any negative environmental or human health impacts. These studies include groundwater flow modelling to look at changes in water levels.

Geochemical assessments have to be done to look at whether mixing different water qualities will cause chemical reactions that may result in precipitates forming which could clog the aquifer and reduce the permeability. Before an injection scheme can be commissioned, a trial has to be undertaken with similar operating conditions to ensure that unexpected changes will not occur.

Going further

Consider the requirements the gas companies have to meet. Are they fair and reasonable? Discuss with your class mates.

CSG Water Management

Although each gas well produces only a relatively small volume of water and over a relatively short time period, approvals for the 4 major projects allow nearly 15,000 wells to be installed. As a result, water extraction by the CSG industry may be of a similar order to existing groundwater extraction, however the industry has a limited life (about 40 years). Because of the large volumes of water that will be produced, the gas companies need to develop appropriate means of managing the water.

The salinity of the water extracted from the Walloon Coal Measures is generally unsuitable for direct use without treatment. Most CSG water will require the salt to be removed by processes such as reverse osmosis. This creates a stream of pure water and a stream of brine.

The Queensland Government has a hierarchy of preferred water management options. In order of preference, this is: injection of water back into aquifers; untreated use (stock water, process water); treatment to an agreed standard for agricultural, industrial and potable use. Non-preferred options include discharge to surface waterways and evaporation.

Brine management options include evaporation of the brine to crystallise the salt, followed by landfill disposal or sale. Injection of the brine into very deep basement is also being used and investigated further.

Going further

What might be some of the problems with putting the pumped water into streams and rivers? What might be some of the advantages?

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Fraccing (Hydraulic fracturing)

In some areas, such as low permeability coals, fraccing is necessary to enable release and flow of gas from the coal seam. Fraccing can unlock these areas of low productivity potential, and can convert a non-productive well into a productive one through increasing the drainage area of each well. This means that fewer wells need to be drilled in order to produce the same amount of gas. Not all CSG wells need to be fracced.

About 99% of the frac fluid is water and sand. It is pumped into the well under very high pressure. The aim of the frac is to open, create and connect fractures, and deposit sand (proppant) in these open fractures. The sand filled fractures create a permeable pathway for gas and water to flow more easily into the well.

Frac fluids are engineered and designed to deliver sand to the formation. The 1% of chemical that are included in frac fluid are the same as those contained in many standard household products. Additives include, acetic acid (vinegar), sodium hydroxide (caustic soda, used in toothpaste), and calcium chloride (found in sports drinks and pickles), guaur gum used in health foods for wheat intolerant people as well as sauces and salad dressings. BTEX chemicals (benzene, tolulene, ethylbenzene and xylenes) are not used in Australian fraccing operations and Queensland has banned the use of BTEX chemicals in fraccing. The additives used during fraccing enable:

- the fluid to form a gel and hold the sand in suspension, allowing more sand to be spread throughout the fractures and less water to be used
- the gel to break down once the process is complete
- pH levels to be balanced, and
- the prevention of bacteria transfer from surface water to the coal seams.

Because the gas wells are pumped, the frac fluid will be removed when the well is brought into production.

Frac wells are designed differently to unfracced wells. The steel casing (pipe) is cemented into the ground over its entire length from the bottom of the hole to the surface. Holes are then punched through the casing at selected intervals where the coal is thickest to allow the frac fluid to be pumped in.

Fraccing is achieved by pumping frac fluid into the well at high pressures which causes natural fractures in the rock to open. Fracs will propagate perpendicular to the direction of the force so they will tend to travel horizontally through the target coal seams. In the Surat Basin, fracs tend to extend approximately 50m from the well.

The Queensland State Government has an extensive set of regulatory controls on hydraulic fracture stimulation, which include legislation on some chemicals, broad range of controls through Environmental Authorities.

Going further

Write out a list of the benefits and risks of fraccing. How do you think they compare? Develop some arguments for and against fraccing and test them with your class mates?

For More Information

http://www.industry.qld.gov.au/lng/index.html

http://www.derm.qld.gov.au/environmental_management/coal-seam-gas/index.html

http://www.appea.com.au/

http://aplng.com.au/

http://www.glng.com.au/

http://www.qgc.com.au/

http://www.arrowenergy.com.au/

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