Dr Andrew Johnson
Group Executive – Environment
EcoSciences Precinct
PO Box 2583 Brisbane Qld 4001
Telephone (07) 38335520 • Facsimile:(07) 38335525 • ABN 41 687 119 230

CSIRO

Committee Secretary
Senate Standing Committees on Rural Affairs and Transport
PO Box 6100
Parliament House
Canberra ACT 2600
Australia

27 January 2011

Dear Committee Secretary

Environment Protection and Biodiversity Conservation Amendment (Protecting Australia's Water Resources) Bill 2011

Thank you for the opportunity to provide comment to the Committee in relation to their inquiry into the Environment Protection and Biodiversity Conservation Amendment (Protecting Australia's Water Resources) Bill 2011.

CSIRO is a research provider across a wide range of disciplines relevant to mining developments and water resources. We have broad research capability related to: the study of surface water and groundwater; the environment; land management and agriculture; biodiversity; resource characterisation; energy production; and socio-economic science.

We provide research results, scientific modelling and scientific advice to a range of stakeholders, including government, industry and the community. We collaborate and partner with universities, government departments and agencies, non-government organisations and industry.

There are two aspects of the Bill on which CSIRO would like to provide comment:

1. Mine closure does not seem to be catered for as a mining operation that could significantly affect water resources (as they are defined in the proposed amendment). Many mine closure plans consider landforming the minesite, which can significantly alter surface water and groundwater flow paths and discharge zones. Other closure options also can have impact on water resources. This issue could be covered by an insertion of a clause (iv) in 24E (1)(a) of the proposed amendment document.

2. The terminology around 'recharge zones' as defined in 24F(b), in particular how they relate to the hydraulic balance of a water resource, is somewhat confusing. In the context of surface water resources, the term 'catchment' is generally used to describe the area from which runoff to rivers and streams is sourced.

   In the case of groundwater resources (i.e., aquifers) the term 'recharge zone', whilst commonly used in hydrogeology and groundwater management, has no consistent definition.

   For example, shallow alluvial aquifers can be recharged beneath rivers and streams, as well as via widespread infiltration of rainfall where soils are of sufficiently high permeability. In stark contrast, the recharge area for deep, confined aquifers such as the Great Artesian Basin (GAB) might include: relatively small areas of the basin where the aquifer rocks outcrop at or near land surface; or deeper areas of the basin where hydraulic conditions allow downward flow from shallow aquifers into the GAB aquifer; or very deep areas of the basin where leakage from overlying or underlying aquifers causes a net gain of water into the GAB aquifer; or some combination of these.

Due to the complexity of groundwater recharge processes, and the inconsistent definitions outlined above, we stress the need for caution when formulating legislation to address impacts of groundwater extraction on recharge zones.

In addition to these specific comments, there are a number of CSIRO information sources which may be of interest to the Committee in their deliberations:

- In November 2011 CSIRO published *Water: Science and Solutions for Australia* which provides the latest scientific knowledge on the challenges and prospects for managing Australia's water resources. The book seeks to provide a bridge from peer-reviewed scientific literature to a broader audience of society and contains several chapters relevant to this inquiry. A hardcopy of the book was provided to all parliamentarians and it is also available at http://www.csiro.au/water-book

- CSIRO's Minerals Down Under Research Flagship is working with industry and partners to help address Australia's key national challenges and opportunities in the minerals domain. Information about the Flagship's activities and related capabilities can be found at http://www.csiro.au/org/MDU-Overview

- CSIRO has prepared a series of fact sheets regarding groundwater research, the Great Artesian Basin and the Coal Seam Gas Industry which are attached to this letter.

If you would like more information about any of the issues raised above, or CSIRO's relevant capabilities and research outcomes, please contact Dr Sandra Oliver from CSIRO's Ministerial and Parliamentary Liaison Office at mplo@csiro.au or telephone 02 6276 6231.

Yours sincerely

Dr Andrew Johnson
Group Executive - Environment

Coal Seam Gas Factsheet #1

Introduction

Coal seam gas (CSG), also known as coal bed methane, is a form of natural gas, typically extracted from coal seams at depths of 300-1000 metres.

CSG is a mixture of a number of gases, but is mostly made up of methane (generally 95-97 per cent pure methane).

Underground, CSG is typically attached by adsorption to the coal matrix, and is held in the coal underground by the pressure of formation water in the coal cleats and fractures.

COAL SEAM GAS PRODUCTION IN AUSTRALIA

Australia has relatively large supplies of CSG resources, especially in Queensland and New South Wales (NSW).

CSG has been produced in Queensland from the Bowen Basin since 1997 and in the Surat Basin since 2005. Exploration is also occurring in other Queensland basins, northern NSW, and other parts of Australia where there are known coal deposits.

DIFFERENT FORMS OF GAS

Conventional and unconventional gas

Unconventional gas (including CSG, shale gas, and tight gas) and conventional gas differ in the geology of the reservoirs from which they are produced.

Conventional gas reservoirs largely consist of porous sandstone formations capped by impermeable rock, with the gas trapped by buoyancy. The gas can move to the surface through wells without the need to pump.

Unconventional gas is generally produced from complex geological systems that prevent or significantly limit the migration of gas and require innovative technological solutions for extraction.

CSG

CSG is entirely adsorbed into the coal matrix. Movement of CSG to the surface through wells normally requires extraction of formation water from the coal cleats and fractures. This reduces the pressure, allowing methane to be released from the coal matrix. Over time, water production decreases and gas production increases. CSG production normally requires a higher density of wells than conventional gas production, however CSG wells are typically shallower than conventional wells and cost much less to drill.

Shale gas

Shale gas is generally extracted from a clay-rich sedimentary rock which has naturally low permeability. The gas it contains is either adsorbed (i.e., closely to the surface matrix of the organic matter) or in a free state in the pores of the rock. *[Note: the US documentary 'Gasland' refers to coal and shale gas; there are important differences between the two in terms of the geological location and characteristics of the reservoirs they are found in and the processes employed to extract them].*

Tight gas

Tight gas is trapped in ultra-compact reservoirs characterised by very low porosity and permeability. The rock pores that contain the gas are minuscule, and the interconnections between them are so limited that the gas can only migrate through it with great difficulty.

Underground Coal Gasification

Gas from Underground Coal Gasification (UCG) can also be sometimes confused with CSG. UCG is the *in situ* conversion of coal into a combustible gas that can be used as a fuel or chemical feedstock.

USEFUL WEBLINKS

http://www.qwc.qld.gov.au/csg/about.html (Queensland Water Commission, CSG facts)

http://www.qwc.qld.gov.au/csg/pdf/csg-qwc-role.pdf (Queensland Water Commission's role in groundwater management)

http://www.cabinet.qld.gov.au/MMS/StatementDisplaySingle.aspx?id=72747 (media release on legislation passed by the Queensland Government to manage and protect Queensland's groundwater near CSG projects)

http://www.derm.qld.gov.au/environmental_management/coal-seam-gas/csg-water.html (Queensland Government policy for managing CSG water)

http://www.dme.qld.gov.au/mines/coal_seam_gas.cfm (Queensland Government Department of Employment, Economic Development and Innovation: Mines and Energy, CSG information)

http://www.dpi.nsw.gov.au/minerals/geological/overview/regional/sedimentary-basins/methanensw (NSW Government Primary Industries, CSG in NSW)

http://www.appea.com.au/industry/csg/introduction.html (Australian Petroleum Production and Exploration Association, CSG in Australia, with further links to fact sheets on CSG industry, CSG production, fraccing, groundwater and salt management, industry's economic benefit, CSG environmental performance and response to the US documentary 'Gasland')

http://www.environment.gov.au/epbc/notices/pubs/gladstone-ga-report.pdf (Summary of advice in relation to the potential impacts of CSG extraction in the Surat and Bowen Basins, Queensland. Report provided by Geoscience Australia and Dr MA Habermehl, for the Australian Government Department of Sustainability, Environment, Water, Population and Communities)

http://www.abare.gov.au/publications_html/energy/energy_10/ch_4.pdf (Joint Geoscience Australia and ABARE report on energy resources – Chapter 4 includes information on CSG)

http://www.frogtech.com.au/bowen-surat-basin-csg/ (FrOG Tech ('From Oil To Groundwater') is an Australian based natural resources consultancy; this website provides information on CSG in Bowen and Surat Basins)

http://www.frogtech.com.au/gloucester-basin-csg/ (FrOG Tech information on CSG in Gloucester Basin)

http://www.frogtech.com.au/clarence-morton-basin-csg/ (FrOG Tech information on the Clarence-Morton Basin)

http://topdocumentaryfilms.com/gasland/ (link to watch the 'Gasland' documentary online)

For further information:

Contact: Dr Glen Walker, Theme Leader, CSIRO Water for a Healthy Country Flagship
phone 08 8303 8743, email glen.walker@csiro.au

Contact: Dr John Carras, Director, CSIRO Advanced Coal Technology
phone 02 9490 8644, email john.carras@csiro.au

Contact: Prof. Mike McWilliams, Chief, CSIRO Earth Science and Resource Engineering
phone 07 3327 4486, email mike.mcwilliams@csiro.au

Please note: the information contained in this factsheet is presented as background material for the Senate Rural Affairs and Transport Committee's inquiry into coal seam gas mining in the Murray Darling Basin. This factsheet was compiled using publicly available information from various organisations, including state government departments and non-government organisations/companies.

Coal Seam Gas Factsheet #2

CSG Produced Water and Site Management

COAL SEAM GAS (CSG) EXTRACTION

Target coal seams for CSG production are generally 300-1000 metres below ground surface. Production normally requires the drilling of many wells at a more dense spacing than normally required for conventional gas production.

CSG is adsorbed into the coal matrix and is held in place by the pressure of formation water. To extract the gas, a well is drilled into the coal seam and formation water from the coal cleats and fractures is pumped and withdrawn. The removal of water in the coal seam reduces the pressure enabling the CSG to be released (desorbed) from the coal micropores and cleats, allowing the gas and 'produced water' to be carried to the surface.

In some cases (historically 5 to 30 per cent) the coal permeability is low and gas production is small (sub-economic). In these cases, to further assist the flow of gas through the coal to the producing well, the coal can be hydraulically fractured or ‘fracced’ (see Factsheet #3 for further information on fraccing).

CSG PRODUCED WATER

Produced water (also known as CSG water or wastewater) is the water that is pumped out of coal seams in order to release CSG. The gas comes up with the produced water. Over time, the volume of produced water normally declines and the volume of produced gas normally increases.

Once they reach the surface, the produced water and the methane (along with other gases) are separated. The methane is collected and passed to a central compressor station where it is added to a pipeline network for delivery to users.

How much water is produced from CSG production?

No two wells or coal seams behave identically and water production can vary from a few thousand to hundreds of thousands of litres a day, depending on the underground water pressures and geology.

Whether the process of water extraction poses a problem or not will depend on the interaction, if any, between CSG production and aquifer systems and on what is done with the produced water.

What is the water quality like?

The water that is produced from a coal seam has generally been underground for a long time with very little fresh water penetration. As a result, the water is often quite salty. CSG water contains mainly sodium chloride (varying from 200 to more than 10,000 milligrams per litre), sodium bicarbonate and traces of other compounds.

CSG WATER TREATMENT AND USES

Water quality is highly variable from site to site, but it is generally not fit for human consumption. Depending on its quality, produced water can be used directly, treated and then used, or directly reinjected.

What are the potential uses for CSG water?

CSG produced water has a number of uses, depending on its quality and quantity. However, generally, without treatment, the beneficial uses of CSG water are limited.

The potential uses for CSG water include:

- water as a supply for local farmers and communities
- irrigation of agricultural crops or plantation forestry
- dust suppression
- industrial purposes (e.g. drilling, coal washing for coal mining, cooling in power stations)
- discharge of interim or occasional surpluses of treated water into local river or weir/dam systems (if the water is treated and conditioned to equal standards for discharge into rivers, it can contribute favourably to environmental outcomes for river systems already exposed to heavy irrigation demand)
- reinjection into suitable underground aquifers or discharge as surface water.

How is coal seam gas water treated?

Treatment of CSG water depends on the quality and quantity of the produced water, the intended use of the water, and the prevailing environmental laws and regulations.

To treat the water to a standard suitable for town water supply or other purposes, such as farm irrigation, would require at least reverse osmosis (RO), or a similar technology to remove the dissolved salts and other chemical compounds. RO is a robust and well-proven technology that can filter out up to 95 per cent of the salts and organic compounds. Some operators have used RO to treat produced water, which is then used on plantations, in fish ponds and for other beneficial uses.

The treatment process results in a super saline brine or solid salt, depending on the process used, which can require further treatment or disposal. For instance, brine can be disposed of by injection into deep geological formations.

How is CSG water disposed of?

At present in Queensland most untreated CSG water is disposed of in evaporation ponds ranging from 1 to 100 hectares in area. Evaporation ponds, however, are to be discontinued as a primary means for the disposal of CSG water because of concerns over leakage of saline waters into soils, aquifers and rivers. Remediation of all ponds is anticipated to occur within three years.

Treated CSG water can also be reinjected into suitable underground aquifers, surface water systems or back into the subsurface, but impacts to those aquifers need to be considered.

MONITORING AND MANAGEMENT OF CSG SITES

Characterising CSG sites for production and for drilling wells is important in assessing the potential of CSG production. Technologies such as three-dimensional geophysical surveying techniques, mathematical based modelling and imaging of underground reservoirs can be used to observe subsurface aquifers and geological strata, determine how coal seams are connected to aquifers and assess the potential for groundwater contamination.

Groundwater modelling can assist in indicating the extent to which coal seams are connected to aquifers, and to predict whether drawing water from one can impact levels in the other. Seismic mapping technologies can be used to map fracture locations and channels for water movement underground.

Although absolute guarantees about potential impacts are not possible, existing knowledge from research on aquifers and groundwater models make it possible to estimate the level of risks of adverse impacts.

What monitoring and management procedures are used to assess the suitability of a site for CSG operations?

A number of detailed evaluation tests and analyses can be used to help determine the suitability of a site for drilling and extraction of CSG.

These analyses can include:

- geological site descriptions from well data – to characterise the rock layers associated with each coal seam well and their distribution, deposition and age;
- seismic surveys – to define the geological structure beneath the ground surface and identify faults or fractures that could potentially create leakage pathways that may also be associated with subsurface water movement;
- formation pressure measurements – to map the rate and direction of groundwater movement;
- hydrodynamic assessments – to determine the connectivity of aquifers in the subsurface;
- analysis of water quality samples – to measure barriers to flow between the deep and shallow groundwater zones or areas;
- analysis of groundwater samples – to determine the existing water quality levels at the site before CSG production, and to use as a baseline to monitor any changes during and after production.

Information gathered from all the analyses and geological characterisations can be used to build computer models of the site. These models can then be used to make predictions on the impact of CSG production.

For further information:

Contact: Dr Glen Walker, Theme Leader, CSIRO Water for a Healthy Country Flagship
phone 08 8303 8743, email glen.walker@csiro.au

Contact: Dr John Carras, Director, CSIRO Advanced Coal Technology
phone 02 9490 8644, email john.carras@csiro.au

Contact: Prof. Mike McWilliams, Chief, CSIRO Earth Science and Resource Engineering
phone 07 3327 4486, email mike.mcwilliams@csiro.au

Please note: the information contained in this factsheet is presented as background material for the Senate Rural Affairs and Transport Committee's inquiry into coal seam gas mining in the Murray Darling Basin. This factsheet was compiled using publicly available information from various organisations, including state government departments and non-government organisations/companies.

Coal Seam Gas Factsheet #3

Hydraulic Fracturing (Fraccing)

Hydraulic fracturing, or fraccing, is a method used by the oil and gas industry since the 1940s to increase the rate of oil and gas extraction and the total amount extracted from reservoirs. Fracturing has been used to enhance CSG production from coal seams since the 1970s in the United States (US) and since the mid 1990s in Australia. Increased CSG activity, mostly in Queensland and New South Wales, has caused a parallel increase in the use of hydraulic fracturing.

This factsheet contains information about the technology of the fraccing process. Although the technological aspects of fraccing are known, the impacts of fraccing are less well characterised.

Estimating the likely impacts of fraccing is complex, and depends on various factors such as the nature of land use in surrounding areas, geology, and hydrodynamics, which need to be considered on a regional and case by case basis (see Factsheet #5 for further information about estimating impacts of CSG production).

TECHNOLOGY OF THE FRACCING PROCESS

Why is fraccing necessary?

Without the recent and significant technological advancements made in horizontal drilling and fraccing, a portion of the natural gas found in coal seams would be uneconomic and unrecoverable. Fraccing is the most common method used to increase the production from a CSG well, but not all gas wells require fraccing. Generally only wells that intersect lower permeability coal seams require fraccing and these are usually deeper seams.

Where has fraccing been used in Australia?

Fraccing has been widely used in Australia. Fraccing for stimulation of petroleum wells, as distinct from CSG wells, has been used in most states in Australia with most of the activity in South Australia and Queensland.

How is fraccing carried out in CSG production?

The decision to frac a well is often made before drilling commences because the process requires additional considerations in well design and construction procedures.

Typically, a well is fully cased from top to bottom with steel casing. To gain access to the coal, the casing is perforated at specific intervals along the well, where the fracture treatment is to be carried out.

Fraccing involves injecting fluid made up of water, sand and a few additives under high pressure into the cased well. The pressure caused by the injection typically creates one fracture in the coal seam where the well is perforated that, for a large CSG treatment, might typically extend to a distance of 200 to 300 metres from the well. The fractures grow slowly. For example an average velocity may be less than 10 metres per minute initially and slowing to less than 1 metre per minute at the end of the treatment.

The last part of the fracture treatment involves adding a proppant (usually quartz sand) into the fluid, which acts to keep the fracture open after injection stops, and forms a conductive channel in the coal through which the water and gas can travel back to the well.

After the fracturing is complete, part of the fluid injected (which is made up of at least 96 per cent water) is brought back to the surface and treated before being used again or disposed of.

How deep is hydraulic fracturing performed?

Hydraulic fracturing takes place hundreds of metres below ground, generally deeper than local groundwater supplies. Targeted fraccing zones are typically located at around 300 to 1000 metres below the freshwater zones and are separated by low permeability shales and sandstones. The fracture treatments are designed to grow only in the zone of rock that contains coal seams because growth out of zone increases the cost and reduces the effectiveness of the treatment. Each site must be characterised by measuring rock properties and stress so that the potential for fracture growth can be assessed.

What does the fraccing fluid contain?

Water and sand make up more than 96 per cent of the fraccing fluid.

Other materials that make up the remainder of the fluid are added to make the mixture thicker and more viscous and then to break these fluids to a thin fluid at the end of the injection. Some commonly used chemical additives include:

- sodium hypochlorite (used in bleach and as a biocide in swimming pools)
- hydrochloric acid (a strong corrosive acid)
- surfactants (used in soaps)
- cellulose (the structural component of the primary cell wall of green plants)
- guar (used as a gelling agent, e.g. as a food additive to thicken some food products)
- acetic acid (the basis of vinegar)
- bactericides (to inhibit bacteria forming that may corrode the steel casing or plug the permeability in the fracture and coal seam).

Added chemicals make up about 1 per cent of the fraccing fluid.

The exact nature of the fraccing mixtures used by CSG companies may vary depending on the well and may be commercially confidential.

How much water is used during the fraccing process?

Generally between 100 and 10,000 cubic metres of water may be used to frac a well. A well may be fractured at different depths along the wellbore.

What happens to the frac fluid after it is pumped down the well?

Some of the frac fluid is flushed from the coal seam soon after fraccing operations are completed. These fluids are brought to the surface inside the steel casing. This fluid is then pumped to lined containment pits or tanks. Wherever possible, the fluid is recycled for further frac treatments or taken to an off-site location to be disposed of safely and appropriately with the produced water.

A portion of the fracturing fluid remains in the fracture and in the coal seam until the well is put on production. This frac fluid is then produced along with the seam water and handled and treated with the produced seam water.

What are the strategies undertaken to ensure that groundwater is not contaminated by fraccing activities?

Similar to CSG production wells, wells to be fractured are fully lined with steel casing, which are cemented in place to isolate and protect all aquifers overlying the target coal seam. Before fraccing is conducted, the integrity of the cement bond between the casing and rock needs to be confirmed and verified.

The risk of groundwater contamination is assessed by characterisation of the CSG site and monitoring and management procedures. Characterisation methods are used to assess the rock that separates the coal from any water bearing aquifers. These methods include geophysical logging of the rock penetrated by the well using special well logging tools, three-dimensional geophysical surveying techniques, mathematically based modelling and imaging of underground reservoirs to observe subsurface aquifers and geological strata. Stress and well testing are often carried out to measure stress and pore pressure in the rock strata.

Coal seams are typically comprised of softer lower stressed strata compared to the rock layers above and below the coal seam. This contrast in stiffness and stress, together with the precise positioning of fraccing perforations made in the CSG well casing, help keep the fracture confined to the coal seams being treated.

Monitoring methods also provide quality control on the fracture design and fracture growth, to ensure the fractures extend only in the target coal seam regions. The extent of fracturing can be measured at the time of fraccing through well logging and remote monitoring.

Models that predict fracture growth are used with the remote monitoring methods to assess potential risks of fracturing into zones above or below the coal seams. However, absolute guarantees about fracture growth are not possible because estimation of the growth is based on limited data reflecting the statistical variation of parameters in a sequence of rock layers.

If a hydraulic fracture grows into a groundwater aquifer, the extraction of gas and water from the CSG well means the flow of fluid will be from the aquifer towards the CSG well.

For further information:

Contact: Dr Glen Walker, Theme Leader, CSIRO Water for a Healthy Country Flagship
phone 08 8303 8743, email glen.walker@csiro.au

Contact: Dr John Carras, Director, CSIRO Advanced Coal Technology
phone 02 9490 8644, email john.carras@csiro.au

Contact: Prof. Mike McWilliams, Chief, CSIRO Earth Science and Resource Engineering
phone 07 3327 4486, email mike.mcwilliams@csiro.au

Please note: the information contained in this factsheet is presented as background material for the Senate Rural Affairs and Transport Committee's inquiry into coal seam gas mining in the Murray Darling Basin. This factsheet was compiled using publicly available information from various organisations, including state government departments and non-government organisations/companies.

Coal Seam Gas Factsheet #4

The Great Artesian Basin and Coal Seam Gas

The Great Artesian Basin (GAB) is Australia's largest groundwater basin and underlies more than 1.7 million square kilometres of eastern Australia (Figure 1). The GAB extends beneath parts of Queensland, New South Wales, South Australia and the Northern Territory and is one of the largest natural underground water reservoirs in the world. It comprises a sequence of aquifers within rocks ranging from 65 to 250 million years old, deposited in the Triassic, Jurassic and Cretaceous periods.

The primary target of coal seam gas (CSG) production is from coal seams contained within specific GAB rock layers laid down in the Jurassic period. These coal seams are referred to as the Walloon Coal Measures and are located in the Surat and Clarence Moreton Basins.

What is the relationship between the Murray-Darling and the key basins?

- The Murray-Darling Basin (MDB) is the catchment for the Murray and Darling rivers and tributaries (extent shown on Figure 1). The MDB is one of 12 major drainage divisions in Australia.
- The GAB is a groundwater basin delineated by the extent of Jurassic and Cretaceous beds that include the main confined aquifers.
- The GAB underlies a large portion of the MDB in northern NSW and southern Queensland and its extent is depicted in Figure 1.
- The GAB consists of a number of different geologic basins where sediments were deposited in the Triassic, Jurassic and Cretaceous periods. These depositional basins include the Surat Basin, Eromanga Basin, Carpentaria Basin and a portion of the Clarence Moreton Basin. The boundaries between these depositional basins are defined by geologic structures, such as ridges and major faults in the sub-surface.
- The GAB also overlies older geologic basins, such as the Bowen Basin. These basins are deeper than the GAB, and in the case of the Bowen Basin, have a boundary that extends beyond the boundary of the GAB. The Bowen Basin contains older, deeper coal seams and the Fairview and Scotia gas fields.

GROUNDWATER IN THE GAB

Groundwater resources in the GAB and Bowen Basin support an extensive pastoral industry, inland population centres, mining activities, and other extractive industries. There are many resources present in the basins – water, gas, oil and geothermal energy – and demand for these resources is increasing. From the perspective of the whole-GAB, water from rain and some rivers enters the groundwater along the elevated margins. From these areas of recharge, groundwater is driven by topographic gradient to lower-lying parts of the landscape where it can discharge back to the ground surface. From the perspective of the whole-GAB, groundwater discharge occurs through springs, artesian bores, extraction bores and very slowly by a diffuse seepage process across broad sections of arid land.

The mechanics of groundwater flow in the GAB, or hydrodynamics, is governed by the structure and nature of the sequence of aquifers. Across much of the GAB, the Jurassic and Cretaceous beds that form aquifers are confined by nearly impervious rock layers. These confining beds and relative elevation difference with the more elevated recharge areas results in the artesian groundwater pressure. A schematic slice representation of groundwater flow through the GAB is illustrated on Figure 2.

Within the Walloon Coal Measures CSG is trapped by groundwater pressure. CSG extraction occurs by drilling into the coal seam and lowering the groundwater pressure (see Factsheet #2 for further information).

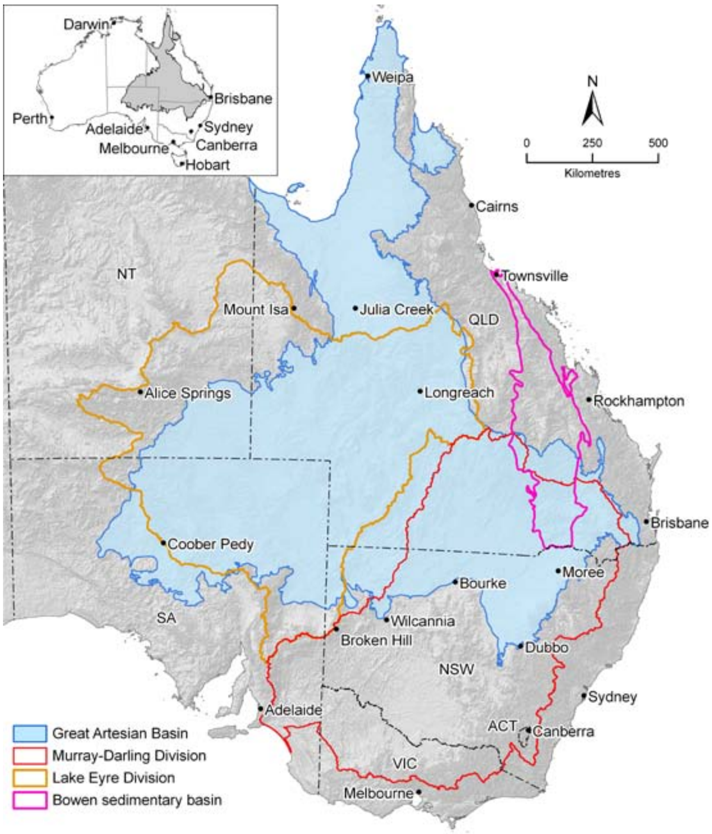

Figure 1. Geographic extent of the Great Artesian Basin and selected overlying surface water drainage divisions.

What is the connection between the MDB and GAB?

The MDB and GAB are related by the upward groundwater pressures exerted by the GAB in central and western NSW and Queensland, and leakage from rivers and alluvial sediments of the MDB to the GAB where Jurassic and Cretaceous beds are exposed along the western slopes of the Great Dividing Range. Areas where rivers are known to cross GAB aquifers include the Macquarie-Castlereagh region of NSW, Border Rivers region of NSW and Queensland, and the Condamine-Balonne region of Queensland.

The connection between MDB rivers and alluvial aquifers and the underlying GAB is complex and spatially variable. While some rivers are known to gain or lose water with GAB aquifers, in some locations this connection is restricted and leakage from rivers and alluvial aquifers is rejected and becomes river baseflow.

How is groundwater monitored?

Many of the GAB aquifers, particularly the Cadna-owie Formation – Hooray Sandstone aquifers, have been the subject of many investigations and groundwater flow is generally well understood. Yet, information on the layering of confining beds is sparse. The thickness and structure of confining beds will govern whether vertical flow from one aquifer to another is impeded.

As part of monitoring CSG sites the extent to which coal seams are connected to aquifers, and extent and thickness of confining layers, can be mapped. When combined with measurement of groundwater pressure, hydrodynamic assessment can be completed to map the rate and direction of groundwater movement and the connectivity of aquifers in the sub-surface.

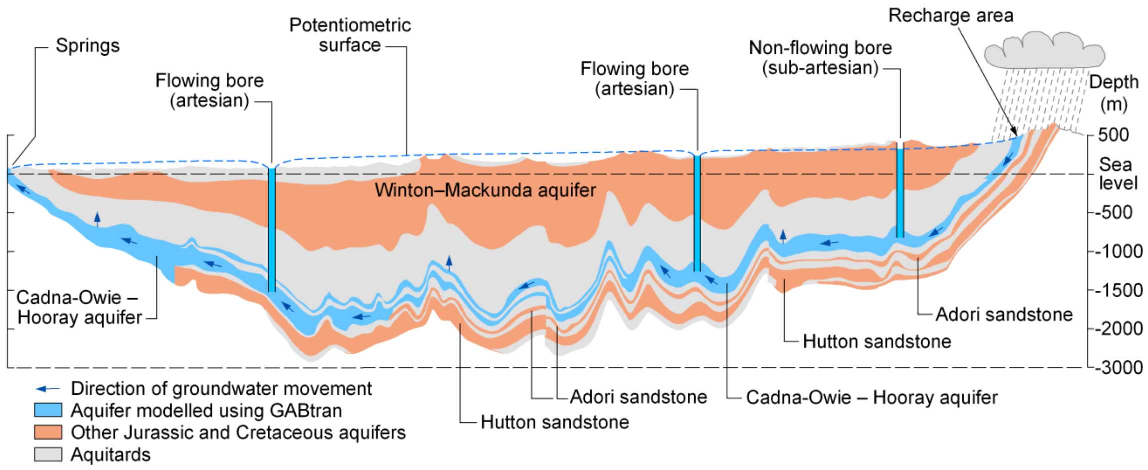

Figure 2. Schematic slice through the Great Artesian Basin illustrating predominant aquifers in the Jurassic and Cretaceous beds in blue, confining layers in grey, and other aquifers in red. The slice represents schematic layering from major spring zones in South Australia (left side of figure) to major recharge areas in Queensland (right side of figure).

THE GAB WATER RESOURCES ASSESSMENT

CSIRO and Geoscience Australia have initiated an integrated re-appraisal of the latest hydrogeology and hydrochemistry of the entire GAB to better understand how the whole groundwater system operates. This re-appraisal will build on the approach taken by CSIRO and partners in the Murray-Darling Basin, South-West Western Australia, Northern Australia, and Tasmania Sustainable Yields projects and is due to be completed by the end of 2012.

REFERENCES:

Habermehl MA (1980) The Great Artesian Basin, Australia. BMR Journal of Geology and Geophysics 5, 9–38.

Habermehl MA and Lau JE (1997) Hydrogeology of the Great Artesian Basin, Australia. 1: 2,500,000 Map. Australian Geological Survey Organisation, Canberra.

Radke BM, Ferguson J, Cresswell RG, Ransley TR and Habermehl MA (2000) Hydrochemistry and implied hydrodynamics of the Cadna-owie – Hooray Aquifer, Great Artesian Basin. Bureau of Rural Sciences, Canberra.

Herczeg AL (2008) Background report on the Great Artesian Basin. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. CSIRO, Australia.

For further information:

Contact: Dr Glen Walker, Theme Leader, CSIRO Water for a Healthy Country Flagship
phone 08 8303 8743, email glen.walker@csiro.au

Contact: Dr John Carras, Director, CSIRO Advanced Coal Technology
phone 02 9490 8644, email john.carras@csiro.au

Contact: Prof. Mike McWilliams, Chief, CSIRO Earth Science and Resource Engineering
phone 07 3327 4486, email mike.mcwilliams@csiro.au

Please note: the information contained in this factsheet is presented as background material for the Senate Rural Affairs and Transport Committee's inquiry into coal seam gas mining in the Murray Darling Basin. This factsheet was compiled using publicly available information from various organisations, including state government departments and non-government organisations/companies.

Coal Seam Gas Factsheet #5

Challenges, benefits and risks of CSG production

To resolve the issues of water extraction and fraccing across several development proposals and thousands of wells, and to assess the potential cumulative impacts, requires a good characterisation of the basin geology and hydrodynamics.

There are a variety of methods employed to avoid or reduce the risks associated with coal seam gas (CSG) production and each of these is individually complex (see Factsheet #2 for detailed information on monitoring and management methods).

The levels of risk deemed to be appropriate are established by the relevant environmental authorities and based on the evaluation of risks and hazards. Applying comprehensive science can give insights into the risks associated with individual CSG operations.

Industry uses groundwater models to predict and minimise environmental impacts. However, the modelling of a regional groundwater system the size of the Surat, Bowen or even the Great Artesian Basin is a major challenge especially because of the scarcity of groundwater data in these sparsely populated regions.

The difficulty in the Great Artesian Basin is that groundwater flow velocities are slow, waters are old, and unforeseen consequences of extraction may take decades or centuries to work through the aquifers. Estimating the added impact of CSG production is further complicated by the fact that the region has had a significant history of groundwater extraction, for which the long term impacts have not been fully established.

The overriding issue is the uncertainty of the potential cumulative, regional impacts of multiple developments.

KEY ISSUES

Estimating social and environmental impacts associated with CSG production is complex because of dependencies on a number of factors including:

- the nature of land use in surrounding areas
- the amount, density, and location of surface infrastructure required
- geology
- hydrodynamics
- the type of CSG operations being conducted
- economics and logistics of producing and transporting the gas
- management and monitoring practices in place.

Generally each of these, as well as other factors, need to be considered on a regional and case by case basis when assessing the potential impacts of CSG production.

In many areas of Australia, there has been a substantial history of groundwater extraction, for example, for agricultural use. The long term impact of groundwater extraction remains uncertain, which adds to the complexities involved in estimating the likely impacts of CSG production.

ENVIRONMENTAL IMPACTS

The main environmental impacts associated with the production of CSG relate to the volume and quality of produced water, its treatment and the potential for groundwater contamination.

Water quantity

Generally large amounts of low quality water are produced from CSG operations, although the quantity of water withdrawal can vary during the extraction process from a few thousand to hundreds of thousands of litres a day.

The removal of large quantities of water may affect groundwater flow and may result in reduced groundwater levels in the surrounding aquifer systems. This could potentially impact on communities heavily reliant on bore water and potentially have a long term effect on regional subsidence and productivity of agricultural land.

Water quality and treatment

Water produced from CSG production differs in quality from site to site but is normally high in salt content. It can also contain other undesirable dissolved substances such as sodium bicarbonate and traces of other compounds. Depending on its quality, produced water can be used directly, reinjected into the subsurface, or treated and then used or directly reinjected.

Treatment of the produced water would allow for various surface uses or aquifer recharge, but this is expensive and energy intensive, which may increase the carbon penalty (and cost) of CSG extraction. Treating the water also produces a waste stream of super saline brine that needs to be disposed of or further treated to produce commercially usable salts.

Water use and disposal

The salty nature and commonly poor quality of CSG water could potentially be harmful for soil, groundwater and vegetation quality if it is inappropriately used or disposed of. High levels of salt can potentially affect drainage, damage soil structure and potentially increase susceptibility to erosion. Using saline water for irrigation may change soil structure or cause salt to accumulate in the soil.

Disposal into rivers may lead to increased river salinity or concentrations of metals in organisms. Continual discharge of treated water that is of high quality into rivers can also potentially cause clean water pollution, and may alter the natural concentrations of salts, ions and nutrients of river systems and potentially impact on the ecosystems they support.

Groundwater contamination

Poor management of CSG wells and fraccing operations or failure of CSG wells could result in interactions between the CSG-bearing subsurface layers and aquifer horizons. This may result in aquifer depression, effects on groundwater flow and fugitive gas migrating upwards.

Infrastructure footprint

Each CSG field may have about 20,000 wells to depths of up to 700 metres below the ground (in Queensland developments so far). These wells are often laid out on a grid within a few hundred metres of each other and are connected by a network of roads, pipelines and compressor stations.

Although the surface footprint of coal seam gas infrastructure is comparatively small compared to some industries such as mining, it can potentially compromise the scenic quality and economic viability of the landscape, and it may fragment habitat, displace local wildlife populations and may adversely impact threatened or endangered species in a region.

SOCIAL ISSUES

In Australia, a number of significant CSG fields underlie agricultural land. Social impacts flow from the access and use of competing natural resources and management practices, and the effects of potential environmental damage on the long term viability of agricultural productivity and an associated reduction in property values.

Although CSG projects inject funds into a region during their operation, many regional communities are concerned about long term economic viability after production ceases if the productivity of large areas of agricultural land is reduced or lost. Many of these issues are faced by other industries such as mining.

Other potential social impacts include:

- demographic change, immigration, change in labour markets, availability of services;
- reduction in property values due to visual impact of infrastructure;
- potential increase in traffic and noise pollution on affected properties and areas;
- change to rural amenity and community values;
- feelings of “intrusion” by others on farmers’ land.

POTENTIAL BENEFITS OF CSG PRODUCTION

Natural gas extracted from coal seams offers a number of benefits over other forms of energy production, including:

- Natural gas is typically cleaner burning than coal and usually considered one of the cleanest of fossil fuels, burning much more efficiently than coal or oil and generating approximately 50 per cent less greenhouse emissions than conventional electricity generation. One petajoule (PJ) of gas is the equivalent heat energy content to about 43,000 tonnes of black coal or 29 million litres of petrol.
- Currently most of Australia’s electricity is generated from coal fired power, which is one of the most intense greenhouse gas emitters for power generation. As Australia moves towards a lower carbon economy, natural gas presents an intermediate option for energy production between higher emission coal sources, and lower or zero emission renewable sources.
- Natural gas can be directly used for a broad range of heating uses and for powering fast-response, electricity-generating turbines.
- Australia has abundant resources of natural gas. Geoscience Australia estimates Queensland’s coal seam gas resources at around 150 trillion cubic feet (157,500 PJ) – enough to power the whole of Queensland for more than 1000 years.
- Resources are often close to major markets for distribution.
- Gas is relatively easy to store and can be transported over long distances.
- Natural gas energy typically has reduced emissions of carbon dioxide, nitrogen oxides, sulfur dioxides and other harmful gases (particularly for the industrial and electric generation industries) compared to coal.
- Natural gas energy can cause less smog and acid rain compared to coal.
- Natural gas is a competitively priced fuel for electricity generation.
- CSG production leaves the coal resource intact for future extraction.

- Gas can be piped to a liquefied natural gas (LNG) plant where it can be processed into LNG for worldwide export to assist other countries switching from coal to gas fired power.
- CSG exports can potentially provide benefits to Australia in terms of revenue and jobs.

For further information:

Contact: Dr Glen Walker, Theme Leader, CSIRO Water for a Healthy Country Flagship
phone 08 8303 8743, email glen.walker@csiro.au

Contact: Dr John Carras, Director, CSIRO Advanced Coal Technology
phone 02 9490 8644, email john.carras@csiro.au

Contact: Prof. Mike McWilliams, Chief, CSIRO Earth Science and Resource Engineering
phone 07 3327 4486, email mike.mcwilliams@csiro.au

Please note: the information contained in this factsheet is presented as background material for the Senate Rural Affairs and Transport Committee's inquiry into coal seam gas mining in the Murray Darling Basin. This factsheet was compiled using publicly available information from various organisations, including state government departments and non-government organisations/companies.

GISERA

Gas Industry Social & Environmental Research Alliance

Providing the Australian natural gas industry, government and community with quality assured scientific research.

www.gisera.org.au
gisera@gisera.org.au

CSIRO

AUSTRALIA PACIFIC LNG

GISERA

Gas Industry Social & Environmental Research Alliance

Australia's natural gas consumption is predicted to significantly increase as Australia transitions to a lower carbon economy through greater use of gas for electricity generation purposes, as well as rising energy demands associated with increased population and economic growth.

The CSG industry has been operating in Queensland for more than 30 years and now provides around 90% of its gas supplies and fuels about 15% of the State's electricity generation. This well established industry is now working to advance one of the largest resource developments in Australian history. This is an exciting development for Queensland and Australia as a whole because of the significant economic benefits the coal seam gas (CSG) and liquid natural gas (LNG) industry is poised to deliver.

Additional information about the CSG industry is being called for. Science is well positioned to contribute constructively by helping fill knowledge gaps, reduce uncertainty and inform deliberation and action. The Gas Industry Social and Environmental Research Alliance (GISERA) will play a crucial role here.

What is the Gas Industry Social and Environmental Research Alliance?

CSIRO and Australia Pacific LNG Pty Ltd are founding members of GISERA. An initial investment of $14 million over the next five years will fund research into the socio-economic and environmental impacts of the natural gas industry. This initial focus will be directed at Queensland's CSG-LNG industry but will have potential to expand to address impacts and opportunities associated with different gas industries and geographies.

GISERA will deliver constructive, objective and publicly available research

GISERA will undertake integrated, regional, systems-based research that addresses the impacts of gas developments, drawn from an evidence-based understanding of regional processes and issues.

In the first instance GISERA will explore issues in Queensland related to five topics:

- groundwater and surface water
- biodiversity
- land management
- the marine environment
- socio-economic impacts.

GISERA… establishing the framework for a true research collaborative

GISERA has been designed to expand the membership to other companies both within and outside of the industry, as well as research purchasers and providers such as universities and government agencies. Stakeholders such as agricultural industries and communities will also be sought as members. This will ensure public good research undertaken by GISERA will benefit the broader community and industry.

GISERA's research agenda will be underpinned by strong governance arrangements

A robust governance framework has been designed to ensure the delivery of quality peer-reviewed and publicly available science. Research planning will be overseen by a Research Advisory Committee that will draw on formal and informal advice from a range of experts and interests. Research will be conducted with the active collaboration of a range of regional stakeholders and research reports will be made publicly available following review by CSIRO's rigorous peer-review process.

Why CSIRO?

CSIRO's breadth and depth of research includes social, economic and ecological sciences. This places the organisation in a unique position to provide impartial and integrated research to the industry, regulators and wider Australian community. CSIRO's independence will ensure all knowledge generated from GISERA is made widely available, enabling access by all stakeholders.

Why Australia Pacific LNG?

Australia Pacific LNG is the leading producer of CSG in Australia and holds the country's largest CSG reserves position, currently providing over 40% of Queensland's gas supply. Australia Pacific LNG was instrumental in the genesis of GISERA, partnering with CSIRO to provide impartial and independent scientific research for the benefit of industry, government and community alike. The alliance supports Australia Pacific LNG's principal of creating and operating sustainably. They are the founding member of the alliance with CSIRO.

CSIRO | AUSTRALIA PACIFIC LNG

www.gisera.org.au
gisera@gisera.org.au

www.csiro.au

Coal seam gas

Petroleum and Geothermal Research

CSIRO

CSIRO is working on a range of research projects to enhance the characterisation, production and stimulation of coal seam gas reservoirs and address the environmental impact of coal seam gas production.

As Australia transitions to a lower carbon economy, unconventional gas resources will contribute a significant share of our energy supply.

Unconventional gas, such as coal seam gas (CSG), shale gas, tight gas and basin-centred gas, is generally produced from complex geological systems that require innovative technological solutions for extraction.

By providing optimal technologies for characterising and producing unconventional gas, CSIRO aims to accelerate the deployment of gas production for local domestic use and international export.

Coal seam gas reservoir characterisation

For a number of years CSIRO has been carrying out R&D and application projects on CSG reservoir characterisation in the areas of geological/rock framework, stress, geologic structures, gas content and composition, coal characterisation, permeability, hydrology and water chemistry.

The overarching objective is to improve evaluation of CSG resources and its production using specialist expertise and techniques for integrated resource characterisation. R&D priorities include the assessment of:

- reservoir compartmentalisation relative to geologic structures and in situ stress
- variations in gas content and coal composition, including the causes for variation
- permeability behaviour during gas desorption and pressure drawdown
- fracture stimulation of coal for enhanced gas production
- the effects of coal properties on reservoir characteristics and resource delineation
- the role of microbial gas generation on the resource.

> The triaxial stress rig is used for integrated characterisation of coal permeability behaviour with effective stress and gas adsorption.

Enhanced unconventional gas production

Projects focused on enhanced recovery of CSG are evaluating the feasibility of injecting carbon dioxide (CO_2), nitrogen or flue gas from power stations into the target coal seam. The injected gas displaces the CSG that can then be recovered for energy generation.

Using CO_2 to enhance gas drainage from coal seams has the added benefit of reducing greenhouse gas emissions.

Water management

Large-scale recovery of CSG often leads to production of considerable volumes of water.

CSIRO is assessing the environmental impact of CSG production through projects on monitoring water production, aquifer characteristics and water quality.

Projects are currently in place to monitor the Latrobe Aquifer System in the Gippsland Basin to determine the impact of:

- coal mine dewatering
- conventional oil and gas production
- agricultural groundwater extraction
- fault zone characteristics of the compartmentalisation of aquifer depletion.

CSIRO has developed technologies to help with the removal of brine from untreated CSG water. The Ozone Foam Fractionator Column is a technology developed by CSIRO and commercialised through Impulse Hydro Pty Ltd. The column is part of a desalination process to remove brine from CSG water. CSIRO has also developed a salt management system, the Mechanical Vapour Recompression (MVR), which is very tolerant to Total Dissolved Solids (TDS) and produces an output of almost pure water. We are currently looking at hybridising reverse osmosis and MVR technologies to make a desalination plant that is tolerant of variable TDS with lower energy demands.

Microbially enhanced gas

CSIRO is conducting research to enhance the production of CSG by increasing and stimulating natural microbial activity.

Through an industry consortium project, CSIRO is investigating the use and viability of using micro-organisms to optimise methane generation.

Ultimately microbial technologies and application may enable the conversion of carbon dioxide to methane, providing additional capacity for the geological storage of carbon dioxide.

Reservoir engineering

Reservoir engineering work at CSIRO involves technologies for producing coal seam gas and processes that operate during gas migration within the coal.

Within this initiative, the technical challenges associated with the identification and drainage of CSG are being addressed.

A number of reservoir simulators and models have been developed that examine:

- simulation of gas and water migration
- CO_2 dissolution in water
- CO_2 injection behaviour during storage
- simulation of coupled flow and geochemical processes.

Laboratory experiments on core samples have been used to develop a methodology characterising coal permeability models commonly used for reservoir simulation. New experimental equipment has been commissioned for measuring permeability under stress, gas adsorption and pore pressure.

Hydraulic fracturing

Hydraulic fracturing is widely used to stimulate coal seam gas wells and enhance gas drainage.

To stimulate gas drainage rates from the seam, hydraulic fracturing is being used to place sand proppant into the coal from horizontal gas drainage boreholes in coal mines. The gas can then be more completely and quickly drained (often more than 10 times faster) allowing efficient mining at reduced costs. A similar stimulation process can be applied to surface in-seam CSG wells.

New models are being developed to predict the growth of complex fractures as well as improved calculations of fluid loss from stress and permeability interactions around fractures.

Alternative forms of unconventional gas

In order to evaluate resource potential and assess long term sustainability, CSIRO aims to characterise and improve understanding of all Australia's unconventional gas resources including tight gas, shale gas and basin-centred gas, as well as continuing and expanding the research on CSG.

> Models are being developed within the hydraulic fracturing group to treat nonlinear fluid loss and predict growth of T-shaped and offset fractures.

Getting involved

CSIRO collaborates with industry, research groups, universities and government organisations, developing close partnerships to meet the challenges in CSG production. Diverse capabilities are also integrated from numerous divisions within CSIRO for research in CSG.

Australian and international industry and research partners have the opportunity to work with CSIRO via:

- strategic alliances
- project investment in research projects through:
  - joint industry projects
  - exclusive research projects and services
  - development of new facilities.

Contact Us
Phone: 1300 363 400
+61 3 9545 2176
Email: enquiries@csiro.au
Web: www.csiro.au

ESREfs038-10 Coal seem gas

For further information:
Dr Neil Sherwood
Stream Leader, Unconventional Gas
CSIRO Petroleum and Geothermal Research
Phone: +61 2 9490 8976
Email: neil.sherwood@csiro.au

Ms Corinne Turner
Business Development Manager
CSIRO Petroleum and Geothermal Research
Phone: +61 2 9490 8964
Email: corinne.turner@csiro.au