COAL SEAM GAS PRODUCTION: CHALLENGES AND OPPORTUNITIES

John Williams, John Williams Scientific Services Pty Ltd; Ann Milligan ENRiT: Environment and Natural Resources in Text; and Tim Stubbs, Yellow and Blue Pty Ltd: Environmental and Natural Resource Consulting.

Introduction

Coal seam gas (CSG) is a naturally occurring methane found in coal seams. Australia has sizeable known and inferred reserves of CSG, occurring mainly in the large coal basins of Queensland and New South Wales (NSW). The development of Australia’s CSG reserves will contribute to meeting household, commercial and industrial demand in eastern Australia, and supply export markets.

The rapid expansion of CSG production on the east coast has been the topic of much debate, stemming from apprehensions relating to the social, economic, technical and environmental implications of CSG operations. Communities have been unprepared for this expansion and, in some cases, unwilling to accommodate the industry.

Governments and industry have responded with the introduction of legislation and codes of leading practice to minimise technical failures and protect communities and natural resource assets. However, there is not currently a ‘nationally consistent application of leading practices for the regulation of industry activities’ (SCER 2013).

The National Harmonised Regulatory Framework for Natural Gas from Coal Seams (SCER 2013) offers information about CSG operations for governments, industry and communities, particularly in relation to well integrity, water management and monitoring, ‘fracking’, and management of chemicals. It sets out approaches agreed between the Australian state and federal Ministers responsible for resources, to provide guidance on leading practices for CSG operations, based on state and federal policies, legislation and regulations (SCER 2013).

If carefully regulated and managed, CSG production has the potential to have positive economic and social effects, with minimal damage to the natural environment.

CSG in Australia

Australia started using ‘conventional’ gas (a relatively easily accessed form of methane) in the mid-1960s (APH 2008) and CSG in the last decade. When burnt, gas provides twice the energy of coal per unit of weight, with half the greenhouse effect, and it does not produce by-products such as sulfur, mercury, ash and particulates (Cathles et al. 2012). Gas is expected to play an important role in Australia’s energy supply.

The largest reserves of CSG are in Queensland’s Surat and Bowen basins while in NSW the CSG reserves are relatively small (Figure 1). The largest reserves of conventional gas in eastern Australia are offshore of Victoria and in the Cooper Basin (northern South Australia) (AGRA 2012; Figure 2). Western Australia’s gas demand is supplied from its very large

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1 The ideas expressed in this chapter draw on earlier writings in works published by ACEDD, ACOLA and ANU (listed in the references). In particular, the authors would like to acknowledge use of information and insights provided by John Toomey, ATSE, on the history and technical evolution of methodology in the Queensland CSG industry. The authors also gratefully acknowledge the assistance and advice provided by John Scott of ScottCromwell on interpretation and text to explain the new approach to risk analysis.
conventional gas reserves offshore. These reserves are also shipped as liquefied natural gas (LNG) to meet export demand.

By 2012 annual production of CSG was 252 petajoules in Queensland and 6 petajoules in NSW. This accounted for around 35 per cent of Australian east coast gas consumption (SCER 2013). New capacity to produce LNG is being developed on the east coast of Australia, which will enable export of CSG. To meet known domestic and overseas commitments, including new LNG projects, the rate of drilling CSG wells in Queensland is forecast to intensify during 2014–15 (ACIL Tasman 2012 p. 38).

Figure 1. Reserves of coal seam gas, by basin

![Figure 1](image1)

Source: AGRA 2012.

Figure 2. Australia’s gas resources and infrastructure

![Figure 2](image2)

Source: AGRA 2012.
Coal Seam Gas extraction

Coal seam gas is found in cracks, pores and micropores in coal seams, where it is held in place either as free gas, or adsorbed onto coal surfaces (Figure 3). To extract the gas via wells drilled into a coal seam, the hydraulic pressures exerted by water in the seam and/or overlying aquifers must be reduced. Dewatering these strata by pumping groundwater up to the surface (as ‘produced’ water) releases the CSG. The gas rises at atmospheric pressure to the top of the well where it is collected and fed at low pressure to the treatment plant and then into a high pressure transmission pipeline. In most cases the CSG is naturally of ‘pipeline quality’ and, apart from drying, requires minimal treatment. Seams that have plenty of natural fractures are less costly to develop as sources of CSG than those that are more solid and need to be artificially fractured (‘fracked’) to make passage for the gas.

Figure 3. Schematic of gas within a coal seam

Coal seams likely to be tapped for CSG in Australia occur mostly 250–1000 metres below the ground surface. Most CSG production to date in Australia, particularly in Queensland, has not entailed fracking of the coal seams (contrary to the history of gas production in the United States). However, as Australian production taps into deeper coal seams or those less naturally permeable, the need for fracking2 may increase from the current 10 per cent of wells to upwards of 40 per cent (UTS ISF 2011).

CSG and the environment

Potential for contamination

The potential for various types of leaks and spills has been a major reason for concern about contamination during CSG production. Fracking chemicals can include small amounts of toxic substances, and there is potential that if spilled, or not prevented from leaking, such chemicals may contaminate aquifers or catchments used for drinking water (Batley & Kookana 2012). CSG operators in Australia are required to publicise the names of substances

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2 Fracking is the process of pumping water at very high pressure into the coal seam to force open narrow fractures and keep them open so the gas will flow out when the fracking water is removed. The water (often some of the ‘produced’ water already pumped from the seam) is augmented by ‘proppant’ materials and chemical additives. These have various purposes, including easing the widening process and protecting the equipment involved.
they apply during fracking, and they are increasingly using environmentally friendly chemicals (Batley & Kookana 2012).

Water that has been pumped from a coal seam, whether initially to dewater it, or after use for fracking, is often brackish or saline and contaminated with other substances dissolved from the coal seam itself, such as metals and radionuclides which can be toxic to plants, animals and humans (Vink et al. 2008; Moran & Vink 2010; NWC 2011, 2012; QWC 2012; Batley & Kookana 2012). Concentrated brines (with or without toxic chemicals) produced by treating this groundwater need safe and environmentally sensitive management and disposal—a situation for which industry and governments are seeking solutions.

Contaminated produced water needs careful storage and transport or treatment. It cannot be spilt or leaked into crops, native vegetation, surface waters or shallow and deeper groundwaters (which are connected components of the one hydrological system). Even after treatment of the water, its disposal into natural streams can affect stream ecosystems if not matched to stream temperature and natural flow regimes (Levick et al. 2008; Smythe-McGuinness et al. 2012), which can vary from no-flow to flood.

Ensuring well integrity is an essential element in managing potential effects of CSG operations on groundwater resources. Well integrity refers to the permanence and solidity of the cement casing—the lining of a well. If the cement were to shrink as it ages, there could be potential for unwanted groundwater to leak into the well, or of water or gas into the surrounding strata, possibly causing contamination (TRS RAE 2012; Eco Logical Australia 2013). Auditing of well performance with respect to failure can alleviate public concern about well leakage and loss of integrity (Nikiforuk 2013; NSW CSE 2013). Well integrity has improved in wells installed in the last decade following the introduction of stricter standards for preparing wells.

The National Harmonised Framework (SCER 2013) requires that:

‘Decommissioning and well abandonment must ensure the environmentally sound and safe isolation of the well for the long term. It must ensure the protection of groundwater resources, isolation of the productive formations from other formations, and the proper removal of surface equipment’.

It cites the Queensland Code of Practice for Construction and Abandoning CSG Wells and the NSW Code of Practice for Coal Seam Gas—Well Integrity, both of which are intended to ensure ‘long-term well integrity, containment of gas and protection of groundwater resources’.

Sound well integrity can also minimise leakage of CSG itself into the air—which is a direct emission of greenhouse gas (e.g. Alvareza et al. 2012). Greenhouse gas data for CSG are being collected (Commonwealth of Australia 2013), including the primary sources of emissions and reasons for variance in leakage rates.

**Water management**

Volumes of ‘produced’ groundwater are typically large in the early stages of CSG production, and the volumes of gas released are small. However, later in the life of a well (which can be several years) the water produced decreases and methane production increases (Figure 4). Seams that need fracking may produce less water than other seams.
Dewatering of aquifers or otherwise depressurising coal seams to release gas can be followed by a range of potential impacts (NWC 2012; Osborn et al. 2011; Warner et al. 2012). These are listed in the National Harmonised Framework (SCER 2013) as:

- reduced aquifer levels and pressures with volume and quality implications for other users, groundwater-dependent ecosystems and unwanted surface water interactions with groundwater over the short and long term (intergenerational equity)
- cumulative impacts from multiple projects and local versus regional impacts
- altered hydraulic gradients produce mixing and cross-contamination between different aquifers and between aquifers and surface waters with different quality characteristics
- migration of gas (and its rate) into surrounding aquifers, wells and water bores, and the surface
- reduced water pressure in subsurface layers that enables compression of layers, alteration of hydraulic properties and subsidence at the surface.

There are positive aspects to the considerable volumes of groundwater pumped from CSG wells. Once treated for quality, it can be a resource for sale for irrigation purposes. Use of treated produced water for irrigated agriculture and horticulture has shown promise in short-term trials (Santos 2011; Figure 5). Urban and industrial uses have also been suggested (APLNG n.d.; QEHP 2012).
Alternatively, the produced water may be used for restoring the hydraulic pressure in aquifers that have been over-pumped. Reinjection appears to be a nontrivial process, but it is seen as a leading practice for beneficial use (SCER 2013):

‘Providing treated water to water users as a substitute for current aquifer extractions has the potential to reduce demand on a particular resource provided the current water extraction ceases or is reduced...If water reinjection is adopted by the project operator for either beneficial use as an aquifer recharge mechanism or disposal, the evaluation and risk assessment of the reinjection program should include consideration of potential impacts.’ (SCER 2013)

It is often overlooked that groundwater removed by de-watering will over time be replaced from elsewhere to re-establish hydraulic equilibrium. Reinjection of water into a seam when the CSG has been extracted is one way of managing this.

**Land and biodiversity management**

The rapid expansion of CSG drilling activity also brings some other significant environmental and natural resource challenges (CSIRO 2012; NWC 2012; Williams et al. 2012; Randall 2012), such as:

- loss of biodiversity through fragmentation of habitat and native vegetation in the landscape
- land use conflict and loss of landscape hydrological and ecological functions.

By its scale and nature, the ‘footprint’ of an energy-production field of this type cuts across landscape and biological habitat (Figure 6). Within CSG developments in Australia, average density is approximately 1.1 well pads (and 1.6 kilometres of road) per square kilometre of land (Eco Logical Australia 2012).
It is possible that with time, new technology will let well pads be spaced farther apart. Using Australian-developed technology for guidance of drilling deep underground, it is now possible to drill from a vertical well for more than a kilometre horizontally along a target coal seam (e.g. Metgasco 2013). The fewer the drill pads needed at the surface, even if each is a bit larger, the less the intrusion on other land uses in an area. Multiple wells on a single pad imply fewer inroads and gas-gathering systems.

Establishing CSG infrastructure entails direct removal of native vegetation to allow access and clear a firebreak and workspace around the drilling site. As with any other activity that requires land clearing, this could lead to the introduction of invasive species especially weeds, invertebrates and people, and cut into the home or breeding ranges of native fauna such as lizards and birds. A number of scientific studies have confirmed the negative impacts of fragmentation of bushland, regardless of the activity, on native fauna (e.g. Wiens 1985; Forman & Gordon 1986; Franklin & Forman 1987; Saunders et al. 1991; Ries et al. 2004; Cushman 2006; Fischer & Lindenmayer 2007).

Where a landscape has already been extensively cleared for urbanisation or agriculture, in many cases the vegetation that is left is of high ecological value (Hansen & Clevenger 2005; Fischer & Lindenmayer 2007). Clearing for a single well pad and the associated service road and pipeline may intrude into but not badly fragment a patch of bushland. Clearing enough space for many well pads, roads and pipelines in a single patch of bushland results in cumulative fragmentation and requires careful consideration and attention (Shoemaker 1994; New York City Department of Environmental Protection 2009).
The Native Vegetation Acts in both NSW and Queensland, prior to recent revisions, dealt well with issues of clearing of native vegetation, but CSG operations are exempt from these Acts. If there is a particular threat to threatened species then the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 applies, as does state threatened species legislation. However, these Acts do not easily deal with broad-scale fragmentation and cumulative loss of habitat.

Productive farming for food and fibre is also perceived to be at risk from the cumulative fragmentation and potential resource-contamination impacts of CSG operations. Both fragmentation and contamination reduce the usability of strategic agricultural land and water resources.

To mitigate that situation, the Namoi Catchment Management Authority (CMA) has pioneered a new way to make cumulative analysis of multiple industry development (Eco Logical Australia 2011, 2012, 2013). The Namoi catchment supports a range of productive land uses including irrigated agriculture. It also has large coal reserves and consequently there is significant pressure for additional coal mining as well as CSG extraction. The CMA recognised that mining had the potential to deliver substantial benefits to the region but also that mining (not just CSG) was a potential threat to the natural resource assets of the catchment.

The CMA was able to use its detailed understanding of the natural resource assets of its region, through its catchment planning process, to assess the impacts of any one mining development on the natural resource assets of the catchment and the potentially cumulative impacts of a number of mining developments. The result of this planning process is a strategic vision for the Namoi catchment in the form of a framework inside which a risk assessment process can be undertaken for mining and CSG development. Using this framework (Figure 7) and a GIS modelling tool, the CMA has produced a cumulative risk statement on the individual and cumulative impacts associated with any real or hypothetical mining scenario. A further aim is to enable mining and CSG developers to run a range of scenarios and determine how best to structure their operations to minimise, or remove completely, any negative impacts on the natural resource assets of the Namoi catchment.

**Figure 7. Framework for cumulative risk assessment in the Namoi catchment**

*Source: Eco Logical Australia 2011.*
Like the Namoi CMA, the Murray CMA has now made its own cumulative risk assessment (MCMA 2012), and other catchment management teams across Australia have been applying locally collected data to manage their areas of responsibility in a holistic, cumulative way, via Catchment Action Plans. Where water catchments are managed as whole units (as in Integrated Catchment Management), there are now tested and practical processes and methods available for determining the points at which landscape function\(^3\) will stop being resilient and begin to fail (NSW Natural Resources Commission 2012; Williams 2012).

While extensive grazing would appear to be a form of agriculture better at co-existing with CSG production than dryland and irrigated cropping, the experience in the Namoi catchment suggests a balanced co-existence of mining and the various forms of agriculture and forestry may be possible—with careful management supported by bioregional planning and cumulative risk assessment.

Other examples of cumulative risk assessment have included the Land Use Conflict Risk Assessment (NSW DPI 2011), and methods applied in the Alligator Rivers Region of the Northern Territory (which encompasses mining, indigenous values and conservation; SEWPaC 2011), and the land use impact model developed in Victoria (MacNeill et al. 2006).

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) and the COAG agreement with the States on these matters offer a means by which integrated risk management incorporating cumulative risk assessment could be achieved as part of the bioregional assessment process.

A number of residential communities have also been resisting co-existence with CSG industry development in Queensland and NSW, for a range of reasons including access and nuisance (Poisel 2012; Swayne 2012; Lloyd et al. 2013). With conventional open-cut coal mining, the standard practice for decades has been for the mining company to purchase the land at valuations well above commercial value. As a result, there are rarely any disputes with property holders about access. For CSG, the intensity of well-field developments proposed and the distributed placement and irregular spacing of wells make total acquisition of properties impractical. Under current mining legislation and regulation in Australia, property holders have virtually no ownership rights to minerals (including CSG) below the topsoil.

During 2013, the Queensland Government is expected to revise its ‘land access and compensation framework that governs how resource companies access private land for resource exploration and production’ (Carter Newell 2013). In NSW, in response to rising public concern, recent changes to government policy have restricted the freedom of CSG companies to develop potential gas fields. According to draft legislation being prepared (as at May 2013), gas operations may not proceed within 2 kilometres of residential areas or industry cluster areas in NSW, unless the company already possesses a Development Approval. Companies may have already completed exploration and found a potentially valuable field, but the field cannot be developed any further unless it had received approval before mid-February 2013 (Corrs et al. 2013).

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\(^3\) Landscape function is, for example, the capacity of a hillslope to retain water, resist erosion, and sustain plant growth and cycling of plant nutrients (Tongway & Hindley 2005).
CSG and the community
Nevertheless, a rapidly growing CSG industry in Queensland and NSW has the potential to deliver large social and economic benefits to those States and to Australia as a whole (Rayner & Bishop 2013).

For example, economic studies by the Queensland Government indicated that a medium-size 28 million tonne a year industry converting CSG to LNG could (Queensland Government 2013):

- generate more than 18 000 jobs in Queensland, with 4300 jobs in the Surat Basin alone
- increase gross state product by more than $3 billion or 1 per cent
- generate private sector investment of more than $45 billion
- provide royalty returns of more than $850 million a year, which could help fund schools, hospitals and other vital services.

Likewise, APPEA (Australian Petroleum Production and Exploration Association) claims that in Queensland ‘the gas industry has created about 30 000 jobs in recent years, is working in partnership with more than 4000 landholders, and is today revitalising regional communities’ (APPEA 2013). This contrasts favourably against earlier analyses of likely social and economic benefits from CSG and mining (e.g. Petkova et al. 2009, and references cited in Williams et al. Ch. 4). Those studies suggested that capital cities and large centres would gain while regional and communities and landholders bore many of the costs and negative impacts.

Patterns of social and economic impact appear to depend on size of project, community structure and history, and the extent to which a non-resident work force is involved. The level of local support for resource development including CSG is contingent upon economic benefits and opportunities accruing at the community level (Haslam-McKenzie et al., 2013).

Australian governments hold the gas resources in trust, and seek to gain positive economic and social benefits from these resources. One way in which this happens is via the multiplier effects of a series of successive spending rounds (Figure 8; Rolfe et al. 2011). The size of the economic multiplier in a local or regional area principally depends (Jensen & West 2002) on the extent to which project operators purchase inputs, including labour and goods and services, from the local or regional economy, and the extent to which that money spent in the local or regional economy remains there rather than being spent in larger regional centres.
Figure 8. Possible multiplier effects

Source: Rolfe et al. 2011.

To improve local and regional participation in the benefits of industry development, the federal and several state governments have set up Industry Capability Networks (ICN), in Queensland and elsewhere. State-based ICN consultants who know the resources available locally match project operators with local and regional Australian suppliers, so that regional and local companies and communities can share in the wealth-generating opportunities from CSG (ICN 2013).

In Australia, there is strong industry support for the role of a ‘social licence to operate’ as a complement to the regulatory licence issued by government. From an industry perspective, a social licence to operate is about operating in a manner that is attuned to community expectations and which acknowledges that businesses have a shared responsibility with government and society, to help facilitate the development of strong and sustainable communities.

Given the proposed intensity of CSG development in Queensland over the next four years, particularly in the Surat Basin, extraordinary demands will be made on rural infrastructure, housing, and community services in health and education. As a result, communities are likely to raise concerns about the adequacy of infrastructure. The Queensland Government (2012) has published a guideline for the industry, stating that new developments must have a social impact management plan.

Community health, safety and social well-being have increasingly been considered part of the risk management and social responsibilities of resource development proponents. Companies appear to be rising to the challenge, with Santos, for example, announcing good progress in new housing construction in southern Queensland (Santos 2013).

Several studies of social impacts of mining and CSG have identified issues (see summary in Williams et al. 2012 Ch. 4) such as good communication and transparent sharing of information with the communities, as being critical for improving community understanding and acceptance of new industry. They are critical also for good governance, ongoing management of opportunities, and for policy and planning for investment in hard and soft infrastructure to support it, which will underpin long-term benefits.

With respect to human health, a recent report by the Queensland Department of Health (2013) (drawing on the findings of a Darling Downs Public Health Unit investigation conducted in 2012, along with independent medical assessment and scrutiny), concluded...
that there were no adverse health impacts resulting from CSG operations near Tara, which is
300 kilometres west of Brisbane.

Risks and opportunities in summary
The rapid development of the CSG industry and the subsequent challenges it has faced
highlight risks as well as opportunities for Australia’s legislative approaches, both in
management of social and economic effects of industries, and in balanced use of natural
resources.

There are mechanisms for managing risks to landscape function. However, they are often
not consistent across state and federal jurisdictions or applicable to all landscape users in
the same jurisdiction (ANEDO 2013). In response to this inconsistency and subsequent
community concern, new laws are being implemented specifically to address potential
effects of CSG extraction. The National Harmonised Regulatory Framework for Natural Gas
from Coal Seams (SCER 2013) attempts to remove some of the inconsistencies in
management of CSG across state and federal jurisdictions.

In practical terms, it is important for all involved with CSG operations to understand the
nature of the risks the industry poses. Society and economy depend on the ecological,
hydrological and geochemical processes in the landscape. Their vulnerability to failures of
CSG safeguards, not the calculated probability of failure, defines the level of risk. A new
approach to risk management ‘demotes’ the probability assessment, and promotes
realisation of the importance of the consequences of events (ARPI & ScottCromwell 2013).
This model of risk thinking is consistent with the new cumulative risk assessment approaches
in use in the Namoi and Murray Catchment Management Authorities (MCMA 2012; Eco

The effects of CSG operations on water resources, food and fibre production systems, and
biodiversity can be managed in a whole-of-landscape framework that takes account of long
term cumulative impacts. It involves:

- understanding regional landscape capacity, and determining if there is capacity for the
development without crossing landscape limits
- updating current development approval processes so that new developments can only
  be approved on the basis of landscape limits and the expected cumulative impacts of
  the existing and proposed developments
- using insights gained from whole-of-landscape cumulative risk assessment and aligned
  with the limits and thresholds to landscape function, to establish regulation, leading
  practice, monitoring and compliance arrangements to manage risks.

Building trust is a key to securing a social licence to operate for any major resource project,
including CSG operations, and it is important to have a transparent approach to collection
and dissemination of reliable data (NSW CSE 2013). Communities are more likely to accept
information as credible if it comes from a source perceived to be truly independent (Lacey et
al. 2012; Lloyd et al. 2013). Involving local people and landowners in the collection and
understanding of environmental monitoring data has also been shown to increase trust.

Social research suggests that there are better opportunities for the industry if it makes a
direct financial return to communities most affected by CSG operations, improves
communication and collaboration with stakeholders, and invests in infrastructure. These
approaches facilitate ongoing access and strengthen the social licence to operate. The
challenge for the industry is to articulate an agenda that balances its own commercial needs
in a context of broader expectations about contributions to the development of affected
communities and regions.
Research by the CSG industry and relevant research bodies will benefit regulation and management as well as the industry. There are large areas of Australia where there is only moderate data about the natural resources and features relevant to CSG or other mining operations. The National Harmonised Framework calls for companies to establish baseline monitoring and continue monitoring their areas. Independent research bodies can also contribute by obtaining:

- baseline data against which to measure change
- knowledge, predictive tools and appropriate data for predicting cumulative impact and change so that minor impacts can be prevented from significant consequences.

Australia has the capability to meet the challenges posed by CSG operations and to make the most of the opportunities CSG offers. With modern whole-of-landscape strategic planning in place, supported by effective regulation and governance, CSG production has the potential to deliver positive economic and social benefit, and need not damage the natural environment.

References


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