

Chapter 16

Risks of Coal Seam and Shale Gas Extraction on Groundwater and Aquifers in Eastern Australia

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Abstract In the developed world there are growing concerns about water security due to the increase in exploration and production of coal seam and shale gas in peri-urban areas using both the hydraulic fracturing (fracking) technique of gas production and the method of extraction of naturally occurring groundwater by pumping it from coal formations to release coal seam gas (CSG). In Australia there is a competing prerequisite to maintain and increase the natural resource base as well as the need to protect and sustain the supply of potable and agricultural groundwater in peri-urban areas. One identified issue for this chapter is whether the increasing popularity of fracking in peri-urban and semi-rural areas in New South Wales (NSW) and Queensland poses a risk to the quality of groundwater supply as well as its contamination. The other main issue is whether the extraction of groundwater from coal seams where fracking is not needed has a major impact on groundwater depletion; and, if so, investigating the appropriate risk assessment and risk management approaches.

One problem at hand is that fracking is a technique designed to produce gas from coal seams and shale strata. The process involves pumping water, sand and chemicals under high pressure into layers of coal or shale to create fissures or cracks that force gas to the surface where it is collected and processed. The technique impacts on water supplies in two main ways: It requires large quantities of water at the pumping stage and it is alleged to produce vast amounts of contaminated groundwater containing chemicals known collectively as BTEX, methane gas and excessive amounts of salt. Attractors to this method of gas exploration and production are twofold. The drilling technique invented and developed by George Mitchell in 1980s and 1990s made drilling previously inaccessible strata reachable and cheap.

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The other attraction is that in the United States of America (USA), since 2008 the domestic price of 'Henry Hub' gas has fallen from \$12 per million BTUs in 2008 to \$4 per million BTUs in 2012. The impact of this 66 % fall in price has relieved the USA's reliance on imported carbon based fuels momentarily, but has had a deleterious impact on groundwater supplies.

The evidence based on the development of drilling sites using fracking in NSW and Queensland peri-urban areas so far, suggests that environmental concerns may not be given as much consideration as they ought, in particular because compliance with environmental risk assessments is not specific enough. In this chapter, we explore the above issues and report on a methodology to assess the potential risk to groundwater supplies in NSW and Queensland using an environmental risk model for CSG extraction in combination with the 'triple-bottom line' (TBL) process for community consultation informed by the Global Reporting Initiative (GRIG4) guidelines.

Keywords Fracking • Risk assessment • Groundwater • Energy security • Water security

16.1 Introduction

16.1.1 *The Necessity for Risk Assessment and Risk Management Strategies of Fracking in Peri-Urban Areas*

The two main risk factors to consider for this paper are whether or not the fracking process has the potential to reduce the current volume of and access to groundwater/aquifers in NSW and Queensland particularly in peri-urban areas: The major related issue is the possible impact of fracking on the accessibility and quality of water for human consumption and farming purposes. The other main issue for this paper is to examine the impact on water quantity due to the extraction of CSG by pumping groundwater out of coal seams so that robust pro-active risk assessment and risk management approaches can be examined and recommended.

Overseas experience, in particular in the USA, which has a long time-frame of large scale extraction of mainly shale gas, suggests that the impacts on water quantity and quality in peri-urban areas of Queensland and NSW may be adverse if the development and methods of extraction proceed in a similar fashion. Other issues to consider are whether currently used methods of risk assessment for the fracking process and the drawing of water from coal seams in Queensland and NSW are adequate to protect against potential adverse effects on quality and quantity of water as well as health and other environmental impacts. Currently in NSW peri-urban areas there is very little extraction of shale gas and it is highly unlikely that there

will be significant development in the extraction of shale gas because it is extracted from a hard sedimentary rock with low permeability which does not permit water or gas to exude effortlessly; it has to be fracked which is an expensive and environmentally problematic process. However, there are large and accessible coal deposits in NSW in peri-urban landscapes and at the time of writing these are being considered for the extraction of CSG notwithstanding the recommendations for caution in the Final Report of the Independent Review of Coal Seam Gas Activities in NSW conducted by the Chief Scientist and Engineer, Professor Mary O’Kane and released in October 2014 (O’Kane 2014). According to the Office of Water NSW, prior to the publication of the O’Kane (2014) Final Report:

Coal seam gas does not generally require hydraulic fracturing for its extraction. It is the exception rather than the rule. To date less than 5% of CSG wells in Australia have been fracked, and this figure is unlikely to exceed 10%. (NSW Office of Water 2014)

NSW has an abundance of coal seams (broad estimates by Geoscience Australia proclaim that there are about 41 years of economically accessible coal available) which may or may not require fracking and which according to the Office of Water NSW’s projection is likely to double and this may impact adversely on groundwater quality and quantity (NSW Office of Water 2014). Much of NSW coal is accessible for CSG extraction in peri-urban areas which are close enough to transport to urban or export depots to keep costs down. The other driver is that at the time of writing NSW produces only 5% of its own gas and relies on imported gas for the remainder. In November 2014 an estimated 60% of NSW was subject to CSG exploration licences with an estimated tendering process for a quarter of that land mass which encompasses a large number of peri-urban landscapes (Alderman 2014). Therefore, in all probability, considering the accessibility of coal deposits and a new Premier of NSW in office since 23 April 2014 suggests that the Office of Water NSW underestimates the proliferation of peri-urban fracking sites in NSW. Most of Australia’s identified ‘black coal’ deposits are located in NSW and Queensland: 24% of total coal deposits in NSW and 62% in Queensland (Geoscience Australia 2013).

Most of Australia’s Recoverable Economic Demonstrated Resources (EDR) is located in Qld (59 per cent) and NSW (37 per cent) within four coal bearing, sedimentary basins (Bowen, Sydney, Surat and Galilee Basins). Approximately 31 per cent of Recoverable EDR is located in the Sydney Basin (NSW), 31 per cent in the Bowen Basin (Qld), 13 per cent in the Surat Basin (Qld) and 10 per cent in the Galilee Basin (Qld). (Geoscience Australia 2013)

Nearly all of the coal is accessible for fracking or by pumping groundwater out of coal seams where these methods do not compete with the extraction of coal for mining purposes. The Sydney Basin (Fig. 16.1), or giving its full dimensions, the Sydney-Gunnedah-Bowen Basin which extends from Ulladulla on the NSW south coast to Newcastle on the mid north coast and north-westerly through to Narrabri and into Queensland has five major coalfields, the Hunter, Newcastle, Southern, Western and Gunnedah (NSW Government 2011). In the Sydney Basin in particular a sizeable portion of the coal is found in peri-urban/urban regions such as Camden

Sedimentary Basins

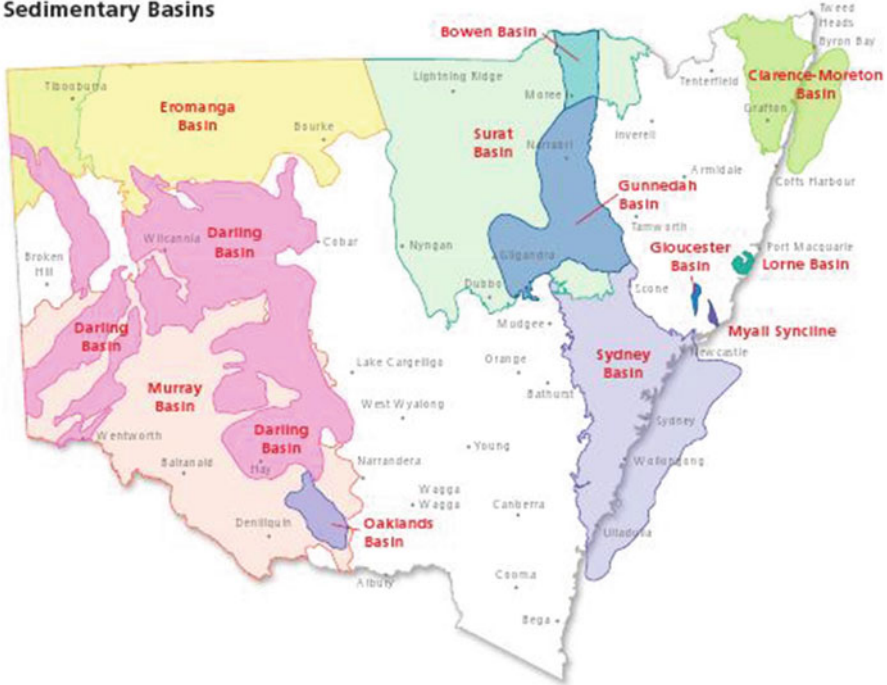


Fig. 16.1 Coal Map NSW 2009 (Source: NSW Government (2011) Atlas of NSW, Geology)

(south west of Sydney) where there are currently 120 CSG ‘well heads’, operated by Australian Gas Light Company (AGL) of which 10% of the 95 tested by the NSW Environmental Protection Agency from September to December 2013 were found to be leaking methane gas, even though AGL’s own previous audit found no leaks (Sydney Morning Herald 2014, p. 5). CSG is also about to be extracted in semi-rural/peri-urban settings such as Gloucester (situated in the Mid North Coast Region of NSW) and Bentley (near Lismore, Northern NSW) where at the time of writing farmers and Green supporters have coalesced to oppose fracking (successfully challenging the development of fracking at Bentley, but not at Gloucester). Similarly, drilling for CSG at St Peters, a western inner-city suburb of Sydney, was abandoned by the energy provider Dart Energy in May 2012 subsequent to objections by residents and Marrickville Council, the relevant local government organisation (Sydney Morning Herald 2012).

Since the installation of the Baird Government in NSW on 23 April, 2014, the cautionary approach to the extraction of CSG using the fracking method seems to have dissipated. In Queensland, both CSG and shale gas are extracted at a higher rate in peri-urban areas than in NSW relying on fracking or by pumping groundwater from coal seams (Queensland Water Commission 2012). Since 2013–2014 CSG

has been the dominant source of gas in Queensland and from 2011 to 2014 about 1100 CSG wells were drilled. Extrapolated from Queensland Department of Natural Resources and Mines (2014) CSG is principally accessed in the Surat and Bowen basins which encompass many peri-urban landscapes reliant on coalmining as well as agricultural activities with the capacity to affect groundwater and aquifers adversely. Accordingly, the essential issues to discuss below are whether or not the process of extracting CSG from coal seams is deleterious to the groundwater above and in the vicinity of coal strata: And, to identify the adverse outcomes and how these may best be subjected to risk assessment and management. For environmental (and safety and health and public health risk exposures) these must be conducted proactively. The undertaking of risk assessments after CSG and shale gas extraction has commenced evades accepted principles of risk assessment and invites avoidable environmental risk exposure.

16.1.2 Groundwater Impacts from the Extraction of CSG and Shale Gas and Prevailing Current Risk Assessment Approaches

According to the 2013 Initial report on the Independent Review of Coal Seam Gas Activities in NSW, conducted by the Chief Scientist and Engineer, Professor Mary O’Kane (2013, p. 2), there are a raft of issues other than those which are the subject matter of this chapter, viz.;

There has been widespread concern about CSG activities across Australia and in particular NSW. The major areas of concern are:

- contamination and depletion of groundwater resources and drinking water catchments
- impacts of the co-produced water from CSG activities on the environment
- impacts on the environment of hydraulic fracturing or ‘fracking’
- impacts on human health from air quality, chemicals, noise, etc.
- rapid expansion of the industry
- land access and landholder rights
- potential impact on property values
- fugitive emissions
- uncertainty of the science, a lack of data especially baseline data and a lack of trust in the data sources
- the industry is moving ahead of scientific understanding and regulation
- cumulative impacts of multiple CSG wells and multiple land uses such as other mining and agricultural activities
- inadequate monitoring by government of industry activity and perceived unwillingness by government to enforce legislation
- complex and changing legislation.

16.2 NSW and Queensland Codes of Practice and Risk Assessment Methodologies

Those major concerns which are specific to this chapter, i.e.; (a) contamination and depletion of groundwater resources and drinking water catchments; (b) impacts on the environment of hydraulic fracturing or ‘fracking’, and; (c) cumulative impacts of multiple CSG wells and multiple land uses such as other mining and agricultural activities, are vigorously contested by opposing interested parties in peri-urban areas as detailed below. What is missing from these concerns and the entire O’Kane (2013) report is an apparent lack of a rigorous all-encompassing pro-active environmental risk assessment tool as well as one that in addition to environmental and economic attributes considers the incorporation of community or social impacts as a risk factor. Instead, the Report recommends compliance with Australian/New Zealand/ISO Standard *AS/NZS ISO 31000:2009 Risk management-Principles and Guidelines* (ISO 31000), a generic risk Standard which although mandatorily required by the 2012 *NSW Code of Practice for Coal Seam Gas Fracture Stimulation Activities* does not include a risk ‘tool’ precluding it from conducting a comprehensive risk assessment unless a risk methodology is incorporated into the already over-complicated risk process of the Standard. In addition, there is no compliance requirement to use ISO 31000 under the 2012 *NSW Code of Practice for Coal Seam Gas Well Integrity* an inexplicable divergence of risk management policy which is discussed further below. In Queensland there are two Codes of Practice (CoPs) which have application to CSG; the *Code of Practice for constructing and abandoning coal seam gas wells and associated bores in Queensland* and the *Code of Practice for coal seam gas well head emissions detection and reporting*, neither of which mandate a specific risk assessment tool. Further, the latter of the two is specific to CSG leaks only whereas the former applies to CSG wells and water bores but, unlike in NSW, there is no CoP which has application to fracking. The lack of specificity relative to fracking in all probability leads to evasion of legal requirements to make the exploration and extraction of CSG safe for groundwater, aquifers and the environment generically.

16.2.1 *The Applicability of ISO 31000 vs. Triple Bottom Line Risk Assessments*

Owing to the complexities and range of direct and ancillary hazards associated with CSG and shale gas extraction, a raft of dedicated risk tools may need to be imported into ISO 31000 to manage the array of risks of fracking and groundwater extraction methods. Due to these complexities the application of one dedicated risk model in conjunction with the Triple Bottom Line (TBL) approach of risk management is suggested below owing to the latter’s capacity to address the environmental, social and economic aspects of CSG and shale gas extraction. However, as with the ISO

31000, the TBL approach, even though it is promoted by Federal government departments as the appropriate risk approach for community consultation, is not mandated at law. TBL was not mentioned in the O’Kane Final Report which is not surprising as it is not mandatory. Even so, there was an implicit recognition that the community should be incorporated into a risk mitigation approach; viz., under the heading ‘There are no guarantees’, the Report (p. 2) opined:

All industries have risks and, like any other, it is inevitable that the CSG industry will have some unintended consequences, including as the result of accidents, human error, and natural disasters. Industry, Government and the community need to work together to plan adequately to mitigate such risks, and be prepared to respond to problems if they occur.

Nonetheless, it may be more appropriate to resort to the Quadruple Bottom Line (QBL) approach which incorporates corporate and public sector governance, as well as environmental, social and economic attributes although like TBL it is not mandatory and is not discussed here.

16.2.2 How the Nature and Location of CSG in Coal Beds Governs Extraction Processes

It is instructional in this regard to acknowledge the terms of reference of the New South Wales Legislative Council General Purpose Standing Committee Report (No. 5) Inquiry into coal seam gas, 2012 which were to inquire into and report on the environmental, economic and social impacts of CSG activities, including exploration and commercial extraction activities, allowable under the NSW Petroleum (Onshore) Act 1991 (the umbrella enabling legislation for minerals exploration). The root causes of how extraction of CSG impacts on water quality and water quantity are inherent to the location and nature of the gas and the processes required to bring it to the surface. CSG occurs naturally during the formation of coal seams in varying quantities and mainly consists of methane developing in the coal.

Methane accumulates during the geological process of coal formation (coalification) when organic plant material is converted into peat and then coal over millions of years due to the pressures of underlying and overlying strata. The methane is confined in the coal seam by the coalification process comes adsorbed to micropores (tiny openings) on the coal surface and held within the natural fracture system, called cleats. The combined pressures trap the methane in place after the coalification process has ended which means that for it to be released it must either be accessed by a vertical well by pumping groundwater from the coal seam or by fracking if it does not exit up the well. Typically coal seams are closer to the surface than ‘conventional’ natural gas reservoirs hence the designation ‘unconventional’ gas for CSG as well as for shale gas which require less drilling.

CSG extraction drilling techniques started to evolve in the 1980s in Australia to extract (bleed) methane from very ‘gassy’ underground coalmines to minimise explosions, initially letting it escape to the surface. However, methane began to be

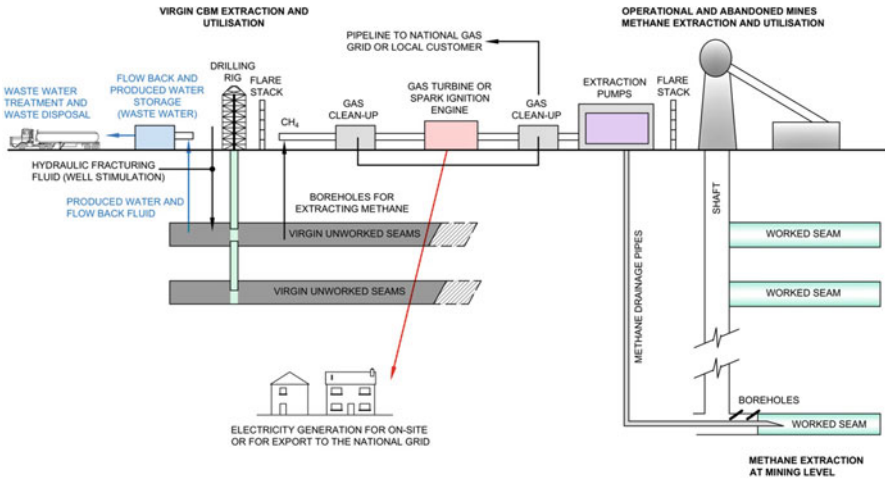


Fig. 16.2 Options for methane extraction and utilisation (Adapted from DTI 2001a) (Source: Environment Agency, UK (2014))

harnessed to pit top turbines from wellheads to produce electricity for mine usage initially, but eventually putting electricity into main grids to create cost offsets. Earlier in the USA these extraction techniques evolved when the USA government offered large tax incentives for the production of CSG to minimise the reliance on petroleum hydro-carbon fuels. Since this period CSG drilling has evolved quickly with the adaptation of traditional oil and gas techniques such as fracking to the already existent coal mining techniques of bleeding methane (Fig. 16.2).

16.2.3 *The Extraction of CSG and Managing the Risks of ‘Produced’ Water*

To extract gas without fracking the pressure of the water in the coal seam must be lowered. This is done by pumping water from the coal seam to the surface through one or more wells. This dewatering process results in significant quantities of saline water, known as incidental or produced water, to be brought to the surface which according to legislative requirements, typically by CoPs in NSW and Queensland, must be safely disposed of. Water that has been pumped from a coal seam to enhance the flow of methane can often be saline or brackish and may be polluted with other substances dissolved from the coal, such as heavy metals and radionuclides, which can be toxic to plants, animals and humans. Concentrated brines (with or without toxic chemicals) found in expelled groundwater need environmental risk management and disposal based on proactive risk assessments (Bureau of Resources and Energy Economics 2013).

Contaminated ‘produced’ water also needs risk immune storage, transport and treatment predicated on proactive risk assessments. Relevant risk assessments may ameliorate and/or prevent spills or leaks into crops, native vegetation, surrounding surface waters, aquifers and groundwater above and underneath the pumped coal seam which may be articulated portions of the same hydrological system. Even after treatment of produced water, its disposal into rivers and creeks can affect stream ecosystems if not matched to stream temperature, constituents and natural flow patterns (Bureau of Resources and Energy Economics 2013). In December 2013, AGL attempted to dispose of produced water from its Gloucester pilot CSG wells by having it transported in tankers to be disposed of at Hunter Water, the state agency managing Newcastle’s sewage network, but which Hunter Water rejected. One of the reasons cited was that, ‘it viewed the dangers as too high to rely on local waste processing sites to remove all potentially harmful chemicals before discharging the remaining water into its network.’ (Sydney Morning Herald 2015).

Ensuring structural integrity of CSG well casings, usually made from concrete, is also an essential element of managing potential impacts of CSG operations on groundwater by conducting proactive risk assessments to manage contamination of groundwater due to cracking, fracturing and shrinkage of the cement casing required under CoPs in NSW and Queensland. Well casing failure could result in ‘produced’ water leaking down the well into surrounding strata causing contamination of aquifers and groundwater (Bureau of Resources and Energy Economics 2013).

The National Harmonised Regulatory Framework for Natural Gas from Coal Seams under the Standing Council on Energy and Resources (SCER) also 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

and:

Sound well integrity can also minimise leakage of CSG into the air a direct greenhouse gas emission. Greenhouse gas data for CSG are being collected, including the primary sources of emissions and reasons for variance in leakage rates. (Bureau of Resources and Energy Economics 2013)

These and other regulations are requirements of relevant NSW and Queensland CoPs are discussed below.

In Queensland CSG was, and is, produced since 1995 from the Walloon Coal Measures of the Surat Basin and the Bandanna Formation of the Bowen Basin from many thin coal seams separated by layers of strata which exude water easily and are known as aquifers using the method which pumps groundwater to the surface. Significantly, the Walloon Coal Measures are a geologic layer of the Great Artesian Basin which comprises layers of lower permeability rocks alternating with aquifers of high economic importance which also feed springs of high ecological and cultural importance (Queensland Water Commission 2012). More water is taken out during ‘unconventional/unnatural’ CSG extraction than during ‘conventional/natu-

ral' petroleum and gas production which, according to the Queensland Water Commission Report in 2012, used 1800 ML of water per year whereas water extraction from CSG was about 18,000 ML per year. According to the Queensland Water Commission Report the combined impact of petroleum and gas extraction on groundwater extraction was deemed significant enough to declare a cumulative management area in 2011 because;

When water is extracted from a gas well, the groundwater levels fall in the area surrounding the well. Where a petroleum well field is established, the impacts extend laterally beyond the extent of the well field. If there are multiple well fields adjacent to each other, the impacts of water extraction from the fields on water levels will overlap. (Queensland Water Commission 2012)

16.3 Fracking and the Potential for Adverse Impacts on Groundwater, Aquifers and the Environment

On the other hand, if gas extraction is slow due to the gas being 'tightly held' within the coal seam, hydraulic fracturing must be used to improve gas recovery. Fracking involves high-pressure injection of sand, water and chemical compounds, the BTEX chemicals (benzene, toluene, ethylbenzene and xylene) into the coal seam to fracture the rock and hold the fractures open to release the gas as with 'conventional' gases such as LPG and LNG that occur in deeper underground porous sedimentary rock reservoirs. The potential for deleterious effects of CSG extraction on water quality and quantity are great although not yet definitively investigated in Australia. Currently, the National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia (the National CSG Chemicals Assessment Project) conducted by the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Department of the Environment and Geoscience, Australia has not yet reported notwithstanding that the assessment was due in 2014 (Australian Government 2014). Even though in NSW and Queensland stricter legislation and companion CoPs have been introduced it seems that the impact of chemicals used for CSG extraction are either intentionally or inadvertently not observed.

In NSW, for example, in 2011 the Government banned the use of BTEX chemicals in CSG fracking fluids and banned the use of evaporation basins for the disposal of CSG produced water (NSW Office of Water 2014). According to the NSW Office of Water (2014), 'The NSW Aquifer Interference Policy was released in September 2012 and ensures that the impacts of CSG and other mining developments on groundwater resources are now subject to greater scrutiny and control'. Whether it is effective, or not, is uncertain. Two CoPs applying to hydraulic fracturing and CSG developments were released by the NSW Government in 2012 to strengthen the controls applying to gas exploration and production. There is also a draft CoP for CSG Exploration.

16.4 Peri-Urban Community Concerns About Fracking in NSW and Robust Legislation

In NSW and Queensland there were and are attempts to evade the legislative and regulatory framework. As the New South Wales Legislative Council General Purpose Standing Committee Report (No. 5) Inquiry into coal seam gas released in May 2012 shows most of these evasions affect peri-urban communities (NSW Parliament 2012). In the Foreword the Chair, the Hon. Robert Brown MLC, from the Shooters Party found generically that;

This Inquiry received nearly 1,000 submissions and took evidence from approximately 130 witnesses. The evidence highlights a number of recurrent themes. With particular reference to property rights, there is a marked lack of equity between landholders and mining companies with regard to land access.

The Committee therefore recommends that the Petroleum (Onshore) Act 1991 [the primary legislation granting CSG exploration licences] be reviewed with a view to strengthening landholder rights and achieving a fair balance between the rights of landholders and coal seam gas operators. The practices of coal seam gas companies are variable at best, and on the whole have been less than acceptable. This was the case not only with regard to negotiating land access, but also with regard to community consultation.

The actions of successive NSW governments also leave room for improvement. Governments have not done enough to provide accessible and factual information about the development of the industry, which has contributed to a high level of alarm amongst communities affected by coal seam gas exploration. In addition, it is clear that the industry's development has outpaced the ability of governments to regulate it, particularly in relation to technical practices such as the storage and disposal of 'produced' water and fracking [*sic*] fluids. To address the concerns around fracking, the Committee recommends that the ban on fracking remain in place until the National Industrial Chemicals Notification and Assessment Scheme assesses the safety of fracking chemicals. The Government also needs to do more to monitor the industry and ensure compliance with the regulatory regime. (NSW Parliament 2012 p. xiii)

Specifically, 35 recommendations were made. Word length considerations only permit those most relevant to the subject matter of this paper.

The key issues considered in this report, and the Committee's recommendations, are summarised in the following paragraphs:

Water

A key question faced during this Inquiry was whether coal seam gas activities could contaminate or deplete water resources. The scientific evidence on this question is contested. The Committee considers that the uncertainty about the likelihood of these impacts occurring underscores the need for more data to be gathered and analysed in regions where exploration is taking place. To this end the NSW Government should actively engage with the Commonwealth's Independent Expert Scientific Committee, and request that regional-scale water assessments be finalised as a matter of urgency in regions where exploration is taking place (Recommendation 1). In addition, some of the data needed to assess cumulative water impacts is held by coal seam gas companies and is considered by some coal seam gas companies to be commercial in confidence. Gaining access to this data should be a priority for the Commonwealth's Independent Expert Scientific Committee (see also Recommendation 1).

Fracking

Inquiry participants expressed particular concerns about fracking and its potential to heighten the risks of water contamination and depletion. It would be premature for the Government to lift its moratorium on fracking before the chemicals used are tested, and a stringent regulatory framework is put in place. The Committee is also concerned that any leaks or spills of fracking fluids or produced water could contaminate water resources. The Committee therefore recommends that the open storage of fracking fluids and produced water be banned (Recommendations 8 and 10).

Remediation

Coal seam gas companies must be held accountable for remediation in the event of deleterious environmental impacts. The Committee recommends that an effective model be developed to hold coal seam gas companies to account for the full costs of remediating any potential environmental impacts, such as water contamination or depletion, even if such impacts occur decades into the future p. xiv.

Community Engagement

A number of Inquiry participants, and key stakeholders such as local councils and indigenous communities, are disgruntled about the lack of genuine community engagement in relation to the coal seam gas industry in New South Wales. In many instances community consultation appears to have been inconsistent, poorly timed and restrictive. As one means to improve its engagement with regional communities, the Committee recommends that the NSW Government establish regional 'shop fronts'.

Land Access and Compensation

Many Inquiry participants are concerned that coal seam gas companies will take an aggressive approach to enforcing their access rights. Despite evidence to the contrary from several coal seam gas companies, the Committee cannot dismiss the evidence that some operators have attempted to pressure landholders for access, nor the possibility that companies may force access in the future. As such, the Committee believes that the Petroleum (Onshore) Act 1991 must to be reviewed with a view to strengthening landholder rights (Recommendation 16) p. xv.

Agriculture

Numerous Inquiry participants said that coal seam gas development cannot coexist with agriculture and food production in many areas across the State, and called for 'no go' zones to be established. However other Inquiry participants, such as the NSW Government, called for 'balanced coexistence' between resource development, agricultural production and environmental protection. To achieve 'balanced coexistence' the Government has developed Strategic Regional Land Use Plans. The Committee is concerned that only two Plans have been completed to date, and recommends that the development of the remaining Plans, including for coastal areas, be expedited (Recommendation 24) p. xvi.

Regulation

Inquiry participants identified a number of claimed deficiencies in the regulatory regime including fragmentation across government agencies, inadequate monitoring and enforcement, ineffective complaints handling, and insufficient resourcing. In addition, there is a potential conflict of interest in the role played by the Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS). To address these deficiencies, the Committee has therefore made several recommendations, drawing on Queensland's experience of regulating the coal seam gas industry.

The Committee recommends that a new Industry Unit be established within the Division of Resources and Energy, DTIRIS. The Unit should function as a 'one-stop-shop' on coal seam gas issues responsible for issuing licences, driving policy development and acting as a 'knowledge bank' within Government. In addition, a new Compliance Unit should be established in the Environment Protection Authority with responsibility for monitoring coal seam gas activities, investigating incidents, and taking enforcement action where required (Recommendation 31).

As noted by the Ombudsman, there are 'obvious challenges' for DTIRIS in its responsibilities for promoting the industry and issuing licences, as well as conducting monitoring and enforcement activities. There should instead be a clear division between the agency or agencies responsible for monitoring the coal seam gas industry to ensure compliance with industry regulation, and taking enforcement action where required, and the agency or agencies charged with supporting the industry's development and issuing licences. NSWLC Inquiry into coal seam gas (2012) p. xvi

In other words, to counteract the perceived conflicts of interest of DTIRIS' functions of being a development consent body which also provides paid industry services that partially fund its operations. Aside from the need to address fragmentation, the Committee considered it imperative that the Government act to address the potential conflict of interest in the role played by DTIRIS.

16.5 Peri-Urban Community Concerns About Fracking in Queensland and Robust Legislation

In Queensland community concerns in peri-urban areas about fracking also resulted in increased CSG-LNG legislation and enforcement. Briefly, according to the Queensland Government Business and Industry portal;

The Queensland Government has put in place laws to:

- Protect groundwater and the Great Artesian Basin – Landholders and rural communities depend on groundwater and the Great Artesian Basin. The Office of Groundwater Impact Assessment (OGIA) provides the groundwater management functions previously carried out by the Queensland Water Commission. OGIA is responsible for assessing potential future cumulative impacts on groundwater and developing management responses that help to minimise those impacts.
- Adopt a precautionary approach – The Queensland Government has introduced an adaptive environmental management regime. This allows for the alteration of environmental conditions placed on a project on the basis of new information and/or research as it becomes available.
- Control water quality – The Queensland Government has banned the use of evaporation dams and strengthened conditions around the treatment and use of CSG water. These measures further protect the Great Artesian Basin, creeks and rivers, and farming land.
- Prohibit harmful chemicals – CSG operators are not allowed to use the petroleum compounds benzene, toluene, ethylbenzene and xylene – also known as BTEX – as a deliberate component of hydraulic fracturing fluids.
- Protect landholders' water quality – CSG operators must measure the water quantity in landholders' water bores before CSG activities start and during CSG extraction. This provides baseline information for monitoring impacts over time and compensation if bores are affected.

Also a range of enforcement tools and penalties are in place to deal with environmental incidents and compliance breaches. The Queensland Government has also

established the CSG Compliance Unit (formerly the LNG Enforcement Unit) to monitor CSG operators and ensure that they are in compliance with industry laws and regulations (Queensland Government Business and Industry Portal 2014).

16.6 The Impacts of Predicted Large Scale Development of Shale Gas in Queensland

Relative to contested concerns about the economic benefits, such as thousands of jobs especially in regional and peri-urban areas, expressed during the NSW Legislative Council Inquiry into CSG, albeit in shale gas, recent proposed expansion in shale gas exploration in Queensland seems to contradict the predictions of the Inquiry. The first shale gas well in Australia began operation in the Cooper Basin in South Australia in October 2012. According to the United States Energy Information Administration's (EIA) 2013 survey of world shale deposits, Australia has great potential for the production of shale gas: 'With geologic and industry conditions resembling those of the USA and Canada, Australia has the potential to be one of the next countries with commercially viable shale gas and shale oil production' (Ross and Darby 2013, p. 9).

Whereas probably Queensland is the most promising potential source of shale gas, a study of shale gas in Australia found that while it is likely to be plentiful in Australia, the lack of infrastructure in this country (relative to the United States) is likely to add to production costs making shale gas production less feasible (Cook et al. 2013). However, more recent private sector estimations of Queensland's prospective shale gas deposits in January, 2014 have solicited the following article in Bloomberg news online, headed, 'Shale's 'Next Big Play' Draws U.S. Gas Producer to Australia.' It was qualified with the tag-line '...shale-s-next-big-play-draws-magnum-to-australia-s-cooper-basin.html.'

Paton (2014), a Bloomberg on-line correspondent, reports:

Australia has the most attractive shale gas prospects outside North America, according to Magnum Hunter Resources Corp. (MHR), a Houston-based producer that says it has scoured the world looking for deposits of the gas that has revolutionized energy supply in the U.S.

Paton (2014), quoted Kip Ferguson, executive vice president of exploration at Magnum Hunter Resources Corp, who said in an interview in Sydney:

We've looked at Colombia, we've looked at Mexico, we've looked at Argentina, we've looked at Poland, and we've looked at China of course. 'None of those areas are prepared to allow the unconventional technologies to develop these plays. They aren't as far advanced as Australia.' (Paton 2014)

Further;

The Cooper Basin, an area straddling the border of South Australia and Queensland states, has also lured investment from Chevron Corp. and BG Group Plc (BG/) ahead of expected shortages of the fuel to feed more than \$60 billion of liquefied natural gas projects in eastern Australia that will ship to Japan, South Korea and China.

With such determined intentions of massive capital investment and proposed economic benefits, the contested terrain between major regional economic development and potential large scale vitiation and diminution of available groundwater remains unresolved. Furthermore, with the gradual contraction of infrastructure projects in the Australian minerals sector, dwindling coal prices and exports in Queensland and NSW (and iron prices in WA), as well as the downscaling of China's economic growth, economic pressures on state governments may result in a softening of state CSG and shale gas environmental regulation affecting peri-urban areas. This is so, notwithstanding recent improved legislation and regulation in NSW and Queensland relative to groundwater quality and quantity. It is not suggested in this paper that these governments are biased towards private sector CSG and shale gas companies, but that economic reality will have to prevail perhaps to the detriment of the environment. Notwithstanding the take-up of CSG and shale gas extraction, the risks associated with the processes remain and the risks must be comprehensively assessed, but more importantly they must be managed to avert the vitiation of groundwater and aquifers as well as addressing the impacts on communities in peri-urban locations as most CSG and shale gas development is likely to occur near these.

16.7 Complexity of Assessing and Managing Risks for CSG and Shale Gas Extraction

As outlined above, the process of assessing and managing risks associated with the extraction of CSG and shale gas is complex because there is no one comprehensive CSG and shale gas specific risk assessment approach that encompasses community concerns and consultation and the entire CSG shale gas extraction process. In addition, as outlined above, in NSW there are two contradictory risk assessment requirements. Similarly, in Queensland there is no all-encompassing risk assessment methodology that addresses all of the above concerns. Complications also arise in both jurisdictions because of the competing interests of gas producers and communities and the highly politically charged government decision making processes. As explained above, governments are caught between an economically driven imperative to extract CSG and shale gas and a community objective to prevent the vitiation of potable water, groundwater and aquifers.

Relative to divergence of the two legislatively mandatory NSW (CoPs) there are contradictory risk assessment requirements for fracking and gas wellhead extraction methods: On the one hand the *Code of Practice for Coal Seam Gas Fracture Stimulation Activities* requires a Fracture Stimulation Management Plan (FSMP) that must be in place prior to the commencement of a fracture stimulation activity and, on the other hand, 'The FSMP is a non-technical document which is designed to demonstrate to the NSW Government and other stakeholders that the titleholder will appropriately manage the risks associated with the fracture stimulation activity

and comply with the mandatory requirements of this Code' (NSW Government 2012a, b, p. 2). Further, mandatory requirements of the CoP are:

The FSMP must demonstrate that all risks to the environment, existing land uses, the community and workforce, as a result of the fracture stimulation activity, are managed through an effective risk management process that includes identification of hazards, assessment of risks, implementation of control measures and monitoring of the integrity and effectiveness of the control measures. (NSW Government 2012a, b, p. 2).

In addition, 'The FSMP should incorporate a risk assessment conducted in accordance with relevant Australian or international standards to identify the risks posed by the fracture stimulation activity and to ensure that the likelihood and consequence of these risks is properly understood.' And as a mandatory requirement, 'The FSMP must include a risk assessment complying with AS/NZS ISO 31000:2009 Risk management – Principles and Guidelines (NSW Government 2012a, p. 5).' On the other hand, contradictively under Section 16 of the COP 16, Application of Australian and international standards under mandatory requirements states that;

Titleholders must comply with the following standards in so far as these standards are of an equal or higher standard than those identified elsewhere in this Code and do not conflict with the NSW regulatory framework: a) AS/NZS ISO 31000:2009 Risk management – Principles and guidelines; b) NSW Code of Practice for Coal Seam Gas Well Integrity. (NSW Government 2012b)

This declares that compliance relies on the higher criteria of Standards which are erroneously not identified in the CoP and on risk management standards in the NSW Code of Practice for Coal Seam Gas Well Integrity (NSW Government 2012b) which does not mention ISO 31000 at all. The latter CoP only refers to a generic risk assessment. Therefore as a result, the implication is that if the mandatorily required risk assessment based on ISO 31000 is not implemented there is no infringement of the NSW regulatory framework. Consequently, owing to the fact that no specific risk assessment is required by either of the two relevant Queensland CoPs, better risk management outcomes may be produced by implementing an environmentally specific risk assessment approach in conjunction with TBL.

16.8 Limitations of ISO 31000 to Assess Risks of CSG and Shale Gas Extraction

ISO 31000 has been heavily criticised. For example, typical critiques are:

Initial reviews of the ISO 31000 have been promising. Touted as a well-written standard, the layman's terminology used transcends limitations of other standards directly written for existing Risk Management executives and professionals. Easily understood by layman and executives alike, the ISO 31000 offers companies a process-oriented manual easily utilized company-wide. However, drawbacks of the ISO 31000 Risk Management Standard include:

- Not control-oriented/does not offer practical implementation tools for Risk Managers to create reliable risk data

- Complete risk identification is not guaranteed
- No risk taxonomies, heat maps or templates provided
- Published without certification.

The ISO definition would seem to suit the relatively simple ‘business’ risk situations rather than the broader and far more complex multi-dimensional relationships that exist with the risks posed to communities in emergencies or disasters. Risk Management-ISO 31000 (2013)

In addition, ISO 31000, while strong on communication and consultation attributes, does not have a risk assessment capability which makes the laborious process of imported risk tools necessary (as noted above). Furthermore, ISO 31000 does not include the identification of hazards, nor does it recognise hazards; a critical flaw in the requirements for robust risk assessment for environmental (and occupational safety and health) management. Further, as noted above, because it is mainly focused on organisational risks it recognises risk as positive and negative: Whereas for environmental (and occupational safety and health) purposes all risks are always negative; there is no such thing as a positive risk. Therefore it would seem imminently sensible to ‘marry’ a dedicated ‘hard’ environmental risk assessment (ERA) for environmental and community risks such as the tool developed by the United Kingdom (UK) Environmental Agency for coal bed methane CBM (known in Australia as CSG) and enhanced coal bed methane (ECBM) which in the UK is the recovery of CBM by injecting carbon dioxide, nitrogen and/or chemicals (known in Australia as hydraulic fracturing or fracking), with the ‘soft’ TBL social, environmental and economic attributes.

The reasoning underpinning the joining of the two approaches is that while the UK Environmental Agency ERA tool is robust in identifying environmental and community hazards as well as risks, it does not include consultation with affected communities, nor does it consider the social and economic costs that might impact on communities affected by CSG extraction whereas TBL does.

16.9 The Efficacy of the United Kingdom Environmental Agency ERA Tool to Assess and Manage Risks for CSG and Shale Gas Extraction

As well as CBM and ECBM the UK Environmental Agency ERA tool also applies hazard identification and risk assessments for coal mine methane (CMM) recovery for operational coal mines as well as for abandoned mine methane (AMM) after coal mines cease operations. Each of these is subject to the same iterative risk assessment process discussed here only for CBM and ECBM and as an example of the ERA process only the CBM process is mentioned here. Briefly, the ERA covers the following stages which may apply to each phase of CBM production (Fig. 16.3) including the exploration, appraisal, operation and abandonment stages:

- groundworks
- water acquisition

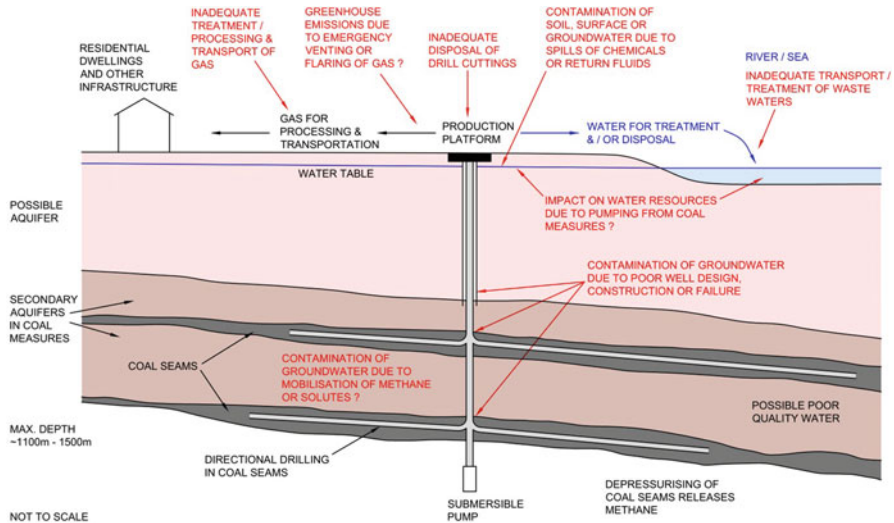


Fig. 16.3 Potential environmental risks from CBM production activities (Source: Environment Agency, UK (2014))

- chemical mixing
- borehole design, installation and integrity
- hydraulic fracturing
- management of fluids, including produced water and flowback fluids
- gas management including onsite compressors, combustion plant, and clean-up plant
- land stability
- well closure and abandonment

A well-established approach to determine the potential risks from CBM production was adopted using a standard source–pathway–receptor model. This approach can be summarised as follows:

- identification of hazards
- identification of consequences
- estimation of the probability of the hazards occurring
- estimation of the magnitude of the unmitigated risk with industry standard controls in place
- identification of risk management options
- estimation of the residual risk after the use of regulatory controls

To aid this process a conceptual model of the environmental risks posed by a single well pad and borehole was produced. This model, which is shown in Fig. 16.3, identified the main sources, pathways and receptors presented during the CBM lifecycle (Environment Agency, UK 2014, p. 8).

16.10 The Risk Magnitude Matrix: Calculating Risk Scores from Probability and Consequences

Risks are then classified according to the magnitude of risk premised on the magnitude of unmitigated risk which is a combination of the probability or likelihood of an event occurring and the consequences or severity for people and the environment if it does. The accompanying risk magnitude matrix has a vertical consequence column which ranges from very low, low, medium through to high whereas the horizontal rows of probability columns also range from very low to high in various permutations in each of the subsequent horizontal rows (Table 16.1). Three colours are used to indicate combinations of consequences and probabilities; light blue for low; yellow for medium and orange for high. Definitions of probabilities are; very low – rarely encountered, never reported or highly unlikely; low – infrequent occurrences; medium – can be expected to occur several times per year; high – repeated occurrences: Whereas definitions of consequences are; very low – slight environmental effect that does not exceed a regulatory standard; low – minor environmental effect which may breach a regulatory standard, but is localised to the point of release with no significant impact on the environment or human health; medium – moderate, localised effect on people and the environment in the vicinity of the incident; high – a major environmental incident resulting in significant damage to the environment and harm to human health (Environment Agency, UK 2014, p. 9).

16.11 Qualitative vs Quantitative Risk Assessment Approaches

The methodology of combining probabilities and consequences to determine a qualitative risk category instead of a quantitative score is commonly used for environmental and occupational safety and health risk matrices and is an acceptable practice worldwide as is the use of the intensity of colour to indicate the magnitude of risk. What is missing from this approach is frequency and duration of risk exposure in combination with consequence and probability, and therefore arguably the approach is only bi-dimensional and too unsophisticated in that it also should consider

Table 16.1 Risk magnitude matrix

Consequence	Probability			
	Very low	Low	Medium	High
Very low	Low	Low	Low	Low
Low	Low	Low	Medium	Medium
Medium	Low	Medium	Medium	High
High	Medium	Medium	High	High

Source: Environment Agency, UK (2014)

frequency and duration. Undisputedly, irrespective of probability and consequences these will expand the magnitude of risk exposure if frequency and duration increase. Consequently, the risk of probability and consequences will increase. Notwithstanding, arguably countervailing the bi-dimensionality of the approach is its easiness in that almost anyone from a worker to a senior manager can use it quickly to provide instantaneous risk assessments unless they are illiterate and/or colour blind. Similarly, small mining contractor businesses could use it after a small amount of training. Also, it’s relatively easy application to a multitude of risks stands in sharp contrast to ISO 31000 which could take weeks or even months to assess risks of this nature. Further, the complex numerous requirements and large process cycles of ISO 31000 is more suited to large organisations and probably are too unmanageable for small businesses.

The results for environmental risks categorised in the Risk Magnitude Matrix are then summarised in separate tables for CBM, AMM and CMM for overall risks for those three categories in terms of the exploration, appraisal, operation and abandonment phases of the CBM/CSG extraction process comprising risk assessments of overall environmental risks (Table 16.2 portrays a partial overview of the extent of major risk exposure categories which in total number more than 40).

Table 16.2 Overall environmental risks – coal bed methane

	Exploration	Appraisal	Operation	Abandonment
Source (hazard) – what is the agent or process with the potential to cause harm?	Negative environmental impact to water as a resource, wildlife and their habitats, the atmosphere, human health, property and infrastructure caused as a direct result of an activity undertaken as part of one of the four phases of CBM extraction			
Pathway – how might the receptor come into contact with the source?	Uncontrolled release of pollutants to ground, air or water, physical disturbance of ground or infrastructure			
Receptor – what is at risk?	Groundwater, surface water, wildlife and their habitats, the atmosphere, human health, property and infrastructure			
Harm – what are the harmful consequences if things go wrong?	Breach of an environmental standard; loss or damage to a habitat or resource; injury, ill health or death; damage to property or infrastructure; air pollution			
Probability of exposure – how likely is this contact?	Low	Medium	Medium	Low
Consequence – how severe will the consequences be if this occurs?	Medium	Medium	High	Low
Magnitude of risk – what is the overall magnitude of the risk?	Medium	Medium	High	Low

(continued)

Table 16.2 (continued)

	Exploration	Appraisal	Operation	Abandonment
Justification for magnitude	The process is new to the UK and its particular geology. There is mixed evidence from overseas activity. Independent experts note the potential consequences are high if the process is not regulated properly or industry best practice is not followed			
Current regulatory controls – on what regulatory basis can the environment agency impose controls?	Water Resources Act 1991			
	Water Framework Directive (2000/60/EC) Groundwater Daughter Directive (2006/118/EC) Mining Waste Directive (2006/21/EC)			
	The Environmental Permitting (England and Wales) Regulations 2010 (as amended)			
	Control of Pollution (Amendment) Act 1989			
	The Waste (England and Wales) Regulations 2011 – registration of waste carrier and brokers			
Current regulatory controls – on what basis can others impose controls?	Town and Country Planning (Development Management Procedure)(England) Order 2010			
	Town and Country Planning (Environmental Impact Assessment) Regulations 2011			
	The Environment Agency is a statutory adviser to the Minerals Planning Authority on planning applications and Environmental Impact Assessments			
	Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996			
	Borehole Sites and Operations Regulations 1995			
	The Hydrocarbons Licensing Directive Regulations 1995			
	The Petroleum Act 1998			
Residual risk –what is the magnitude of the risk after management?	The Coal Industry Act 1994			
	Low. The Environment Agency will use appropriate controls under the legislation above (where it is the competent authority) to manage the identified risks, supported by monitoring and compliance work (for example, site inspections)			

Source: Environment Agency, UK (2014)

16.12 TBL Incorporating GRI Social, Environmental and Economic Assessment Indicators

Owing to the fact that there are no standardised formats for the application of TBL, a suitable approach should be chosen and the most appropriate come from generic sustainability models. There are many sustainability assessment methodologies for evaluating the performance in the extractive industries including CSG and shale gas mining organisations. Those that stand out are the Global Reporting Initiative (GRI 2002; updated in 2013 to GRIG4) and development of standards (OECD 2002), the key drivers for adoption of sustainability management in economies globally (Singha et al. 2012 p. 282). TBL in terms of social, environmental and economic assessment is compatible with GRI which since 2003 has been endorsed by the Business Council of Australia which represents a large number of major companies that in Australia use GRI in conjunction with TBL. It is also used worldwide (BCA

2013). However, TBL does not inherently possess the metrics that are necessary to produce quantitatively measurable data. Nonetheless, as well as environmental attributes found in GRI and ERA and social and economic features inherent to GRI and TBL, each of these and other related features must be measurable. Qualitative data gathered for the social, environmental and economic attributes of TBL is measurable providing that recognised methods, such as community semi-structured focus groups, mixed method survey instruments with scaled items, such as Likert scales, as well as open ended qualitative items are used. Azapagic (2004) developed a framework for sustainability indicators for the mining and minerals industry which is also compatible with GRI (Singha et al. 2012, p. 282). Significantly, it is also fully compatible with TBL. Indicators and composite indicators are increasingly recognised as a useful tool for policy making and public communication in conveying information on a country's performance in fields such as environment, economy, society, or technological development' (Singha et al. 2012).

16.13 Composite Indicators for Sustainability

The construction of composite indicators involves the selection of various methods/tools at different stages. 'However, this may result in various issues of uncertainty due the selection of data, erroneous data, data imputation methods, data normalisation, standardisation, weighting methods, weights' values and aggregation methods' (Singha et al. 2012, p. 287). Yet, in the literature implementing composite indicators is regarded as the most appropriate way for evaluating sustainable development.

Composites indices can be constructed with or without weights depending on its application. Indices are very useful in focusing attention on and often simplify the problem. Use of uncertainty and sensitivity analysis can assist in identifying the gaps and check the robustness of the composite indicator, which further enhances the transparency and credibility of the indices. Tools for sensitivity analysis should evaluate the output variation in models and also be able to apportion composite indicator quantitatively or qualitatively, to different types of variation in the study (Singha et al. 2012 p. 287).

Therefore, for the purposes of this paper composite sustainability indicators are chosen, drawing on the ERA, as the principal environmental tool, in conjunction with GRI indicators as the preferred methodology to inform the social, environmental and economic attributes of TBL when applied to peri-urban well development and CSG extraction.

16.14 Conclusions

This chapter has briefly detailed the complexity of the contest between energy security and groundwater security owing to the potential increase in coal seam and shale gas projects in NSW and Queensland peri-urban areas. Competing environmental

and economic imperatives, briefly outlined above, may determine that Australia's scarce groundwater supplies could be adversely impacted. On the one hand, the projected decline of the Australian minerals and boom suggests that alternative, possibly cheaper, supplies of 'unconventional' gases may provide a much needed boost to the Australian economy, in particular in the labour market in regional areas where hitherto small towns may be at the forefront of peri-urban expansion as a result.

In some locations in NSW, and more so in Queensland, peri-urban development is already evident, in the first instance due to the increase in coal mining production, and to a smaller degree in CSG and shale gas exploration and to a lesser extent in production. However, this paper has suggested that due to the seemingly unavoidable entry of large scale overseas CSG, and especially shale gas, producers, the production of shale gas will increase exponentially in peri-urban areas in particular. Accordingly, unless legislation and Codes of Practice are strictly adhered to by these producers and/or rigorously enforced by government the evidence produced in this paper proposes that the impacts on groundwater could be severe. In addition, pro-active robust all-encompassing risk assessment and management is essential in this regard.

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