

**Submission
No 457**

INQUIRY INTO COAL SEAM GAS

Organisation: Northern Illawarra Sustainability Alliance

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A Submission to the NSW Upper House Standing Committee (No.5) Inquiry into Coal Seam Gas



A Call for Coal Seam Gas Mining to be Excluded from the Areas of the Sydney Metropolitan Catchment Management Authority, including the Sydney Catchment Authority Special Areas



A Call for NSW to be Australia's Leading Renewable Energy State

This submission is made with the support of the following community groups:



Illawarra Residents for Responsible Mining



Lock the gate



**National Parks Association of NSW
Illawarra, Macarthur and South Sydney
Branches.**



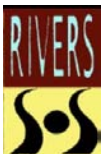
Northern Illawarra Sustainability Alliance



Stop CSG Sydney



Otford Eco



RiversSOS



Stop CSG Illawarra



Sutherland Climate Action Network



Sutherland Shire Environment Centre



Wollongong Climate Action Network



Stop CSG Sutherland

Botany Bay and Catchment Alliance

Georges River Environmental Alliance

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Summary of Key Points

- CSG mining threatens catchments, prime agricultural, high conservation value land, important ecosystems and habitats with land clearing, produced water spillage and leakage, aquifer contamination and draw-down, fracking chemicals, de-watering and fracking triggered subsidence, mini-earthquakes, and fugitive methane emissions risking fires and compounding climate change. The Precautionary Principle of Ecologically Sustainable Development should be applied, as provided for by The Environmental Planning and Assessment Act 1979 (NSW). That is, coal seam gas mining should be excluded from these key areas in the interest of water and food security, conservation and biodiversity.
- Remediation of contaminated aquifers and subsidence caused or compounded by CSG mining may not be possible. Subsidence would compound the impacts of dewatering and hydraulic fracturing, resulting in water quality and quantity loss, and methane emissions.
- Abandoned CSG exploration and mining wells pose an on-going threat, with evidence suggesting casings and/or cement may fail within 80 years. This would cause aquifer contamination and methane release. Subsidence or an earthquake could simultaneously rupture many abandoned wells.
- The CSG industry has a record of accidents, failure, obfuscation, denial and over-confidence. Improved regulation may reduce accidents and failure, but they will not be eliminated. Assessments and assertions from the gas industry should be treated with the same caution as those from the tobacco, oil, asbestos, chemical and nuclear industries.
- CSG mining threatens the Sydney Catchment Authority (SCA) Special Areas, which provide high quality drinking water for more than 5 million people. CSG mining on SCA Special Area land contradicts the clear purpose of the NSW parliament in establishing the SCA in 1998. CSG must be excluded from the Special Areas, and the adjacent National Parks, Nature Reserve, State Conservation Areas and their inter-connecting green corridors.
- The coal seams of the Illawarra have low permeability and hydraulic fracturing is accordingly used in the Camden gas fields. Hydraulic fracturing would likely be used at some point if CSG mining was to be allowed in the SCA Special Areas.
- Two recent NSW Planning Assessment Commission reports have highlighted the importance of the geological and ecological integrity of the SCA Special Areas in the provision of high quality water for Greater Sydney.
- Preliminary findings of the NSW Scientific Committee recommend listing the Upland Swamps of the Woronora Plateau as an Endangered Ecological Community. The swamps are key habitat for 12 of the region's most threatened animal species. The threat posed by CSG mining is explicitly recognised by the Scientific Committee, described as having impacts similar to longwall mining. Longwall mining has damaged the SCA Special Areas.
- CSG mining should be listed a 'Key Threatening Process', as provided by the Threatened Species Conservation Act, as was done for longwall mining in 2005.
- The Southern Sydney Metropolitan Catchment Management Authority (SMCMA) areas contain some of the region's most pristine parcels of native bushland, and these areas are home to some 80 threatened fauna and flora species. Several vegetation communities have been recognised as endangered ecological communities (EECs) under the Threatened Species Conservation Act 1995.

- The SMCMA areas contain assets recognised by the Australian Government as being of National Environmental Significance, including the Dharawal Nature Reserve and the wetlands of the O'Hares Creek Catchment. The Garawarra State Conservation Area has National Heritage listing. The Dharawal National Park should be established as a matter of urgency, and protection should be provided for the regions green corridors.
- SCA powers should be strengthened and should be granted the rights of a registered landholder. Its representations on projects proposed for SCA land should be given greater weight than those of the Department of Planning. Its recommendations should override those of the Department of Planning.
- Mining project proponents should not choose Environmental Assessment consultants.
- New York is to ban drilling within its prime aquifers and surface drilling on state owned parks and other lands. NSW must do the likewise.
- Adopting gas as an energy source contradicts the need for green house gas emissions to peak before 2020 in order to have a reasonable chance of keeping global warming below 2 degrees. Concern mounts that 2 degrees may prove unacceptably dangerous.
- A recent study by the IEA suggests current global gas use trends result in an atmospheric CO2 concentration of 650 ppm and a minimum temperature increase of 3.5 degrees. This does not take into account fugitive emission effects or warming feedback effects. NSW should not contribute to this very dangerous scenario, either by using or exporting gas.
- The prospects of carbon capture and storage (CCS) being deployable in a safe, cost effective and timely manner are diminishing. A full scale CCS plant will cost at least as much as the power station it serves.
- NASA research suggests the green house impact of methane is significantly higher than accepted by the IPCC in 2007.
- Recent research suggests the greenhouse gas benefit of gas relative to coal is undermined by fugitive emissions, and may not be as great as the gas industry suggests.
- The 2011 AEMO Statement of Opportunities makes it clear that NSW does not need gas powered electricity in meeting its electricity needs to 2020 and beyond.
- NSW has an excellent opportunity to position itself as the leading renewable energy state, with wind providing a cheap and rapid development path to be complemented by solar energy.
- Concentrated solar thermal power with molten salt heat storage is as dispatchable as gas.
- NSW, with a population of 7 million and a land area more than twice that of Germany currently has around 150 MW of wind power. Germany, with a population of 81 million, has 27,214 MW of wind driven capacity.
- The deployment of 3000 MW, around 20% of the NSW capacity from all sources, of renewable energy would not be sufficient to ensure NSW emissions peak before 2020. More is needed
- A 2010 study undertaken for the NSW Government showed strong community support for wind power. Rallies and surveys demonstrate the opposite for coal seam gas.

Preface

This submission to the Inquiry elaborates on a letter sent in July of this year to the Premier and relevant Ministers calling for coal seam gas mining to be excluded from the Sydney Catchment Authority (SCA) Special Areas and the nearby State and National reserves and green corridor areas of the Illawarra and Wollondilly. This call is made in the public interest to ensure water security, biodiversity, environmental conservation and tourism growth for the Illawarra, Sydney and the Wollondilly.

The letter and its call have been endorsed by the following groups: the Illawarra, Macarthur and South Sydney branches of the National Parks Association of NSW, RiversSOS, Stop CSG Illawarra, Stop CSG Sydney, Stop CSG Sutherland, Sutherland Shire Environment Centre, Sutherland Climate Action Network, Wollongong Climate Action Network, Northern Illawarra Sustainability Alliance, Illawarra Residents for Responsible Mining, Otford Eco, Georges River Environmental Alliance, Botany Bay and Catchment Alliance, and the Lock the Gate Alliance.

Effectively constant media coverage reflects growing community concern about the coal seam gas mining industry. The need for this Inquiry demonstrates the uncertainty and lack of knowledge of the environmental, health and social impacts of coal seam gas mining. The Precautionary Principle of Ecologically Sustainable Development, provided for by The Environmental Planning and Assessment Act 1979 (NSW), would dictate a halt be called on all coal seam gas exploration and mining activity until the impacts risks of the industry are properly understood . The government has yet to apply the Precautionary Principle of Ecologically Sustainable Development.

While this submission has a focus on the Sydney Metropolitan Catchment Management Authority areas and, in particular the Sydney Catchment Authority Special Areas, many of the comments have broader relevance. Catchments, key aquifers, prime agricultural land and high conservation value areas must not be exposed to the risks of coal seam gas mining. That is, in accord with the Precautionary Principle, coal seam gas mining exclusion zones must be declared for these important areas.

Several international bodies have pointed out the climate change dangers posed by a global shift to gas. NSW should accordingly bypass gas and take a national lead in deploying renewable energy sources and in developing renewable energy industries.

The comments in this submission are made with respect to the Terms of Reference for the Inquiry.

Dr Peter Turner, co-convenor Northern Illawarra Sustainability Alliance.
September 2011.

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1. The environmental and health impact of CSG activities

1.a. *Effect on ground and surface water systems*

1.a(i). The Sydney Catchment Authority Special Areas

A critically important duty for government is to protect the water supply resources of NSW, as the population grows and climate change relentlessly progresses. A government that does not apply the Precautionary Principle of Ecologically Sustainable Development in assessing project proposals that may compromise water security fundamentally fails in a core responsibility to those it is elected to serve.

The Sydney Catchment Authority (SCA) Special Areas were established in 1998 under the Sydney Water Catchment Management Act (SWCM Act) to protect the water catchments of the Avon, Cataract, Cordeaux, Nepean, Warragamba and Woronora Dams, and ensure an ongoing supply of high quality water for their reservoirs. These dams hold water for the residents of Greater Sydney and its nearby southern regions – more than 5 million people or some 60% of the population of NSW (see Figure 1).

The Southern Coal Fields Inquiry (SCI) was established with an independent panel of experts in 2006 as a response to rising community concerns over both past and potential future impacts of mine subsidence on the significant natural features in the Southern Coalfield. These concerns first surfaced in the community in 1994 when the bed of the Cataract River suffered cracking and other subsidence impacts. The Inquiry's comprehensive and lengthy report was released in 2008[1]. As the NSW Scientific Committee recently pointed[2], many of the concerns and considerations arising from longwall mining in the Southern Coalfields apply to the prospect of coal seam gas mining in the region (see section 1.d. below).

With respect to the importance of the SCA Special Areas, the SCI report observes on page 26 “ ... SCA states that the Special Areas are a critical element in its multi-barrier approach to protecting drinking water quality. This approach includes managing the hydrological catchments, the storages, quality treatment and delivery of water to retail customers. The Special Areas essentially act as a filtration system for water entering water storages by reducing nutrients, sediments and other substances that can affect water quality. **The ecological integrity of the Special Areas is therefore important in their role of protecting water quality.**”

No matter how low the risk, a precautionary approach to the protection of water supply requires that any activity that may adversely impact on the quantity and quality of water supplied to the SCA reservoirs should not be allowed to proceed. That is, the application of the Precautionary Principle, which is enshrined in NSW law (see section 4 below), dictates that *the appropriate risk management strategy in critical water catchments is not to accept any risk*. The water supply catchment for more than 5 million people cannot sensibly be used as a geo-engineering field experiment in the interests of State revenues from gas exports that are, in effect, green house gas exports.

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Advocated by the National Parks Association, the Colong Foundation for Wilderness and the Total environment Centre, the NSW Planning Assessment Commission (PAC) explicitly applied the Precautionary Principle (see section 4 below) in its July 2010 report[3] recommendations for the BHP Bulli Seam Operations (BSO) project. The report also states “*The Panel is of the view that it is no longer a viable proposition for mining to cause more than negligible damage to pristine or near-pristine waterways in drinking water catchments or where these waterways are elements of significant conservation areas or significant river systems.*” The catchments of the Illawarra and Wollondilly and their adjoining National Parks, Nature Reserve, State Conservation Areas are largely pristine because they have been set aside by Acts of the NSW Parliament so that current and future generations may enjoy the benefits of these priceless areas. Following the release of the PAC report, BHP made significant changes to the BSO project, removing five large mining areas near the Woronora River, Cataract River, O'Hares Creek and the 226 swamps that supply water to these rivers.[164]

Apex Energy NL[4] currently holds PELs 442 and 444 in the Illawarra and PEL 454 in the Wollondilly. Contradicting the wisdom of earlier governments, in September 2009 the then Labor government approved 15 coal seam gas exploration bores in PELs 442 and 444, and the current government oversaw the approval of an exploration bore in PEL 454 in June this year. The area covered by these PELs includes the Warragamba and Woronora dams and their catchments, and the surrounding high conservation areas. Apex and their joint venture partner Ormil[4] seeks commercial yields of methane from abandoned coal mine workings and unmined coal seams in these PEL areas. ***Much of the area covered by these PELs is SCA Schedule 1 Special Area land.*** Schedule 1 is the highest SCA catchment protection classification; access requires SCA approval without which trespassers risk heavy fines. Nine of the approved CSG bores are on SCA Schedule 1 Special Area land.

The sensitivity, vulnerability and importance of other areas within or nearby these PELs is emphasized by National Park, State Conservation Area and Nature Reserve listings. The Garawarra State Conservation Area, like the Royal National Park, has National Heritage status.[5] The fragility of the Wollondilly environment has been highlighted by the as yet unexplained drying of the ancient and world heritage-listed Thirlmere Lakes.[6] ***These important water catchment and conservation areas are largely pristine because to date they have been protected; they are now gravely threatened by the possibility of coal seam gas mining.*** Water security is a trigger-point issue, and the possibility of environmental zone downgrading and CSG mining has in the recent past galvanised the community with thousands attending rallies[7], signing petitions and making submissions[8] calling for protection.

CSG exploration should never have been approved for PELs 442, 444 and 454. Exploration approval suggests subsequent mining approval. Permitting CSG mining in these areas would be a

contradiction of their classification and listings, and would figuratively and literally undermine water security for the region. It would be a rejection of “... *the foresight and wisdom shown by the NSW Parliament in setting these areas aside for nature and water conservation.*”.[9] As discussed below, CSG mining presents a number of now widely recognised risks to water.

The Sydney Catchment Authority (SCA) has a statutory responsibility for the protection of drinking water catchments that supply Sydney, the Blue Mountains, the Illawarra, Shoalhaven and the Southern Highlands communities. The State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011, (the SEPP), requires all proposed development in the Sydney drinking water catchment to have a neutral or beneficial effect on water quality (NorBE test).[172] The SCA accordingly is opposed to a proposal from Apex Energy N.L. for a new coal seam gas exploration bore on SCA Special Area land near Darkes Forest in the Illawarra.[173] The Apex proposal has nonetheless been recommended for approval by the Department of Planning and Infrastructure.[139] This bizarre situation should not be possible. For reasons discussed within, coal seam gas mining should be excluded from the SCA Special Areas, the adjacent National Parks, Nature Reserves, State Conservation Areas and linking green corridors. It should be excluded from all of the SMCMA areas.

1.a(ii) Contamination of surface and subsurface waters by produced water from coal seams

Methane extraction from coal seams requires the removal of water that otherwise holds the gas in place under pressure. Over several years very large quantities of water are extracted and brought to the surface as so called ‘produced water’ (Fig. 2). As Table 1 indicates, this water is typically highly saline, of varying alkalinity, naturally contaminated with salts that can include heavy metals[10] and radionuclides[11], and hydrocarbons[12], including carcinogenic organic compounds.

Representative compositions of produced water associated with coal seam methane

Major components mg/l		Trace elements & hydrocarbons µg/l	
Total dissolved solids	4,000	silver (Ag)	1.1
		aluminium (Al)	40
chloride (Cl ⁻)	2,000	barium (Ba)	2,780
sulphate (SO ₄ ²⁻)	12.9	cadmium (Cd)	5
bicarbonate (HCO ₃ ⁻)	597	chromium (Cr)	3
carbonate (CO ₃ ²⁻)	0.008	copper (Cu)	5.6
fluoride (F ⁻)	2.6	mercury (Hg)	0.13
nitrate (NO ₃ ⁻)	3.0	lithium (Li)	92
iron (Fe)	10	manganese (Mn)	250
calcium (Ca)	89	nickel (Ni)	29
sodium (Na)	1,906	lead (Pb)	55
potassium (K)	7.5	antimony (Sb)	30
		selenium (Se)	25
pH	7.8	strontium (Sr)	4,000
		vanadium (V)	5
		zinc (Zn)	109
		total hydrocarbons	210

Table 1. Representative produced water composition.[15]

Strata	pH	EC (μ S/cm)	Na (mg/L)	Al (mg/L)	Fe (mg/L)	Mn (mg/L)	Ni (mg/L)	Zn (mg/L)	As (mg/L)
Hawkesbury Sandstone	5.19 \pm 0.48	92.3 \pm 40.2	9.2 \pm 2.8	0.071 \pm 0.065	0.457 \pm 0.748	0.132 \pm 0.180	0.073 \pm 0.046	0.374 \pm 0.537	
Bulgo Sandstone	5.88 \pm 0.71	281 \pm 272	14.3 \pm 3.4	0.02 \pm 0.01	1.012 \pm 0.819	0.307 \pm 0.167	0.497 \pm 0.298	4.477 \pm 3.450	
Scarborough Sandstone	8.07 \pm 0.28	844 \pm 89	176 \pm 32	0.009 \pm 0.01	0.561 \pm 0.632	0.028 \pm 0.030			0.002 \pm 0.001
Wombarra Shale	7.60 \pm 0.23	1741 \pm 61	405 \pm 19	0.007 \pm 0.005	0.029 \pm 0.012	0.017 \pm 0.002			0.038 \pm 0.009
Wongawilli Seam	7.98 \pm 0.20	6605 \pm 7	2030 \pm 269	0.015 \pm 0.014	1.56 \pm 2.17	0.023 \pm 0.003			
NWQ Guidelines	6.5-7.5	30 - 350	n/a	0.055 (pH>6.5)	n/a	1.9	0.011	0.008	0.013

Table 2. Some groundwater qualities associated with major strata in the Illawarra provided by Apex Energy.[163] The limited data show the water to be saline and alkaline. Though not given in this table, the National Drinking Water Guidelines give an upper limit for sodium of 180 mg/L.

Table 2 is taken from the Environmental Assessment for the Apex coal seam gas exploration project[163] and shows some of the character of water in the seams of the Illawarra. It does not for instance list the hydrocarbon concentration or make-up and a number of metal ions and counter-ions are not listed. The limited data show the water to be saline and alkaline and similar in character to that sampled in Wyong (Table 1). The National Drinking Water Guidelines give an upper limit for sodium of 180 mg/L.[174] and iron in drinking water should not exceed 0.3 mg/L. The coal seam water exceeds these levels by a factor of 10 and 5 respectively.

Scientists have recently highlighted the treatment and disposal problems posed by the large quantities of salt contained in the high volumes water produced by industrial CSG mining.[13] The produced water problem is not new, the following comment was published in 1996; “*The disposal of co-produced water has proved to be the biggest environmental problem associated with exploitation of coal seam methane fields in the USA, although the quantity and quality of the water can vary enormously between coal basins.*”[14]

The extraction of produced water from the coal seams below the surface of SCA Special Area land constitutes an accident waiting to happen in a highly sensitive area (see Fig. 3). Of direct relevance, water samples[15] taken from nearby coal seam gas exploration bores were a key factor in the previous government’s decision to reject the Wallarah 2 coal mine proposal. Figure 4 depicts the level of total dissolved solids found in coal seam water relative to Australian water standards.[15b]

Downplaying the risk posed by CSG mining in the Illawarra, the COO for Apex Energy N.L. stated recently that the Illawarra coal seams were relatively dry in comparison to seams in Queensland, suggesting a CSG well might yield only 40 or so barrels over a two week period, which would correspond to around 450 litres a day.[16] This assertion was made without reference to any independent assessments and likely refers to drainage from coal seams that have been largely discharged as a result of coal mining. Produced water yields are typically several thousand to tens of thousands of litres per day. The 2009 Planning Assessment Commission Report for the Peabody operated Metropolitan Coal Mine lease extension gives a very different perspective with estimates of an initial 146 ML a year on starting to mine longwall 20 rising to 1277 ML a year of water on completion of mining.[17] This corresponds to about 0.4 ML a day rising to 3.4 ML a day of seam water a day, and the report expresses concern that Peabody were inadequately prepared for the

quantity of water expected from the new coal seam panels. The well completion report for the only bore drilled by Apex in its PEL areas, Darkes Forest Number 1, states “*Water flow during air flushing was measured at 2.2 litres per second (equivalent to 1,750 gallons/hour, 1,200 barrels/day or 0.2 megalitres/day).*”[168] In the absence of independent research providing estimates of water yields for a range of CSG mining techniques, industry assurances of minimal water yields for a well cannot sensibly be accepted at face value.



Figure 2. An aerial photograph of a CSG produced water ‘pond’. While ponds will be banned in NSW, the threat of produced water remains.

The water yield from CSG mining would depend on the nature and intensity of the mining technique used, the number of wells and the number of seams being mined. A CSG well using horizontal drilling methods may drill laterally into a coal seam in many directions and may mine more than one seam in the local area strata. A horizontal bore may extend for more than two kilometres. Irrespective of mining company assurances to the contrary, coal seam water extraction to the surface of SCA Special Area land and any subsequent reinjection or relocation of that water poses a serious spillage threat to the water supply quality of Greater Sydney. An accident waiting to happen.



Figure 3. Scalding in an Upland Swamp on the Woronora Plateau, upper end of Lizard Creek, as a result of alkaline mine water discharge. [162]

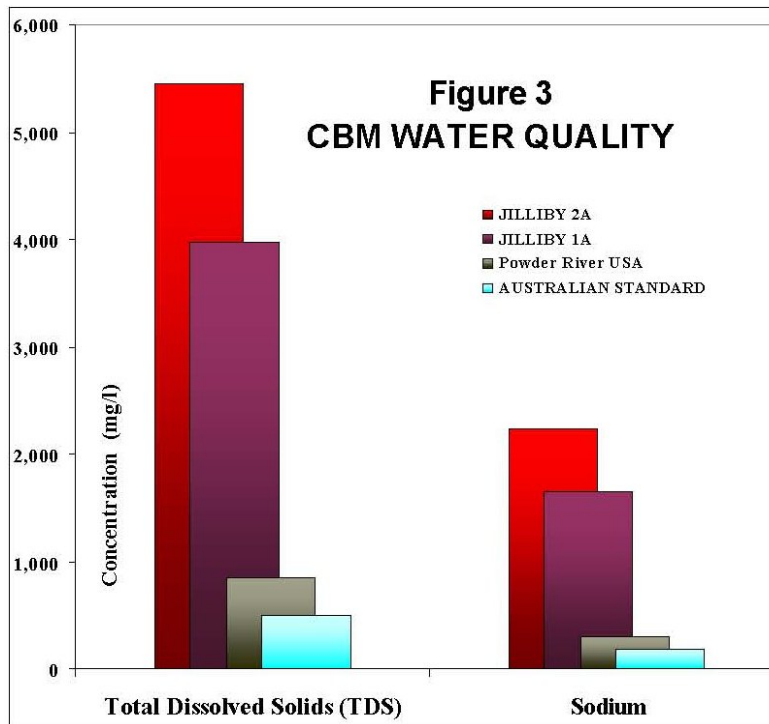


Figure 4. Coal seam water in the Wyong area of NSW relative to Australian water standards and contaminated water in Powder River in the USA.[15(b)]. Coal seam water in the Illawarra is similar to that in Wyong.

1.a(iii) Water quantity and quality loss as a result of coal seam ‘de-watering’

A University of Queensland CSG groundwater impact scoping study[18] for the Queensland Government suggests “Coal seam gas extraction may alter the connectivity between coal seams and aquifers through the following means:

1. Changes in hydraulic conditions that control water movement within and between aquifers = Hydrological risk ; and /or
2. Permanent physical changes to the strata containing the aquifers = Physical risk.”

Hydrological risk and gas seepage: Reflecting the first possibility, a report[169] by WorelyParsons provided to Campbelltown City Council in November 2010 states the following with respect to coal seam methane (CSM/CSG) extraction “The production of CSM requires the reduction of hydrostatic pressure in the target coal seams of the Illawarra Coal Measures, through groundwater extraction. Consequently, the potentiometric surface (or the level of the groundwater within the confined space of the coal seams) will be lowered within an area of influence of CSM production. Vertical hydraulic gradients will also be affected, creating a pressure differential between the coal seams and overlying and underlying units. **The pressure differential has the potential to transmit groundwater vertically from overlying and underlying aquifers towards the coal seams through intervening units (aquitards) or along open pathways.** The magnitude of the groundwater transfer is governed by the pressure differential between the units and the ability of the intervening layer to transmit the groundwater vertically; a function of the unit’s vertical hydraulic conductivity and thickness.” That is de-watering may result in a change in the flow direction of both ground and surface water towards the de-watered seam.

The same effects are presented in a 2005 hydrogeological report on the consequences of coal seam gas mining in Wyong; *“Dewatering of coal seams will allow for groundwater migration towards coal seam voids. This has a significant potential to effectively dewater sections of the study area. Dewatering of the coal seams will adversely effect the groundwater system and will have a flow on effect of reduced or lost stream flow.”*[15(a)] The PAC report for the Metropolitan Coal Project describes the same effect as a result of dewatering caused by coal mining.[17]

The WorelyParsons report was requested by Council because of repeated inadequacies in the Environmental Assessments (EA) for an expansion of the AGL Camden Gas Project. Rejecting the EA, Council is critical of the responses of the Department of Planning and Infrastructure.

The WorelyParsons report observes *“Improperly constructed CSM wells have the potential to transmit pressure reduction effects directly from the coal measures to overlying and/or underlying aquifers. Possible consequences include increased groundwater level drawdown in overlying and underlying aquifers that may potentially resulting in decreased water bore yields, reduction of flow to environmental receptors, and gas migration to overlying aquifers.”* Council reflects this advice in its response to the AGL EA *“ ... this specialist advice contends that the contamination of surface waters as a consequence of gas migration associated with extraction activity is a potential impact associated with the project.”*[169(b)] That is, dewatering can change water flow direction and may contaminate ground and surface water with methane.

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The same risks are described in the 2005 hydrogeological report from Northern Geoscience addressing the prospect of coal seam gas mining in the Dooralong and Yarramalong Valleys in NSW; *“Once coal bed gas is liberated by the withdrawal of water reducing the hydrostatic head, the methane is free to migrate. Geological structures, inadequately cemented conventional gas wells and extraction of produced water from coal bed methane wells can contribute to natural gas resource losses and to methane migration into surface soils and groundwater.”*[15(a)]

A recent paper published in the US Proceedings of the National Academy of Sciences (PNAS) reports that methane concentrations in shallow aquifers increase with increasing proximity to shale gas wells that use hydraulic fracturing to extract gas. Explosive levels of methane were found in the study. This paper is discussed further in section 1.c below.

Physical risk and subsidence: The Queensland University study mentioned above suggests a physical risk in addition to a hydrological risk. Seam depressurisation associated with water and gas removal risks seam compaction, slumping, fracture network propagation, subsurface subsidence and the possibility then of surface subsidence. Aware the AGL EA asserts that coal shrinkage is likely to be no more than a few millimetres, Campbelltown Council nonetheless state *“ ... it is considered imperative that the EA accurately quantify the short and long -term extent of surface subsidence that could occur within urban areas of the Campbelltown LGA as a consequence of lateral drilling in the subsurface areas.”*[169(b)]

The December 2010 position statement of the National Water Commission on CSG[19] recognises the risks of “... *land subsidence over large areas, affecting surface water systems, ecosystems, irrigation and grazing lands*” and “*reductions in surface water flows in connected systems*”

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The industry has undertaken numerical modelling to estimate subsidence as a result of coal seam gas mining.[20] Subsidence caused by coal seam gas mining was raised as an issue in an ABC 7:30 Report story on September 21, reporting on the Queensland governments protection of key agricultural land. The CSG company Bandanna Energy concedes subsidence is a risk “*Substance could be anywhere from zero up to perhaps a metre, based on preliminary work, that that is well within the tolerances of what is manageable from a restoration viewpoint.*”.[156] The comment illustrates the industry’s untested confidence.

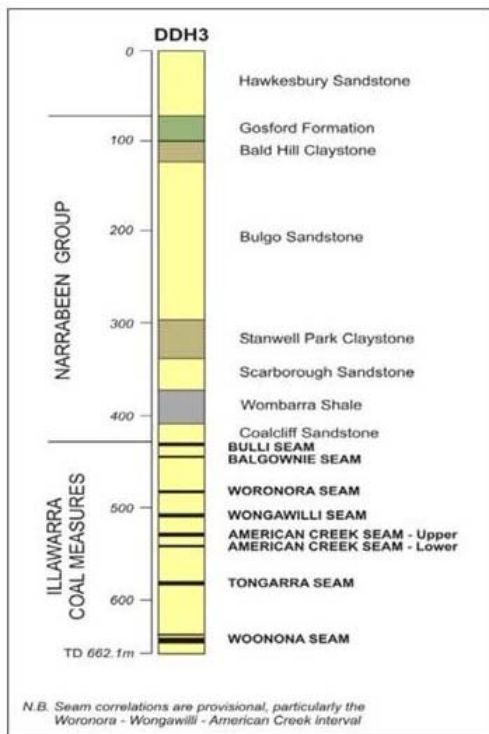
Subsidence was highlighted as a concern in a hydrogeological investigation of coal seam gas mining impact risks in the Dooralong and Yarramalong Valleys, which form the headwaters and recharge zones for the central coast Wyong catchment “*As coal seam methane production progresses it is anticipated that the coal will effectively shrink or slump as the hydrostatic pressures are reduced through dewatering. This can result in land subsidence and is highly probable as the Wyong area is a declared coalmine subsidence zone.*”[15(a)]

Likewise, subsidence from coal seam gas mining in the catchments of the Southern Coalfields is made much more likely by the presence of existing and ongoing subsidence caused by longwall mining. The Wollondilly and Illawarra contain declared subsidence zones. Subsidence in the Illawarra is described in some detail in the SCI report[1] and PAC report for the Metropolitan Coal Project (MCP).[17] The latter for instance observes: “*The environmental consequences for watercourses impacted by subsidence can be severe. There is abundant evidence of this in the reaches of the Waratah Rivulet that have been undermined by previous longwalls.*”

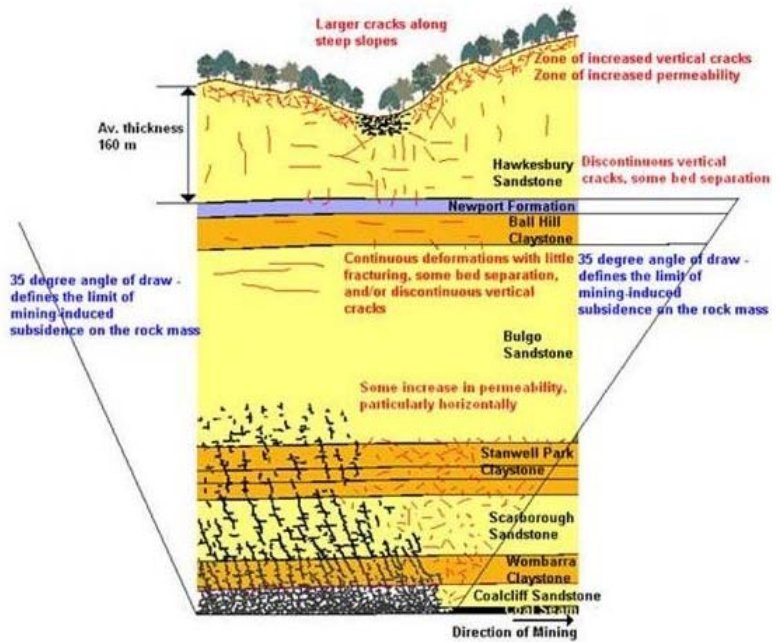
“*The environmental consequences for watercourses impacted by subsidence can be severe. There is abundant evidence of this in the reaches of the Waratah Rivulet that have been undermined by previous longwalls.*”

Subsidence ‘settling’ can continue for several years following the initial collapse, with persistent residual stress. *Adding an additional subsidence trigger in the form of coal seam gas mining would be folly.*

The SCA Special Areas are characterised by deeply incised valleys with sandstone groundwater aquifers.[1] In the Northern Illawarra there are four water bearing aquifers above the Bulli coal measures(see Fig. 5), where coal mining occurs. Surface waters flow over the Hawkesbury Sandstone and this is the main water bearing formation supplying the Woronora Reservoir, which provides water for Southern Sydney and the Northern Illawarra.



(a)



(b)

Figure 5. (a) Typical Stratigraphical Cross Section of the Southern Coalfield. (b) Sandstone aquifers and clay aquitards shown with respect to the Waratah Rivulet profile (provided by the Sydney Catchment Authority).

Surface subsidence can divert and disrupt both surface and subsurface base flows (see Fig. 6), with consequential reductions in water supply quantity and quality, as chemical interactions occur between freshly broken rock faces and percolating groundwater, and iron bacterial mats form. [1(page 75)]

As mentioned, the SCA Special Areas of the have already suffered significant subsidence impacts (see Fig. 7) from longwall coal mining. The Southern Coalfield Inquiry (SCI) report of 2008[1] details the causes and consequences of mining subsidence in the Northern Illawarra region, and this includes dramatic images of shattered sections of the Waratah Rivulet, loss of standing pools and surface flows, iron staining [1(e.g. Figures 28, 30 and 36)] and iron bacterial mats and gas bubbling out of water ways (see also Fig. 8 below). The Sydney Catchment Authority has presented detailed studies of the impacts on the Waratah Rivulet.[21]

The Waratah Rivulet typically supplies 30% of the water to Woronora Reservoir and up to 50% during dry periods (see Fig. 9). Periods of drought are expected to increase as climate change progresses, increasing the importance of this already damaged and altered water course. The SCA has documented a loss of surface flow in the Waratah Rivulet reflecting a diversion of flow into the subsurface ground water flow. During high flow periods the diverted water appears to re-emerge over two days some two kilometres downstream[21(a)].

The SCA finds that this diversion and mixing with the ground water degrades the water quality, with lower oxygen levels, altered pH and increased concentrations of salts including the salts of metal such as strontium and barium [21(c)]. The 2009 Planning Assessment Commission report for the Metropolitan Coal Project (MCP) comments on the impact of subsidence on the Waratah Rivulet “As a consequence, during low flow periods, some sections of waterway may dry out and pools may drain. Where water that is flowing through new cracks and fissures reappears at the

surface, it can contain elevated levels of dissolved iron, manganese and aluminium.” And “There is a high likelihood of water quality consequences arising from redirected flows along Waratah Rivulet. These changes in water quality are brought about either by interception of localised groundwater flow systems (through cracking) and/or by water-rock interactions along new pathways.” [17]

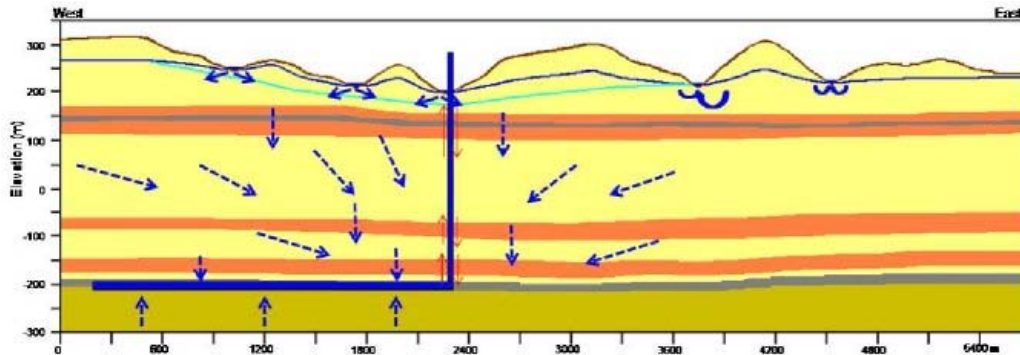


Figure 6. Sydney Catchment Authority (SCA) depiction of the effects of de-watering on surface and base flows. De-watering can result in aquifer compaction and subsurface subsidence leading to surface subsidence and a cone of depression. Existing fractures are enlarged and new ones created. There are consequential changes in ground water flow direction and reduced baseflow discharge. Seam stimulation would aggravate these effects and increase vertical water movement at the expense of horizontal flows. Used with permission of the SCA.

The SCI report observes on page 16 “Runoff with a weak base flow component yields a very high quality water which is typically low in total dissolved salts (TDS commonly less than 100 mg/l) and weakly acidic (pH range of 5 to 7). Increasing contributions from base flow during dry and drought periods are reflected in a higher TDS, possibly as high as 250 mg/l, and a pH range from 4 to 8.” That is, during times of low surface flow, water quality is lowered by the base flow contribution.



Figure 7. Waratah Rivulet damage from longwall mining. Photograph taken in 2011 by Natasha Watson and used with permission.

Importantly, the SCA studies show that during periods of low surface water flow, the diverted surface water is not recovered downstream and there is then a net loss of water flow to Woronora

Reservoir.[21(a)] That is, *the supply capacity of the Woronora catchment during dry periods has been reduced as a result of subsidence caused by mining.* The SCA describes the Waratah changing from a ‘connected gaining’ stream to a ‘disconnected losing’ stream as consequence of subsidence damage.[22]

During dry periods the Waratah Rivulet has in the past has supplied up to 50% of the flow into the Woronora Dam. Subsidence has resulted in both a loss of water quality and quantity from the Waratah Rivulet during dry periods. Dry periods will increase as climate change progresses.

Limited remediation is being attempted by the coal mining company responsible for the recent damage, however the effectiveness and long term durability of the filling of fractures with polyurethane resin has yet to be independently assessed. The Planning Assessment Commission (PAC) report for the Bulli Seam Operations project comments on the Waratah Rivulet remediation on page 56 “*The main concerns appear to relate to potential breakdown of the sealant at the surface and long term durability.*”.[9]



Figure 8. Methane gas bubbling in the Waratah Rivulet photographed in March 2011. Photograph taken by Julie Sheppard, Rivers SOS. Methane is a potent green house gas. Photograph used with permission.
<http://www.flickr.com/photos/53515439@N05/sets/72157626103042195/>

The 2009 PAC report for the Peabody expansion project (Metropolitan Coal Project) for the Metropolitan Mine expansion observes that subsidence from the new longwalls is expected to “... *increase the average frequency of no flow days as a result of the Project from 2% to 15% and increase the average frequency of low flows (less than 2 ML/day) from 36% to 40% of days.*”[17] The report does not point out the likely increase in no-flow or low-flow days arising from climate

change. Remarkably, particularly so in the context of climate change and an increasing need for water security, this project was approved by the then Labor government.

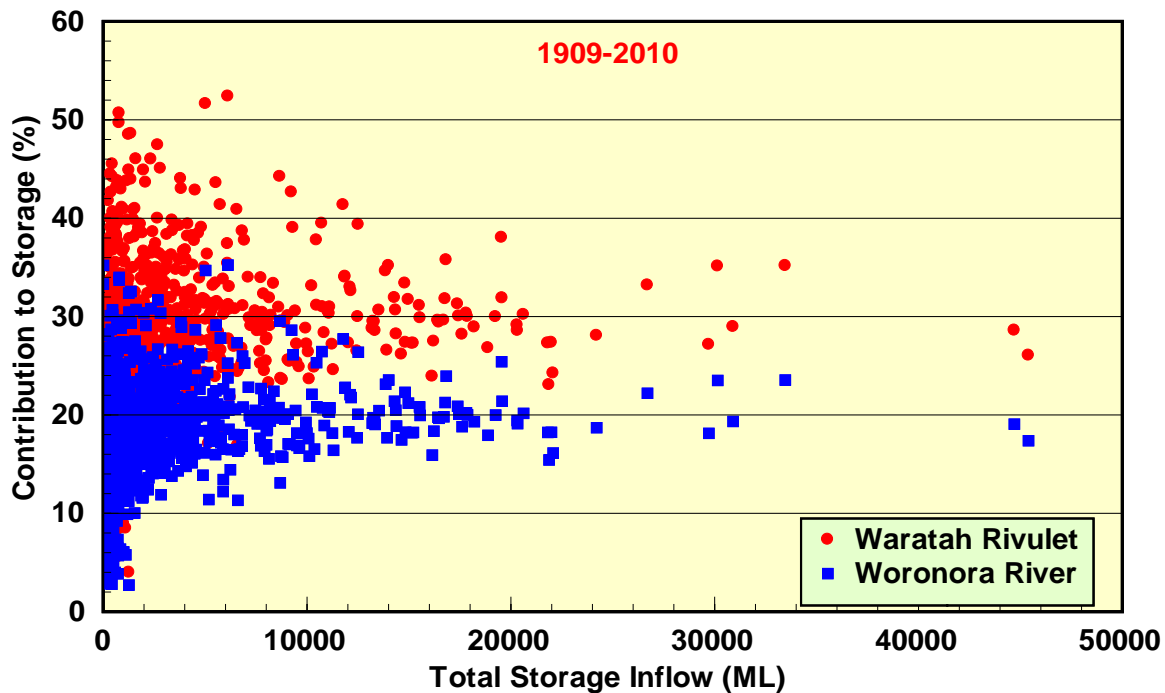


Figure 9. Yearly flow contribution to Woronora Reservoir from 1909 to 2010, showing the Waratah Rivulet provides up to 50% of the flow in dry periods (provided by the Sydney Catchment Authority)

Demonstrating subsidence impacts on deep aquifers, the Dendrobium Coal Mine workings under the SCA's Metropolitan Special Area had two major water inflow events in June 2007 and February 2008.[1] Chemical testing has indicated that each inflow event was sourced from separate aquifers which had been breached by subsurface cracking. The water from the 2007 event appears to have been sourced from the Scarborough Sandstone and the 2008 event appears to have come from groundwater in strata immediately above the Wongawilli Seam (see Fig. 5).

1.a(iv) Subsidence and mini-earthquakes triggered by hydraulic fracturing

The characteristically low permeability of the coal in the Illawarra formations of the Southern Coalfields has necessitated the use of hydraulic fracturing by AGL in order to extract commercial yields of gas from its Camden Gas Project. Apex have noted that the permeability of the Illawarra formations is lower than that encountered in coal seam gas mining in the US.[170]

Should hydraulic fracturing be used, as seems likely and necessary, in the 'tight gas' formations of the Illawarra and Wollondilly, the risk of new subsidence and the aggravation of existing subsidence damage would be significantly heightened.[1, 23] This may result a breach of the aquitards that are assumed to protect the Metropolitan Mine workings from inundations of the kind suffered by the Dendrobium mine in 2007 and 2008. Subsidence may also provide connectivity that would result in loss of surface water and loss from the Woronora Reservoir.[17]

The Southern Coalfield contains faults, sills, dykes and diatremes that could increase the risk of hydraulic connections forming as a consequence of dewatering and/or fracking. These geological features are noted in the SCI report (e.g. page 70) and the PAC report for the Metropolitan Coal Project (MCP), and the 2003 Apex report for PEL 442 (no other reports appear to be publically available) contains a 1975 map showing faults in this region of the Northern Illawarra.[170]

Irrespective of the complicating presence of intersecting geological structures, Campbelltown City Council has expressed concern that fracking may create fracture network connections to the surface; *“Therefore, there is considered to be a level of potential for impacts associated with fracturing of geological strata as part of this process to extend to also impact on surface waters.”* Aware that the project proponents contend otherwise, the Council is also concerned that fracking will cause subsidence similar to that arising from longwall mining; *“There is also considered potential for the fracturing to result in subsidence related impacts to extend to the surface as has been documented in regard to longwall mining operations.”*[169(b)]

There is also considered potential for the fracturing to result in subsidence related impacts to extend to the surface as has been documented in regard to longwall mining

The NSW Scientific Committee has also suggested that coal seam gas mining has similar impacts to those of longwall mining.[2]

The PAC report for the Metropolitan Coal Project notes that subsidence impacts can appear some distance from the mining activity; *“... fracturing does not occur as a single distinct event but it develops over time: fracturing may be initiated while mining is still some distance from a site and may continue to develop until mining has progressed several hundred metres past the site. Mining of adjacent panels may reactivate fracturing.”* The report also notes horizontal stresses intersected by geological features causing over-stressing of valley floors in the Southern Coalfields. This leads to the non-conventional subsidence dramatically manifested in the Waratah Rivulet. The likelihood of CSG activity triggering further subsidence will be increased by the presence of existing subsidence stresses, which may take years to dissipate.

The likelihood of CSG activity triggering subsidence will be increased by the presence of existing subsidence stresses, which may take years to dissipate.

CSG mining also poses a small but not discountable risk of triggering mini-earthquakes, such as have occurred in the US (see also section 5 below) and UK.[24] While the regions faults are relatively benign, earthquakes do occur within and in the vicinity of the Southern Coalfields. A magnitude 3.4 tremor was centred at Picton in 2009, a 5.8 magnitude earthquake at Bowral in 1961 and a 5.5 magnitude earthquake at Picton in 1975.[171] Of note, though not in the Southern Coalfields region, two earthquakes in Orange may have been the result of mining activity. Given the presence of faults and geological stresses in the region, the risk of CSG activity triggered earthquakes and further subsidence cannot be entirely discounted.

1.a(v) Water quality loss as a result of land clearing

A key characteristic of CSG mining that distinguishes it from coal mining is the very large amount of land clearing needed to establish a commercially viable CSG field. The construction and operational work associated with gas production and transport will require land clearing of up to a hectare for each well site (Fig 10). Commenting on the Camden Gas Project, Campbelltown City Council has observed “*soil disturbance and vegetation removal can occur over an area an area of 1 ha.*”[169(b)] Council also notes “*... implications associated with land sterilisation (for a period of 15 to 20 years over the lifespan of the wells)*”.

Additional clearing is required for vehicle access and pipeline laying and servicing (see Fig. 11). There are likely to be large numbers of vehicle movement that will destroy, degrade and disrupt habitat. Vehicle movements on and off site risk the introduction of species from elsewhere, including weeds. Depending on the technique used, wells can be expected every 600 metres or so, as shown in the sobering aerial picture of Queensland’s Chinchilla gas fields given in Figure 10. A fate of this kind awaits the SCA Special Area lands and surrounding areas of the Illawarra and Wollondilly if CSG production proceeds as intended by Apex and Ormil.

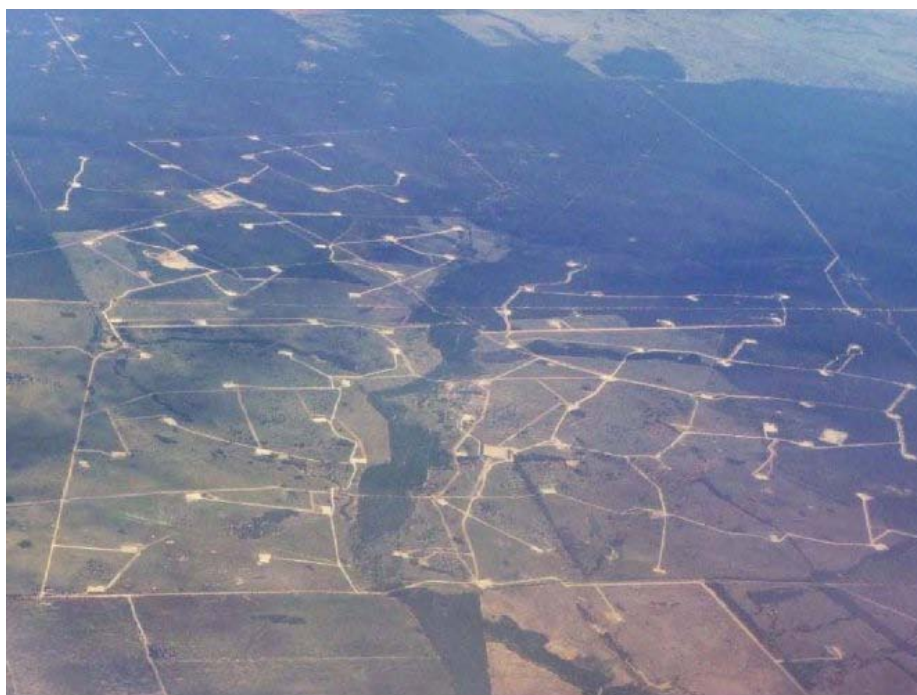


Figure 10. Aerial view of the coal seam methane gas fields near Chinchilla in Queensland. With drill sites every 600 metres or so and occupying up to a hectare each, this fate awaits the SCA Special Area lands and surrounding areas of the Illawarra and Wollondilly if CSG production proceeds as anticipated by Apex Energy NL.

Land clearing on this scale would have an impact on the function of the Special Areas. The SCI report(1) notes on page 26 that “*The Special Areas essentially act as a filtration system for water entering water storages by reducing nutrients, sediments and other substances that can affect water quality. The ecological integrity of the Special Areas is therefore important in their role of protecting water quality.*”

The SCA states “***The greater the ecological integrity of the Special Areas, the more effective their role as a barrier.***”[25] Land clearing for CSG mining would compromise the ecological integrity of the Special Areas and hence the quality of the water derived from these catchments.

“The Special Areas essentially act as a filtration system for water entering water storages by reducing nutrients, sediments and other substances that can affect water quality. The ecological integrity of the Special Areas is therefore important in their role of protecting water quality.”



Figure 11. Land clearing and the laying of gas pipeline.

Forming a particularly important component of the SCA Special Area filtration system are the upland swamps of the Woronora Plateau. The 2010 PAC report for the BSO project states “*Upland swamps are identified as habitats of the very highest conservation value in terms of species diversity and density and protection of threatened species. Overall the swamps in the BSO Study Area were included in one of the four clusters of swamps identified by DECCW as highest conservation value in evidence to the SCI in 2007. They are also regarded by SCA to be critical elements of the Sydney Drinking Water Catchment hydrology.*”, and “*These swamps which dominate the Woronora Plateau and large areas of the SCA Special Areas and Dharawal State Conservation Area, act as significant regional water stores providing baseflow to the drainage systems of the plateau.*”.[9]

The SCI report(1) observes on page 16: “*The water quality or salinity of stream runoff (both quick flow and base flow) is influenced by a number of factors including the organic and inorganic fabrics within swamps ...*” Described in some detail in the SCI report, these swamps formed between 17,000 and 2,000 years ago and occupy more than 6400 hectares of the SCA Special Areas. The distribution of the swamps is shown in Figure 12, and their extent makes them significant regional water stores with very low levels of dissolved salts.[1(page 19)]. The majority of the 15 sites approved for exploration by Apex are close to or at the edge of upland swamps (Fig. 13), including the Iluka and Dahlia Swamps. The project proposal states that 1.2 hectares of swamp would be cleared for exploration; following that initial destruction would be land clearing for another an industrial gas field like that of Chinchilla.

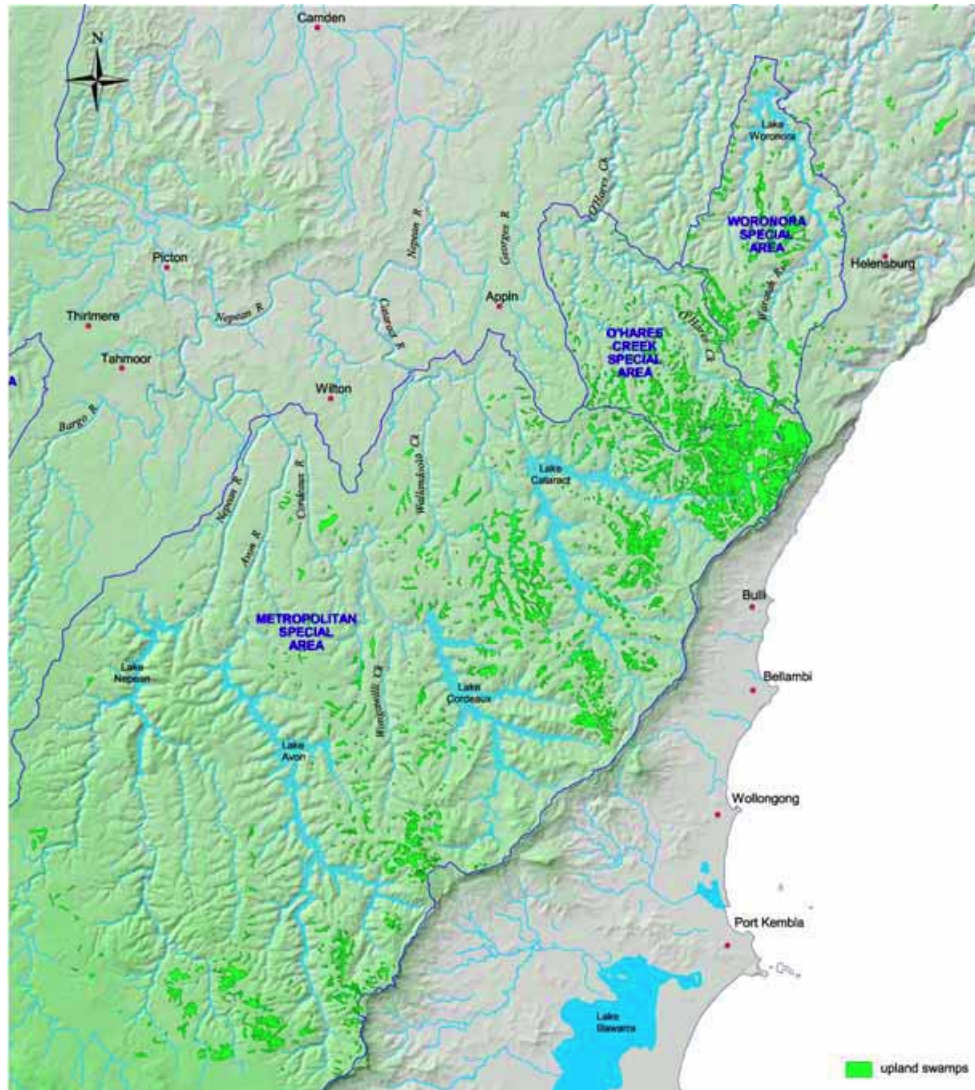


Figure 12. Mapped Upland Swamps in the Southern Coalfield, from the SCI report[1] on page 17.

“These swamps which dominate the Woronora Plateau and large areas of the SCA Special Areas and Dharawal State Conservation Area, act as significant regional water stores providing baseflow to the drainage systems of the plateau.”

“They are also regarded by SCA to be critical elements of the Sydney Drinking Water Catchment hydrology.”

With wells every 600 metres or so and requiring land clearing of up to a hectare and associated clearing for pipeline and service access, an industrial CSG field in the region then poses a serious threat to the integrity of the SCA Special Area filtration system.



Figure 13. View across an Upland Swamp immediately adjacent to the location of approved Apex CSG exploration site AI10. The site is on SCA land, having been relocated about 100m from its original location on the Dharawal Nature Reserve as part of a 2009 approval requirement. There has been no drilling as of September 2011.

Mechanical land clearing is not the only threat; methane poisoning can also kill off vegetation. The 2010 WorelyParsons report for Campbelltown City Council comments “*Gas migration and seepage to the surface has the potential to affect vegetation die-back, human health and safety risks if gas builds up in concentration.*”[169(b)] Dieback from methane seepage is noted in the SCI report of 2008 “*Much less commonly, gaseous emissions through the soil profile close to the river bank and associated heating have induced localised dieback of vegetation communities (e.g. Cataract River gorge above Tower Colliery).*”[1] The SCI report states “*... insufficient study has been conducted to discount the possibility of sustained upward leakage of methane from the coal seam(s). While small occurrences in the form of bubble trains in rock pools and waterways appear to be largely harmless (and have been so reported), the higher volume occurrences such as those reported for the Lower Cataract River where flaring was possible, are considered to be hazardous.*”

“ ... insufficient study has been conducted to discount the possibility of sustained upward leakage of methane from the coal seam(s).”

The 2005 hydrogeological report by Northern Geoscience notes the same risk “*As methane production progresses, seeps can find their way into domestic water wells, or the presence of gas seeps in pastures, manifested by dead vegetation. Anoxic environments created in near-surface regimes by a predominance of methane support bacterial generation of hydrogen sulphide gas and promote plant suffocation by precluding soil oxygen. Methane from soil gas vapours can accumulate in confined spaces, such as beneath domestic dwellings, and may pose potential explosion hazards. Escalations in hydrogen sulphide gas will result in seep sites identified by stands of stressed and dying vegetation, trees and habitat.*”

Water flow change or loss also threatens vegetation, as the Northern Geoscience report for instance observes; “*Environmental impacts to streams through the loss of surface flow caused by lowering of*

groundwater aquifers have the potential to kill off and reduce stream bank vegetation, trees and the associated loss of species.” And “Riparian vegetation and wetlands are at risk by a lowering of groundwater levels and methane migration into the overlying aquifers during gas production. Regardless of well construction geological features provide transient pathways.”[15(a)]

1.b. and 1.c. Effects related to the use of chemicals and effects related to hydraulic fracturing

Hydraulic fracturing (fracking/fraccing), with its cocktail of chemicals[26] and high pressure injections of very large volumes of fracking fluid or ‘slick water’, significantly escalates the threat posed by coal seam de-watering. As stated above, the risks arising from de-watering are sufficient cause for CSG mining to be excluded from the SCA Special Areas whether or not fracking is used as a seam stimulant.

Water produced from coal-associated aquifers has been linked, or is suspected to be linked, to goiter, Balkan Endemic Nephropathy (BEN), multiple sclerosis, and increased rates of cancer morbidity and mortality. Water-soluble organic compounds found in coals include goitrogens such as the hydroxyphenols resorcinol, 2-methyl resorcinol, and 5-methylresorcinol (orcinol), as well as hydroxypyridines. Well waters containing polycyclic aromatic hydrocarbons (PAHs), aniline, aminophenols, and aromatic amines leached from low-rank Pliocene coals may be the cause of, or a contributing factor to, BEN, an incurable interstitial nephropathy that is believed to have killed more than 100,000 people in the former Yugoslavia alone.[12] In September, 2008, experts at the University of Colorado School of Public Health completed a review of data and scientific articles about the health effects of oil and gas drilling and production on neighbouring communities. They found that the chemicals being used and produced pose a potential health risk to local residents, and recommended a thorough health impact assessment before any expansion of oil and gas activities.[27]

Earlier this year the US Congress Committee on Energy and Commerce produced a report on the chemicals used by the industry, including health effect.[28] The report states *“This analysis is the most comprehensive national assessment to date of the types and volumes of chemical used in the hydraulic fracturing process. It shows that between 2005 and 2009, the 14 leading hydraulic fracturing companies in the United States used over 2,500 hydraulic fracturing products containing 750 compounds. More than 650 of these products contained chemicals that are known or possible human carcinogens, regulated under the Safe Drinking Water Act, or listed as hazardous air pollutants.”* A group of scientists recently wrote to the Governor of Albany expressing concern at the inability of drinking water filtration systems to cope with chemicals from shale gas mining.[158] The US Paediatric Environmental Health Specialty Units (PEHSU) network has recently released briefing documents for health professionals and for parents.[159] In June this year the US NGO Food and Water Watch published a review of fracking, with an extensive reference list, that recommends banning[160(a)] the technique, as does a commentary in the science journal Nature.[160(b)] The Nature commentary is accompanied by a counter-point commentary.

Doctors for the Environment Australia have presented health effect considerations to the Rural Affairs and Transport References Committee Inquiry into management of the Murray Darling Basin[29] The National Toxics Network (NTN) finds *“that of 23 common fracking chemicals used in Australia, only 2 have ever been assessed by NICNAS, Australia’s industrial chemicals regulator. The two that were assessed, have never been assessed for use as fracking chemicals.”*

“ ... of 23 common fracking chemicals used in Australia, only 2 have ever been assessed by NICNAS, Australia’s industrial chemicals regulator. The two that were assessed, have never been assessed for use as fracking chemicals.”

The NTN report lists the chemicals used in Australia and their health effects.[26] The concentrations of these chemicals in fracking fluids is low, but they become problematic because of the very high volumes used in hydraulic fracturing. Fracking may involve the injection of 13 to 19 million litres of water per well at pressures of up to 69,000 kPa.[30]

A recent publication in the prestigious Proceedings of the National Academy of Sciences (PNAS) reports that methane concentration in shallow aquifers increases with increasing proximity to shale gas wells that use hydraulic fracturing to extract gas.[30] In active gas-extraction areas (one or more gas wells within 1 km), ***average and maximum methane concentrations in drinking water from shallow aquifers were 17 and 58 times higher than in similar aquifers where gas mining was not taking place.*** At 19.1 mg of methane per litre of water the concentration of methane was sufficient to be a potential explosion hazard, as dramatically demonstrated in the movie length documentary Gasland. The isotopic signatures of the water near gas wells indicated that the gas was thermogenic in character, and came from the underlying shale being mined. In contrast the methane in the water from areas where mining was not taking place was biogenic in character and of natural origin.

The high pressures used to fracture a seam along the length of a horizontal bore risk well casing and valve failure, resulting in blow-outs and surface and aquifer contamination by fracking chemicals and coal seam water, and methane release. Fracking may trigger earthquakes[24, 148] and increases the risk of subsidence, with consequential surface and ground water loss, cross-aquifer contamination and methane release.

The PNAS study attributes the alarming methane levels to a combination of leakage from well casings, and upward migration of gas from the shale deep below to the shallow aquifer via strata fracture networks that were pre-existing or created or exacerbated by fracking. Fracturing is a complex process with consequences that cannot be predicted with any certainty, if at all. It is important to note that gas will also migrate to the surface and escape into the atmosphere, and so add to the greenhouse gas burden.

The high pressures used to fracture a seam along the length of a horizontal bore risk well casing and valve failure, resulting in blow-outs and surface and aquifer contamination by fracking chemicals and coal seam water, and methane release (Figs 20 and 21 below). As discussed in Section 1.a. above, fracking may trigger earthquakes[24, 148] and increases the risk of subsidence, with consequential surface and ground water loss, cross-aquifer contamination and methane release. Campbelltown City Council has expressed its concerns regarding the potential impacts of fracturing, compounding those of dewatering; “ ... *there is considered to be a level of potential for impacts associated with fracturing of geological strata as part of this process to extend to also impact on surface waters. There is also considered potential for the fracturing to result in subsidence related impacts to extend to the surface as has been documented in regard to longwall mining operations.*”[169(b)]

... there is considered to be a level of potential for impacts associated with fracturing of geological strata as part of this process to extend to also impact on surface waters.

The proponents of CSG mining in the SCA Special Areas have stated publically that they do not intend to use fracking, but would instead use other techniques such as zero radius horizontal drilling should they proceed to mine CSG. They have also stated that they would use the technique best suited to the task and, significantly, have not categorically ruled out the use of fracking. The proponents have publically emphasized the very low permeability or 'tight gas' nature of the coal seams of the Illawarra.[16, 170] Fracking was introduced to gas mining as a technique enabling commercial gas yields from low permeability formations. When questioned why fracking was used in a vulnerable aquifer region in Queensland, QGC responded "*The decision to fracture coals in Myrtle 3 was designed to determine whether gas flow rates from this well could be enhanced.*"[31] AGL uses fracking to mine gas in the Illawarra coal measures beneath Camden. Apex would exploit reserves in the Illawarra measures in the Illawarra and Wollondilly.

Zero radius drilling is a form of horizontal drilling and its use would not preclude or exclude the use of fracking. A combination of techniques would maximise yields and have commercial appeal. Apex has suggested the coal cleat structure of the Illawarra seams does not favour fracking, however this suggestion is unconvincing and contradicted by the use of fracking in the nearby Camden gas field of the Southern Coalfield.

Apex and Ormil are small companies with very limited capitalisation and it's very unlikely that they have the capacity to undertake CSG mining in the Illawarra and Wollondilly. The likelihood is that it will be another company that decides whether or not fracking would be used. Given the low permeability of the seams in the Southern Coalfields, fracking would almost certainly be used at some point.

1.d. Effect on Crown Lands including travelling stock routes and State forests and other high conservation value areas

This aspect of the Inquiry should also include World and National Heritage Areas, National Parks, Marine Parks, Nature Reserves, State Conservation Areas, Sydney Catchment Authority Special Areas, wetlands protected under RAMSAR and other international conservation agreements, lands managed for conservation purposes by organisations such as Bush Heritage Australia, private land managed under Voluntary Conservation Agreements, sites of Aboriginal cultural significance, and connecting green corridors that provide wildlife with passages that will be increasingly important as climate change progresses. These corridors include tracts linking otherwise fragmented reserves and, importantly, Travelling Stock Reserves. As a significant example, A recent publication underscores the need for protected green corridors to ensure the viability of the iconic New South Wales waratah as climate change progresses.[32]

The World Heritage listed Wollemi National Park is threatened by CSG mining at Putty, at Pogy drilling is occurring on an in-holding in the Goulburn River National Park; in north-west NSW Travelling Stock Routes are threatened by drilling and gas pipeline infrastructure and in the north-east, a pipeline is proposed through the World Heritage-listed Border Ranges National Park and CSG mining in the Pilliga will clear at least 2,400 hectares and fragment 85,000 hectares of public lands, including State Forests and State Conservation Areas.

These important areas host valuable and often unique habitats providing for biodiversity and their protection now and into the future is unquestionably in the public interest. CSG must surely then be excluded from these areas, which would otherwise be threatened by produced water spillage and leakage, subsidence, land clearing, fires from explosive levels of fugitive methane emissions and climate change further fuelled by fugitive methane emissions (see section 1.f(i)). Given a CSG bore can travel two or more kilometres from the central well site, CSG exclusion zones must include a protected border of this magnitude.

Given a CSG bore can travel two or more kilometres from the central well site, CSG exclusion zones must include a protected border of this magnitude.

Recognising the need to protect the area, the government has to its great credit made a commitment to the establishment of the Dharawal National Park, adding protection to the Dharawal State Conservation Area.[33] Further emphasizing the importance of the area, the rezoning proposal currently before the Wollongong City Council includes assigning the balance of the Garawarra precinct crown lands adjacent to the Garawarra Centre and the Sydney Catchment Authority land to an E2 environmental conservation classification.[34] The Garawarra State Conservation Area, like the Royal National Park, has National Heritage status.[5] *Any land classified as E2 or above should have automatic protection, without exemption, from surface or subsurface CSG exploration and mining.*

The National Parks Association(NPA NSW) of NSW has for some time been advising the government and raising public awareness of the need to provide protected connectivity between the regions current parks, conservations areas and reserves.[35] The recently released video trilogy “The Green Corridors of Southern Sydney”[35(d,e,f)] highlights the importance of these areas and the need to provide comprehensive protection and green corridor connectivity. Protection is needed to ensure the survival and recovery of endangered species, and secure vegetated connectivity is needed to nurture biodiversity as habitats are displaced by the increasing influence of climate change.

NPA NSW is currently releasing a series of video pieces on coal seam gas through its Community Pulse YouTube Channel.[35(g)] This includes a recent interview with geoscientist Dr Ann Young on location at the Apex exploration bore site AI10 on SCA Special Area catchment land. Dr Young pioneered research on the Woronora Plateau and has accordingly provided expert advice to the Planning Assessment Commission. In the interview she emphasizes the importance of protecting the integrity of the vegetation and soil of the catchment areas, and that this dictates that coal seam gas mining should be excluded from the SCA Special Areas and their surrounding parks, conservation areas and reserves. She notes that the community is always having to catch-up with the impacts of mining projects. Recognition and government acknowledgment of the harm caused takes years, and enacting remediation takes yet more time and is generally inadequate, if at all possible.

The Southern Sydney Metropolitan Catchment Management Authority (SMCMA) areas contain some of the region’s most pristine parcels of native bushland, and these areas are home to some 80 threatened fauna and flora species.[36] The following summary is from the Web site:

- National Parks: 7
- Nature Reserves: 5
- State Conservation Areas: 3

- State Forests: 1
- Aquatic Reserves: 11
- Intertidal Protection Areas: 7
- Major surface catchment areas: 8
- Endangered or vulnerable ecological communities: 21
- Endangered or vulnerable ecological populations: 9
- Endangered or vulnerable species: 139

The SMCMA areas contain assets recognised by the Australian Government as being of National Environmental Significance. Assets of National Environmental Significance include endangered ecological communities, threatened species, migratory species, marine protected species, Australian heritage sites, a RAMSAR wetland site and other important wetlands and conservation reserves.

The SMCMA Web site tabulates the assets of National Environmental Significance in the Greater Sydney region, and this includes the National Parks, the Dharawal Nature Reserve and the wetlands of the O'Hares Creek Catchment. The latter is listed in Environment Australia's Directory of Important Wetlands and on the Register of the National Estate.[37] Under the Environment Protection and Biodiversity Conservation Act 1999, *actions that are likely to have a significant impact on a matter of national environmental significance require the approval of the Commonwealth Environment Minister*. An action includes a project, development, undertaking, activity, or series of activities. The act would clearly apply to a proposed CSG mining project.

Appendix D of the SCI report[1] summarises parts of an extensive fauna survey and research project[1, 38] jointly undertaken by the then DECC and the SCA between 2002 and 2007 in the Warragamba, Metropolitan, Woronora, O'Hares Creek, Blackheath, Katoomba and Woodford Special Areas. This region covers the Southern Blue Mountains to the Illawarra coast, including south-western Sydney and Royal National Park. The study integrates the results of other biodiversity surveys undertaken across the region by DECC and other organisations and individuals, including the NPWS. The DECC-SCA survey comprehensively identifies threatened and endangered fauna in the region, 21 of which are listed in Appendix D of the SCI report. Appendix D tabulates additional protected and regionally significant fauna species in specific habitats, and closes with a detailed summary of regional aquatic flora and fauna; little is known about the aquatic communities of the region.

Four priority animal habitats have been identified in the Greater Southern Sydney region[38] :

- Grassy box woodlands as primarily found in the Burratorang Valley of the Wollondilly.
- Alluvial woodlands and forests of the Wollondilly, Natai, Kowmung, Cox's, Keduma Rivers in the Warragamba Special Area; Abercrombie river in the south west of the Blue Mountains National Park, the Nepean and Georges river areas and the Macquarie Rivulet and Duck Creek on the Illawarra coastal plain.
- Coastal wetlands and salt marsh including the Bellambi, Puckey's and Coomaditchy lagoons, Korrangulla Wetlands, Koona Point, wetlands around Lake Illawarra and in the Royal National Park (e.g. Marley Lagoon).
- Upland Swamps; the key habitat for 12 of the region's most threatened animal species. The Woronora Plateau is particularly rich in this habitat, for example Maddens Plains, Stockyard Swamp and Flat Rock Swamp. These areas are very sensitive to disturbances such as changes in hydrology and overly frequent bush fires.

The SCI report notes "*Several vegetation communities have been recognised as endangered ecological communities (EECs) under the Threatened Species Conservation Act 1995 due to a combination of factors which include their naturally restricted distribution, levels of historical*

*clearing and low levels of protection in conservation reserves ... “A survey of the Upper Nepean and Woronora catchments by the NPWS in 2003 identified 48 different vegetation communities. Of these communities, 26 have less than 15% of their remaining area conserved within NPWS reserves in the Sydney Basin Bioregion. The SCI report lists endangered vegetation communities including for instance the Shale Forest in the O’Hares Creek catchment. The Upland Swamps on the Woronora Plateau are considered as perhaps the most significant floristic community that may be potentially significantly impacted by subsidence-related impacts from longwall mining. As the NSW Scientific Committee recently points out[2], they are now additionally threatened by CSG mining; **CSG mining should not be permitted in the Sydney Basin Bioregion.***

CSG mining should not be permitted in the Sydney Basin Bioregion. CSG mining should also be so listed a Key Threatening Process under Schedule 3 of the Threatened Species Conservation Act 1995.

In its submission to the SCI, the DECC reported that the Upland Swamps of the Woronora Plateau “*appear to be encompassed by the definition of ‘Temperate Highland Peat Swamps on Sandstone’ (Commonwealth Department of Environment and Heritage, 2005), an ecological community listed as endangered under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 ... “ In April of 2011, the NSW Scientific Committee, established by the Threatened Species Conservation Act, made a Preliminary Determination[2] to support a proposal to list Coastal Upland Swamp in the Sydney Basin bioregion as an **endangered ecological community** on Part 3 of Schedule 1 of the Act. The listing of Endangered Ecological Communities is provided for by Part 2 of the Act.*

“Exploration and extraction of coal seam gas poses a future threat to Coastal Upland Swamp, as these activities are likely to involve many of the impacts described above for longwall mining. In addition, gas extraction may require dewatering of the coal seams and/or injection of fluids to fracture the coal seam and promote gas liberation/drainage. Sutherland et al. (2011) identified hydraulic fracturing as one of 15 emerging global threats to biodiversity. Significant environmental impacts on hydrological and ecological functions of Coastal Upland Swamp may occur if toxic injection fluids or saline/alkaline coal seam water find their way into the swamps and associated streams.”

The Committee’s online report[2] states in Finding 19 “*Exploration and extraction of coal seam gas poses a future threat to Coastal Upland Swamp, as these activities are likely to involve many of the impacts described above for longwall mining. In addition, gas extraction may require dewatering of the coal seams and/or injection of fluids to fracture the coal seam and promote gas liberation/drainage. Sutherland et al. (2011) identified hydraulic fracturing as one of 15 emerging global threats to biodiversity. Significant environmental impacts on hydrological and ecological functions of Coastal Upland Swamp may occur if toxic injection fluids or saline/alkaline coal seam water find their way into the swamps and associated streams.*” These environments play a vital role not only as primary habitats for threatened species, but also as filtration and recharge zones for the Greater Sydney catchment. They must be protected from CSG mining

In 2005, the alteration of habitat following subsidence due to longwall mining was listed by the NSW Scientific Committee as a ‘Key Threatening Process’ under Schedule 3 of the Threatened

Species Conservation Act 1995.[39] *CSG mining should also be so listed a Key Threatening Process. CSG mining threatens habitats with subsidence, mini-earthquakes, land clearing, produced water spillage and leakage, and fugitive methane emissions causing bush fires and compounding climate change.*

1.e. Nature and effectiveness of remediation required under the Act

1.e.(i) Accidents will happen. History shows that where there is a risk of an industry failure, at some point that risk will be realised. This may be because of a mechanical failure, human failure, a natural event or some combination of these factors. The consequences may be dire and costly, with the Fukushima and Deep Water Horizon disasters being obvious recent examples of catastrophic failure. The Deep Water Horizon disaster was the result of inadequate concrete plugs. A 2010 study of gas mining in Queensland by JPMorgan concluded *environmental damage costs could outweigh revenue benefits*.[40]

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Queensland Director for APPEA Ross Dunn recently conceded that there were grounds for concern with respect to ground water and methane leakage.[41] The latter he attributed to sub-standard equipment and AGL has recently called for higher industry standards.[42] Ironically, AGL has since been embarrassed by a blow-out at Camden in the Southern Coalfields on May 26.[43] A few days earlier there was a dangerous blow-out at a coal seam gas well near Dalby west of Brisbane, propelling gas and contaminated water 40 meters in the air for more than a day.[44] Thirteen farming families from the Save Our Darling Downs group then launched legal action in the State Land Court against the gas company's environmental licence to operate.[45]

Improved regulation, industry practice, equipment and technology may reduce error, accident and failure, but will not eliminate such events and will in general add to operational costs. Regulation compliance requires monitoring and history shows that monitoring and reporting by the operators cannot be relied upon. The industry has a history of over-confidence in assessing risk and remediation capability, and downplaying or denying accidents and failures. The land owner on whose property the Dalby blowout occurred was not informed by Arrow of the event for several hours and is quoted as saying "*They're all very friendly and matey, but when things go wrong they try to hide them.*"[47] A week after BTEX chemicals were found in sites operated by Origin Energy belatedly informed the Queensland Government.[48] QGC have been criticised for long delays in reporting and addressing gas leaks, some of which were shown in the ABC Four Corners documentary Gas Rush.[49,31] In March this year QGC admitted it had made a mistake in proceeding to clear land without required environmental approvals.[50]

The general public is rightfully excluded from the SCA Special Areas, yet an industry increasingly caught up in legal action[46, 148] arising from water contamination, blow-outs, explosions and mini-earthquakes is be trusted in these important and sensitive

On the ABC programme Lateline industry spokesperson Ross Dunn recently observed that Chinchilla like land clearing (see Fig. 10) would have to be accepted if CSG mining is to proceed; “... if you're going to develop an area you will have an impact.” [51] Land clearing in the Pilliga, including State Conservation Area land, by Eastern Star Gas appears to have been carried out without the Commonwealth approval required for a project undertaken on an area of national environmental significance.[52] Problems in the Pilliga were identified in a 2002 report on the environmental hazards of oil and gas exploration by NPA NSW.[10]

"They're all very friendly and matey, but when things go wrong they try to hide them."

In 2010 the NSW asked AGL to clean-up produced water that landowners claimed had been dumped by the company and in response the company denied acting irresponsibly.[53] More recently carcinogenic chemicals have been found in monitoring bores used by Arrow Energy in Queensland.[54] The industry downplays the threat posed by its chemicals, describing them as household chemicals, no more of a threat than applying crop pesticides or exposure to benzene when filling a car with petrol. They are not however chemicals that would be expected or accepted in drinking water.

“ ... if you're going to develop an area you will have an impact.”
– Ross Dunn, APPEA

The pool of CSG mining expertise in Australia is limited, increasing the risk of errors, accidents and failures. The current holders of PEL 442, 444 and 454 for instance have limited CSG experience and limited financial resources; the costs of addressing contamination and damage arising from CSG mining would then be borne by taxpayers.

1.e.(ii) Remediation may be prohibitively costly, inadequate or physically impossible

The practicalities and effectiveness of the remediation of CSG exploration and mining damage to the environment will depend on the nature and extent of the failure. Recovery from a small surface spill of produced water, or isolated and small scale land clearing, or a small methane triggered explosion and localised bushfire in-principle should present little difficulty, but in reality may prove problematic. This would appear to be the case in the Pilliga where environmental damage has not been addressed[55], and near Broke where the operating gas company appears to have failed to act responsibly.[53,56] The costs to project operators, some with very limited financial capacity, of even comparatively small scale remediation work may prevent effective or timely action.

Larger scale remediation will either be very difficult and costly, or impossible in practice. The latter has been emphasized during the hearings of the Federal Senate Inquiry into the management of the Murray Darling Basin system.[57] Examples would include contaminated, drained or subsidence breached aquifers, large scale land clearing for industrial CSG mining, extensive land contamination from produced water spillage and climate change compounded by fugitive emissions of methane.

Should industrial CSG mining proceed in the Greater Sydney catchment areas, the remediation of cleared land will be very difficult if not impossible. The nutrient rich soil that sustains the vegetation so important to the water quality is shallow and once overturned in large scale land clearing, it's unlikely it could be returned to its original health and character.[58] Revegetation may well be possible, but the landscape and its catchment and habitat function would be detrimentally different.

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The PAC report for the BSO project comments on repairing subsidence damage in the Waratah Rivulet; *“In the case of watercourses, it is not yet feasible to remediate an entire upsidence fracture network. Hence, remediation efforts in the Southern Coalfield have to date focused on sealing the fracture network at strategic locations, such as rock bars. At these sites, the fracture network can extend some distance laterally under the toe of valleys and be overlain by talus. It can also be covered by boulder beds within watercourses. These types of settings restrict access for grout injection equipment.”*[9(page 56)]

The Federal Senate Inquiry recently questioned the Queensland CSG Director for APPEA Ross Dunn and others about the contamination of the Springbok Aquifer in the Surat, caused by fracking induced connectivity between the aquifer and the lower Walloon coal seam. The Chair notably expressed frustration: *“How the hell do you make good a contamination of an aquifer? To put that into perspective, you would be aware, I take it, that in the United States at Bakersfield, the community there—the municipality—in a different mining operation is suing a company for \$2 billion because they have contaminated their water. But money is not the solution. How do you make good a contamination?”*. [59]

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The industry response is that the affected area would be sealed off; assuming that is possible, it does not constitute remediation. The Inquiry Chair implies large scale remediation would likely not be possible in practice.

1.e.(iii) The perpetual problem of abandoned CSG wells

In statements to the Federal Senate Inquiry industry representatives have expressed confidence in the durability of well casings, concrete plugs and caps, suggesting an essentially indefinite lifetime and limited need for post lease expiration monitoring.[59(e); e.g. pages 17 and 66] An industry spokesperson states for instance “*There is no possibility that there can be leakage through a well that has been sealed.*” and “*Again I need to stress that well construction techniques and our testing of those wells after they are completed give us absolute confidence that there is no connectivity between aquifers ..*.” Given the very large number of wells likely to be drilled, indefinite monitoring will however be essential. There is no basis for simply assuming, as the industry apparently does[59(e), page 17], that a concrete plug or steel casing will last thousands or even hundreds of years.

Geology professor Marc Durand, a specialist in hydrogeology and rock mechanics, suggests a time frame of as little as 30 years for some wells to begin to fail.[60] In submissions to the Delaware River Basin Commission in 2010[61(a)] hydrogeologist Paul Rubin and chemist Dr. Ron Bishop have similarly argued that large-scale groundwater contamination is inevitable over time as casings, plugs and caps fail. Rubin states “*In my professional opinion, vertical exploratory gas wells, as well as horizontal hydraulically fractured wells, create a high risk of contamination of the water resources of the Delaware River Basin. This risk exists not only at the time of drilling but also increases over time, because of a) the likelihood of failure of the well over time, b) the likelihood of eventual migration of toxic natural and drilling-related substances through extensive natural fractures that exist throughout the region, and c) the exacerbation of a) and b) above by natural or drilling-induced seismic activity. This report also documents significant natural seismic activity in and adjacent to the Delaware River Basin over time. Ground motions from even one significant earthquake, among many that occur over time, may catastrophically shear numerous gas well casings or, at the very least, may result in fracturing and loss of integrity of well casing cement designed to isolate freshwater aquifers from deep saline waters. As such, earthquakes may instantly destroy the integrity of hundreds of gas wells, thereby forever and irreparably compromising the hydrologic integrity of geologic formations that formerly protected freshwater aquifers. Restoration of contaminated freshwater aquifers is probably not possible, thus well failures from any single or combination of mechanisms is likely an irrevocable commitment of natural resources.*”[61(b)]

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Dr Bishop states “*Short-term collateral damage from gas well development is only part of this industry’s hazard profile. In 1992, the US Environmental Protection Agency (EPA) estimated that of 1.2 million abandoned oil and gas wells in the U.S., 200,000 were leaking (9). This represents a 16.7% failure rate; one of every six abandoned wells is releasing its contents to the surrounding area, including the surface. A Canadian research team investigated the mechanisms for these failures, and determined that concrete shrinkage which leads to well casing fissures is essentially inevitable in a fifty-year time frame. They found that this cracking was especially severe at maximum depth, and exposure of steel casings to the hot (140 – 180 °F) brines there accelerated their breakdown, permitting subterranean gases and other fluids to re-pressurize the deteriorating*

wells (10). Wells in regions containing mobile geological faults (such as eastern Pennsylvania) are also subject to casing deformation and shear (11). Therefore, we may reasonably expect higher percentages of gas well casings to fail over time, especially longer than fifty years. The probability that a project scope of as few as ten gas wells will impact ground water within a century approaches 100%; ground water will be contaminated.” [61(c)]

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A 2001 report to the Department of Primary Industries and Resources of South Australia goes into considerable detail in describing well failure processes, including cement degradation,[62] The report concludes with “*The well in the case history started to fail 15 years after the cement had been put in place. Deterioration most probably occurred long before this time. So what timeframe for the isolation of a formation is required? This report does not address the timeframe for the life of cement but one possible outcome concerning cement life may be that the technology does not exist to be able to provide isolation timeframes. Absolute favourable conditions would need to be present to ensure that cement integrity is maintained for an infinite time after well abandonment. This is never likely to occur since wellbore cement is exposed to dynamic conditions and streams of potentially corrosive compounds.*” And “**Current cementing technology is not sufficient in providing an indefinite zonal isolation. New methods need to be considered, particularly when considering the abandonment of the well.**”

Sealed wells may last the lifetime of the mining company lease, but at some point they will fail. Aquifer waters may mix, a build up of high underground pressures may drive highly saline and alkaline water to the surface and methane may be released to the surface. The consequences and costs would be inherited by a subsequent generation.

Shortly before the first hearing of the Inquiry in NSW, at Narrabri, Ross Dunn conceded that “*Drilling will, to varying degrees, impact on adjoining aquifers,*” said the spokesman, Ross Dunn. “*The extent of impact and whether the impact can be managed is the question.*”[63]

“*Drilling will, to varying degrees, impact on adjoining aquifers,*” said the spokesman, Ross Dunn. “*The extent of impact and whether the impact can be managed is the question.*” Sealed wells may last the lifetime of the mining company lease, but at some point they will fail. Aquifer waters may mix, a build up of high underground pressures may drive highly saline and alkaline water to the surface and methane may be released to the surface. The consequences and costs would be inherited by a subsequent generation.

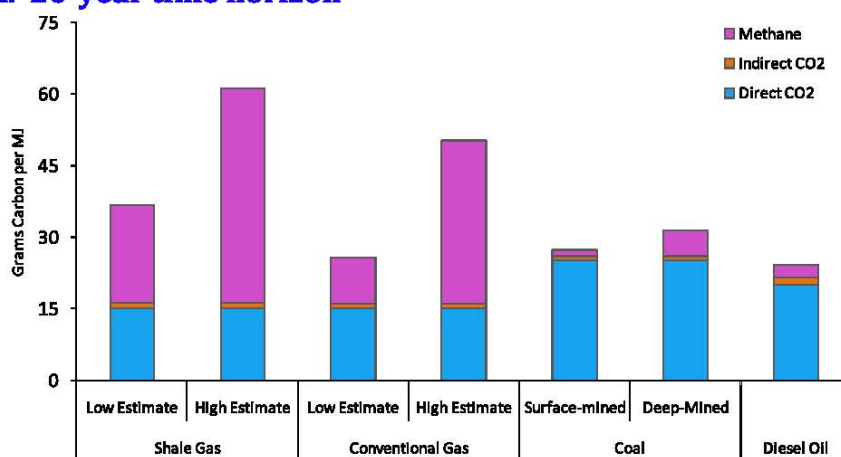
Effectively conceding that CSG mining is an environmental experiment with significant unknowns, Ross Dunn is in agreement with the CSIRO and the National Water Commission.

1.f. Effect on greenhouse gas and other emissions

In principle gas combustion produces around half as much carbon dioxide per unit of energy than does coal combustion. On this basis industry and governments promote gas as a cost effective interim or transitional fuel in a long term transition to a zero carbon emissions economy. There are however three serious concerns that compellingly argue against NSW turning to gas as a source of energy:

1.f(i). Fugitive Emissions: A widely cited recent paper from Cornell University raises concerns that the whole of life cycle emissions from gas mining, transportation, processing, storage, distribution and combustion significantly undermine and may well negate the in-principle benefit gas otherwise has with respect to the green house gas footprint of coal.[64]

A. 20-year time horizon



B. 100-year time horizon

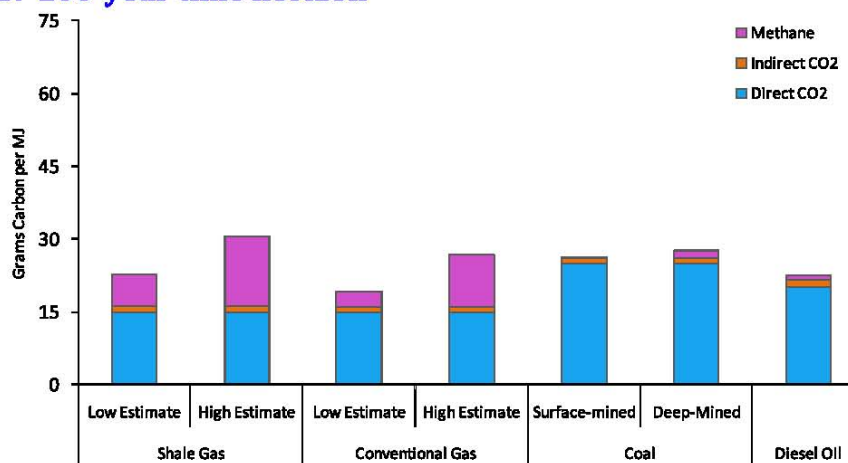


Figure 14. Comparison of greenhouse gas emissions from shale gas with low and high estimates of fugitive methane emissions, conventional natural gas with low and high estimates of fugitive methane emissions, surface-mined coal, deep-mined coal, and diesel oil. Figure a is for a 20-year time horizon, and b is for a 100-year time horizon. Estimates include direct emissions of CO₂ during combustion (blue bars), indirect emissions of CO₂ necessary to develop and use the energy source (red bars), and

fugitive emissions of methane, converted to equivalent value of CO. Emissions are normalized to the quantity of energy released at the time of combustion. The conversion of methane to CO₂ equivalents is based on global warming potentials that include both direct and indirect influences of methane on aerosols. Taken from Figure 1 in reference 64(a).

While the paper has a focus on methane emissions from fracking shale to extract natural gas in the US, it has wider implications and is directly relevant to gas mining from low permeability or ‘tight gas’ coal seams. The research estimates losses during the life cycle of a typical well at 3.6 to 7.9% of the total production of the well. Of this total, up to 1.6% comes from methane that escapes as produced water is returned to the surface (flow-back), so while emissions from non-conventional wells where fracking is not used (e.g. directional or zero radius drilling) would be correspondingly lower – they would nonetheless be problematic. Indeed the paper suggests that the emissions from conventional gas are sufficient to undermine the in-principle combustion benefit of gas relative to coal.

Based on its emissions estimates, the Cornell research finds gas from unconventional wells can have a greater green house gas footprint than coal (see Fig. 14). The greenhouse gas footprint assessments in the paper may prove to be conservative, as methane emissions into the atmosphere from ground and surface waters in the vicinity of gas wells, as highlighted in the recent PNAS paper referred to in sections 1.c and 1.f(i), are not considered. Whether or not fracking is used, de-watering and depressurisation triggered structural changes may be sufficient to provide fissure connectivity, percolation and gas escape through to the surface.[15]

The Cornell paper utilises recent NASA research suggesting methane is a more potent greenhouse gas than previously thought, up to 105 and 33 times that of carbon dioxide on a 20 and 100 year basis respectively, with an uncertainty of plus or minus 23% [65]. On release into the atmosphere methane over time oxidises to carbon dioxide. Given this decade has been identified as a critical decade if dangerous climate change is to be avoided[66], the 20 year time frame is an immediate concern. The very high greenhouse impact of methane on a 20 year scale may be sufficient to trigger irreversible feedback effects, including the release of further methane from permafrost and ocean clathrates.

A month after the Cornell paper was published, the US National Energy Technology Laboratory (NETL) presented the results of a study that appear to contradict the Cornell findings.[67] The role of NETL is to research and enable the use of coal, natural gas, and oil in the US. Its findings are similar to those in a report from the American Clean Skies Foundation (ACSF), an industry group largely funded by Chesapeake Energy, which suggest existing gas-fired generation is, on average, about 51% less GHG intensive than existing coal-fired generation.[68]

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The ACSF report makes a number of criticisms of the Cornell paper, and describes the revised methane green house gas potential recently published[65] by NASA in the leading journal Science as novel and not established. The industry has criticised[69] the Cornell paper, and criticisms have

in turn been made of the NETL report, which appears to underestimate a number of parameters.[70] Neither the NETL or the ACSF reports have been peer reviewed, in contrast to the PNAS, Cornell and Science papers. As a commentary in the prestigious science journal Nature suggests, in summarising and commenting on criticisms of the Cornell paper, there remains cause for concern that fugitive emissions undermine the in-principle advantage gas combustion has with respect to green house gas emissions from coal combustion.[71]

The ACSF report makes a number of criticisms of the Cornell paper, and describes the revised methane green house gas potential recently published[65] by NASA in the leading journal Science as novel and not established. The industry has criticised[69] the Cornell paper, and criticisms have in turn been made of the NETL report, which appears to underestimate a number of parameters.[70]

The concern raised by the Cornell paper is reinforced by a more recent paper[72] published by the US National Center for Atmospheric Research (NCAR), that builds on a comprehensive 2002 paper on the global warming effects of a transition from coal to gas.[73] The climate model used in the study is calibrated to models used by the CSIRO and the Bureau of Meteorology.[72(b)] Using a different methodology to that of the Cornell research, the research concludes that a transition to gas results in “*additional warming out to 2,050 with an assumed leakage rate of 0%, and out to 2,140 if the leakage rate is as high as 10%.*” (see Fig. 15).

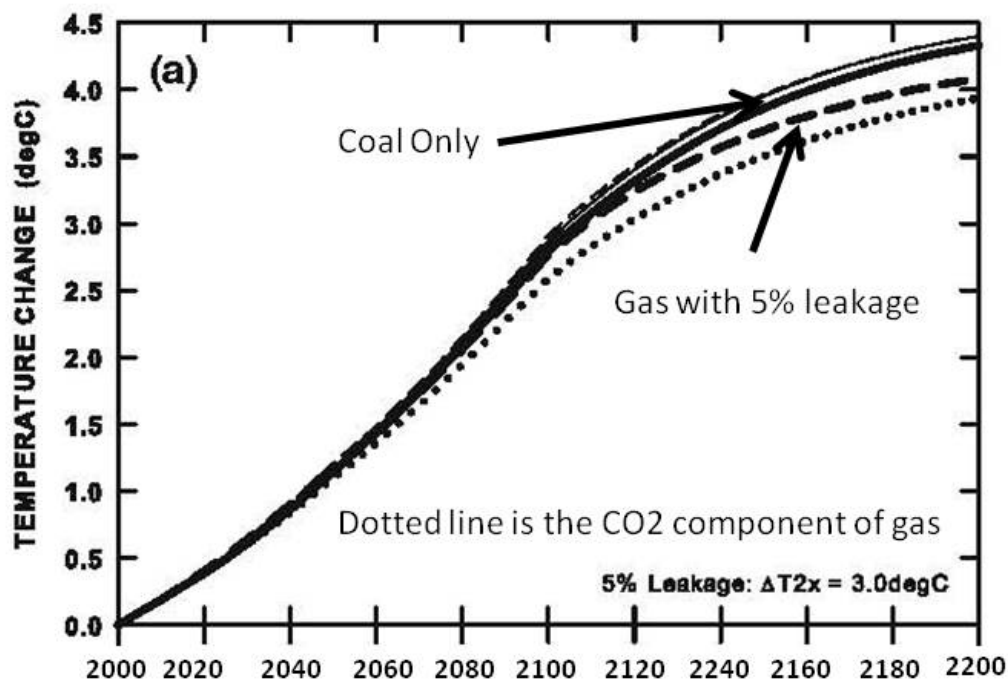


Figure 15. Baseline global-mean warming (solid bold line) compared with a transition from coal to gas. The dashed line shows the influence of 5% methane leakage and the dotted line shows the effect of CO2 alone (i.e. no leakage). Taken from reference 72.

“additional warming out to 2,050 with an assumed leakage rate of 0%, and out to 2,140 if the leakage rate is as high as 10%.” .

The Cornell paper and NCAR papers do not take into account the leakage from the ground in the vicinity of a gas well, as suggested by the PNAS paper[30] and the Wyong study.[15] This may prove to be a serious concern, given the number of well constructions being projected across the country and around the globe.

At a CSG forum in Sydney on May 16[74], the Queensland Director for the industry’s peak body the Australian Petroleum Production and Exploration Association (APPEA) Ross Dunn stated the leakage rates given in the Cornell paper would not be acceptable to the industry, and his expectation was that CSG life cycle emissions of green house gases would be 60 to 70% of those from coal. Comments and risk assessment advice from the gas industry must be treated with the same caution as those from the asbestos, coal, nuclear or tobacco industries. The coal giant Peabody energy argues gas is more problematic as a source of green house gas emissions than is coal, as does the World Coal Association.[75]

The Four Corners documentary Gas Rush[49] has disturbing footage of leaking gas wells and the movie Gasland shows methane bubbling in water ways. CSG mining in the catchments of the Illawarra and Wollondilly would be in areas where strata have already been damaged and stressed by longwall mining. Figure 8 shows methane escaping from the Waratah Rivulet earlier this year. The radiocarbon content of atmospheric methane suggests fossil fuels may be a far larger source of atmospheric methane than generally thought (76).

The Four Corners programme reveals that leaks may go unnoticed and repairs may not be undertaken for months or even years. Two notably significant leaks have occurred in recent months[44,77], the most recent on September 14 being the result of a five centimetre crack in a well operated by QGC in Queensland.[77] An audit of 58 wells in the Tara region in 2010 by the Petroleum and Gas Inspectorate in Queensland found 2% were leaking at or above the lower explosive limit (LEL), all operated by QGC. A further 29 wells belonging to a number of companies were also leaking, but below the LEL. [78] A state wide inspection found 2% of wells leaking at a reportable level. Leaks with air concentrations below 0.5% are not reported.

While there will of course always be equipment or human failures, sometimes life threatening failures[44], the industry has some control over well casing, capping and plugging, pipeline, shipping and storage leakage rates.[78] Operators however have much less control over the migration of gas to the surface from the coal seam following seam fracturing or subsidence following de-watering or fracking.

De-watering alone may be sufficient to cause methane percolation to the surface.[15, 169(a)] The WorelyParsons report commissioned by Campbelltown City Council in 2010 asserts *“Depressurisation of coal seams by groundwater extraction allows the gas adsorbed to the coal cleats to desorb and migrate to the production well for extraction both in the dissolved phase and as free gas. However, at some distance from the edge of the gas field, where the effects of depressurisation are less, the force of buoyancy will overcome that of the pressure gradient. Consequently, these gases may migrate to shallower intervals and potentially discharge to the surface, either through wellbores or via natural geological pathways to surface seeps. Gas migration and seepage to the surface has the potential to affect vegetation die-back, human health*

and safety risks if gas builds up in concentration.”[169(a)] It would also contribute to the greenhouse gas burden.

“ ... the force of buoyancy will overcome that of the pressure gradient. Consequently, these gases may migrate to shallower intervals and potentially discharge to the surface, either through wellbores or via natural geological pathways to surface seeps.”

The concern echoes the 2005 hydrogeological report from Northern Geoscience on the prospect of coal seam gas mining in the Dooralong and Yarramalong Valleys in NSW: *“Once coal bed gas is liberated by the withdrawal of water reducing the hydrostatic head, the methane is free to migrate. Geological structures, inadequately cemented conventional gas wells and extraction of produced water from coal bed methane wells can contribute to natural gas resource losses and to methane migration into surface soils and groundwater.”*[15(a)] The use of hydraulic fracturing increases the level of risk.

1.f(ii). Delay or displacement of the deployment of renewable energy sources - gas is no panacea for climate change

Transitioning to gas fired power stations with a working lifetime of some 20 to 40 years, and possibly longer, is at odds with the emissions cuts needed to avoid dangerous climate change. The record high emissions of 2010 were comprised of 44% from coal, 36% from oil, and 20% from natural gas. The notably conservative International Energy Association (IEA; Australia is a member country) has just released a study showing that based on current trends gas is likely to make up about one-quarter of the world's energy supply by 2035, representing a more than 40 percent increase in demand and the displacement of coal by 2030. This results an atmospheric carbon dioxide concentration of 650 ppm and at least a 3.5C global temperature rise.[79] This warming estimate is likely to be very conservative as it does not include fugitive methane emissions or feedback effects such as methane release from tundra or ocean clathrates.

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The consequences for Australia would be devastating, yet Australia is rushing headlong into this bleak and dangerous future.[49, 80] The IEA report notes Australia is set to become one of the leading sources of unconventional gas; Australia is already a leading exporter of greenhouse gas in the form of coal.

The IEA concludes gas is no panacea for climate change.[79(b)] The IEA report does not take into account the recent research indicating that the greenhouse gas foot print of gas may be significantly higher than previously thought, and may surpass that of coal in some circumstances. The carbon dioxide concentration and global warming impacts of the transition to gas modelled by the IEA may then be significantly underestimated.

The IEA concludes gas is no panacea for climate change.

In the absence of a sufficiently discriminating carbon price structured to favour renewable energy investment, and with gas fired power plant lifetimes of 25 to 40 years, there is a very real risk gas will displace urgently needed investment in renewable energy sources. This concern has been expressed by the IEA, the UK Tyndal Centre at Manchester University, Goldman Sachs and a recent UK Parliamentary Inquiry.[81] With a 0.8 degree temperature rise already here and an equivalent rise on its way even if green house gas emissions stop tomorrow, the prospects for avoiding a 2 degree global temperature rise and dangerous and costly climate change at best look bleak.

1.f.(iii). The declining prospects of carbon capture and storage – *there is no such thing as clean gas*

With realistic demonstration plants costing of the order of \$2 billion[82], and full scale plants likely to cost as much as the power stations they serve, *there is little prospect that carbon capture and storage can be implemented in a safe, cost effective and timely manner on the production scale required.* Entrenching gas fired power hoping that is not the case is at best folly. Prudent policy would assume CSS will not be available as a safe and cost effective technology for power stations within the needed timeframe on the scale required.

To its great credit the NSW government has recently denounced the industry promoted notion of clean coal. In debating a bill to legislate the recognition, Minister Hartcher commented “*The purpose of the Clean Coal Administration Amendment Bill 2011 is to acknowledge the fact that there is no such thing as clean coal and to accept that we all have a responsibility, no matter what our political persuasion or background, to work in our community to minimise or to eliminate carbon dioxide emissions.*”.[83] The Government must take the same pragmatic approach and denounce the fiction of gas being a clean energy alternative to coal; ***there is no such thing as clean gas.*** A transition to gas will heighten global warming.

As recently observed on the ABC Lateline programme[84], industry assurances that CCS is just over the horizon have lost credibility. A special report[85] in the leading journal Science in 2009 concludes “*For the green aspirations of CCS to become real by 2020, funding and immediate building of real projects is needed.*” This has not happened and the acceleration and scale-up of CCS “*from tens of power plants within 5 years to hundreds of large plants by 2025, and then to thousands of small power plants by 2035.*” in order to avoid dangerous and unpredictable climate change increasingly looks unattainable in a cost effective manner. A study[86] released this year by the IEA reveals that costs estimates for CCS have increased significantly since 2007. The study concludes that the capture process alone will cost around USD 55 per tonne of carbon dioxide captured from a coal plant and about USD 80 per tonne from a gas fired power station, as the flue concentration of carbon dioxide is lower and harder to capture. The study does not assess the costs of transport, injection and storage with monitoring.

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A 2009 report for the Australian Department of Resources, Energy and Tourism estimates[87] “ ... cost of CO₂ transport and injection per tonne of CO₂ avoided for single source-sink matches in eastern Australia varies from A\$10 per tonne (for the Latrobe Valley to the Gippsland Basin) to A\$1,539 per tonne of CO₂ avoided (for North Queensland to the Denison Trough). For the combined source-sink cases, our best estimates of the costs range from A\$14 per tonne (for All of Perth to the Bunbury Trough, South Perth) to A\$6,200 per tonne of CO₂ avoided (for All of Perth to the Vlaming Basin). For each single source-sink match, the up-front capital costs range from A\$1.2 billion (for the Latrobe Valley to the Gippsland basin) to A\$162 billion (for North Queensland to the Denison Trough). These capital costs do not include the cost of CO₂ capture or initial compression to supercritical conditions. The capital costs for the combined source-sink matches range from A\$0.8 billion (for All of Perth to the Bunbury Trough, South Perth) to A\$341 billion (for All of Perth to the Vlaming Basin).”

A 2009 Harvard University study suggests the cost of adding first generation carbon capture and storage (CCS) technology to power generators will cost US\$100 to US\$150 per ton of carbon avoided.[88] This considerably more than current carbon pricing schemes, making it cheaper to pollute than to use CCS, and around the current mark where large scale renewable energy deployment becomes cost competitive.

The US Department of Energy (DoE) stated this year “*The cost of CO₂ capture using current technology, however, is on the order of \$150 per ton of carbon - much too high for carbon emissions reduction applications.*”[89]

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The DoE points to the problem of applying CCS to existing plants, with flue gas from coal-fired power plants containing only 10-12 percent carbon dioxide by volume, and flue gas from natural gas combined cycle plants contains only 3-6 percent carbon dioxide. Cost effectively capturing all or most of the carbon dioxide at this level of dilution is beyond current technology. A demonstration plant at the Mountaineer Power Plant in New Haven in the US captures about 1.5 percent of the carbon dioxide it produces for an investment cost of more than USD 100 million.[89(b,c)] Plans to scale-up the project have recently been shelved because of rising costs.[90] The CCS project was abandoned “ .. *after regulators in Virginia and West Virginia refused to allow the utility to charge customers for the cost of building and operating the project.*”[90(b)]

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If CCS proves technically feasible on the scale required for new power plants, CCS costs are expected to decline over a twenty year time frame following the first generation deployments but, as the proponents admit, production scale CCS deployment for fossil fuel power stations is at best 10 to 20 years away. Sharp cost reductions are expected for renewable energy over the coming decade.[91] A 2010 report "EU Energy Trends to 2030" by the National Technical University of Athens concluded that European investments in renewable energy will undermine the viability of CCS in Europe.[92]

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Rising costs[93] would mean using carbon capture in power plants leads to a relative increase in electricity costs of 39 to 64 percent for coal plants and 25 to 60 percent for natural gas plants, depending on the technology used.[93(b)] Costs and technological and logistics problems have seen the US FutureGen CCS project falter and the ZeroGen (Queensland), Finncap (Norway), and Kingsnorth (UK) CCS projects abandoned.[94] The Finncap project was to fit CCS to an existing 565 MW power plant with carbon capture and storage equipment by 2015, while the Kingsnorth project was to have been a new 1.6GW coal plant equipped with CCS. A post Finncap review estimates CCS costs at 70 -100 Euros per tonne of carbon dioxide avoided.[95] UK Carbon capture coal firm Powerfuel has been forced to call in administrators and abandon its plans. Powerfuel was the only company to have so far been awarded a licence to test CCS technology in Britain.[96] The economics of CCS led to the Climate Change Commissioner Prof. Tim Flannery withdrawing his support for the technology.[97]

The technology has yet to be shown to be viable for the scale required, and the required scale is enormous. A letter published in 2009 in Nature Geoscience points out that to capture the emissions of 2009 would require 2000 times the capacity of the world's operating CCS projects.[98] At present the largest sequestration project is the Weyburn-Midale project, which is injecting one million tons of carbon dioxide per year into each of two sites in Saskatchewan in Canada to recover oil.[99] The carbon dioxide is transported by pipeline from a coal gasification plant in North Dakota, and the oil recovery offsets costs. Notably, CCS is not used for nearby coal fired power stations. The 2009 Nature Geoscience letter observes that if only 20% of global emissions are to be sequestered “ ... we would need to find and fill an equivalent of 67 Weyburn sites every year.”

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The recently commenced Gorgan gas field project off the coast of Western Australia is to store 3.3 million tons of carbon dioxide per year, with a CCS construction cost of \$2 billion.[100] With population of 21 million or so, in 2010 Australia emitted some 543 million tonnes of carbon dioxide; by 2050 Australia's population is expected to be 35 million and likely more and electricity demand and, with business as usual, carbon dioxide output is expected to at least double.[101] To capture 20% of the Australia's current emissions would require 27 Gorgan CCS projects. The Gorgan CCS facility does not yet exist.

The 2009 Science review of the prospects of CCS observes that an increased understanding of the dynamic processes of carbon dioxide sequestration are eroding earlier optimistic assessments of global storage capacity: "*For a smaller (4000 km²) North Sea aquifer, a static calculation gave a capacity of 2% of porosity, but this amount dropped to 0.56% of porosity when dynamic reservoir heterogeneity was added, and it dropped further to 0.2% when a pressure limit was also applied (18). Worldwide, the original static estimates of storage capacity are now being substantially downgraded to many decades rather than hundreds of years of emissions.*"[85]

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The estimate of several decades of storage is likely to be optimistic. Though having a higher pore capacity estimate, a 2010 paper in the Journal of Petroleum Science and Engineering concludes "... *that the volume of liquid or supercritical CO₂ to be disposed cannot exceed more than about 1% of pore space. This will require from 5 to 20 times more underground reservoir volume than has been envisioned by many, and it renders geologic sequestration of CO₂ a profoundly non-feasible option for the management of CO₂ emissions.*"[161]

CCS involves piping super-critical liquefied carbon dioxide at high pressure, more than 100 times atmospheric pressure, into underground or undersea reservoirs. In the Gulf of Mexico last year BP demonstrated the consequences of human error and technological failure when handling liquids at high pressure in geological formations. Carbon dioxide is of course ordinarily a gas and, unlike problematic nuclear waste, it does not decay. If it is to be pumped underground at high pressure as a supercritical liquid on the truly enormous scale required, it must be so held accident free and with very low leakage rates indefinitely. Just as nobody wants a nuclear waste site in their neighbourhood, nobody will want a carbon dioxide storage site nearby. The 2009 Science review observes "*Public acceptance is also an issue: Opposition has halted several feasible test sites for CCS in Europe. Governments must require heart-and-mind action from developers, several years ahead of applications.*"[85] The Dutch Barendrecht CCS project was cancelled last year because of local concerns and protests about the safety of CCS.[102]

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A significant and unresolved policy problem for CCS is determining who will be responsible for liabilities in the event of an accident. History shows time and time again that where there is a risk of failure at some point that risk will be realised. This may be because of human error, technological failure, a natural event or a combination of these circumstances. The Deep Water Horizon and Fukushima are recent examples of catastrophic failure. An accident could occur during the operating life of a CCS facility, or it could happen tens or hundreds of years after the carbon dioxide store has been filled and closed. Unanticipated leakage could occur at anytime and may go undetected for decades or more. Given the need to keep carbon dioxide trapped for tens of thousands of years, the use of CCS is a very expensive gamble for which the stakes are very high.

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Gas fired power stations have lifetimes of 25 to 40 years or more and industry investment planning will be made on that basis. Entrenching gas fired power and investing in yet more coal hoping CCS will come to the rescue would be like allowing the sale of cigarettes in the nation's school canteens on the basis of assurances from the tobacco industry that research will deliver a safe clean cigarette in ten to twenty years time. Just as asbestos and tobacco kill, green house gas driven global warming kills – but on a much larger scale and across species. Prudent planning in the public interest should assume that CCS will not be available as a cost effective and safe means of abatement for gas or coal. Incentives and investment for rapid deployment of renewable sources ahead of gas and coal is the only sensible course for NSW, Australia and the world. As the recent Climate Commission report highlights, time is rapidly running out.[66]

2. The economic and social implications of CSG activities

Assessing the economic and social costs and benefits assumes quantification of all aspects of CSG mining in a given context is possible. Coal seam gas mining in the Illawarra and Wollondilly would impact some of the State's most beautiful, pristine and biodiverse areas. The importance of these areas is reflected in the National Park, Nature Reserve and National Heritage State Conservation Area listings, and in the legislated protection for the Special Area water catchments for Greater Sydney. Estimating a remediation cost is problematic; there is nothing to suggest that once broken, these natural systems can be repaired at any price.

In its expansion proposal for the Metropolitan Coal Mine, Peabody Energy put forward a community valuation figure of 95 million dollars for the Waratah Rivulet. The Planning Assessment Commission report for the proposal makes the following comments[17] on page 60 *“The Choice Modeling work described in the EA and expanded on substantially in Section 15.0 of this report indicates that the community places a value of at least \$95 million on protection of the Waratah Rivulet. In this context it should be noted that this figure is probably a significant underestimate of the value since the Panel has concluded that the question on which the survey responses were based was biased in favour of under-valuation.”* Further on page 107, *“The question that remains is therefore whether or not the environmental damages are in excess of the \$436m mining net benefit.”*

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Located in the much same area of the Southern coalfield as the Apex CSG interests, the same criticisms have been made of BHP’s Bulli Seam Operations (BSO) proposal; *“This mine versus environment valuation yielded spurious results as the choices were not based upon adequate, impartial information. The focus groups were led to believe that mining the area would cause minimal damage to the environment. It was also incorrectly suggested to the focus groups that increased environment protection would increase taxation.”*[3] In making their own assessments, proponents will inevitably underestimate damage costs and over-estimate benefits.

BHP abandoned[164] their plans to mine in the vicinity of the Dharawal State Conservation Area, when the highly critical PAC report[3] found the Environmental Assessment provided by BHP to be inadequate. The report also comments “ ... while protection of the significant natural features would involve lower mine profitability, it is likely that society as a whole would gain more from the environmental protection recommended than it would lose in terms of foregone profits.”.

The same considerations would hold for coal seam gas mining in the Illawarra and Wollondilly – the same region as the abandoned BSO project. The coal seam gas industry currently enjoy a 5 year royalty holiday. The royalty arrangement in NSW are 0% for the first five years, 6% in year 6, 7% in year 7, 8% in year 8, 9% in year 9 and 10% in year 10 and for remaining years. In 2010 royalties from coal seam gas was only \$462,000 primarily from the AGL Camden project in the Southern Coalfield. There can be no doubt that the value of the natural assets of the Illawarra and Wollondilly would far outweigh revenues from coal seam gas mining.

3. The role of CSG in meeting the future energy needs of NSW

3.(i). Urgent need to reduce carbon emissions. As the recently released Climate Change Commission’s Critical Decade report and the latest edition of the Copenhagen Diagnosis report make clear,[66] the world needs to be at or approaching zero green house gas emissions by 2050 in order to have a reasonable chance of avoiding global warming of two or more degrees, Beyond two degrees climate change is increasingly unpredictable, dangerous and costly. Limiting global warming to no more than two degrees imposes a fixed upper limit on the total amount of carbon dioxide equivalents that can be added into the atmosphere. This effectively means emissions must peak before 2020 (see Fig. 16) in order to stay below that upper limit.

There is increasing concern in the scientific community that tolerating two degrees of warming will be problematic. Reflecting this concern, the executive secretary of the UN framework convention on climate change, Christiana Figueres, recently stated: *“Two degrees is not enough – we should be thinking of 1.5C. If we are not headed to 1.5C we are in big, big trouble.”*[103] She also pointed to the very high costs of further delaying effective action.[104]

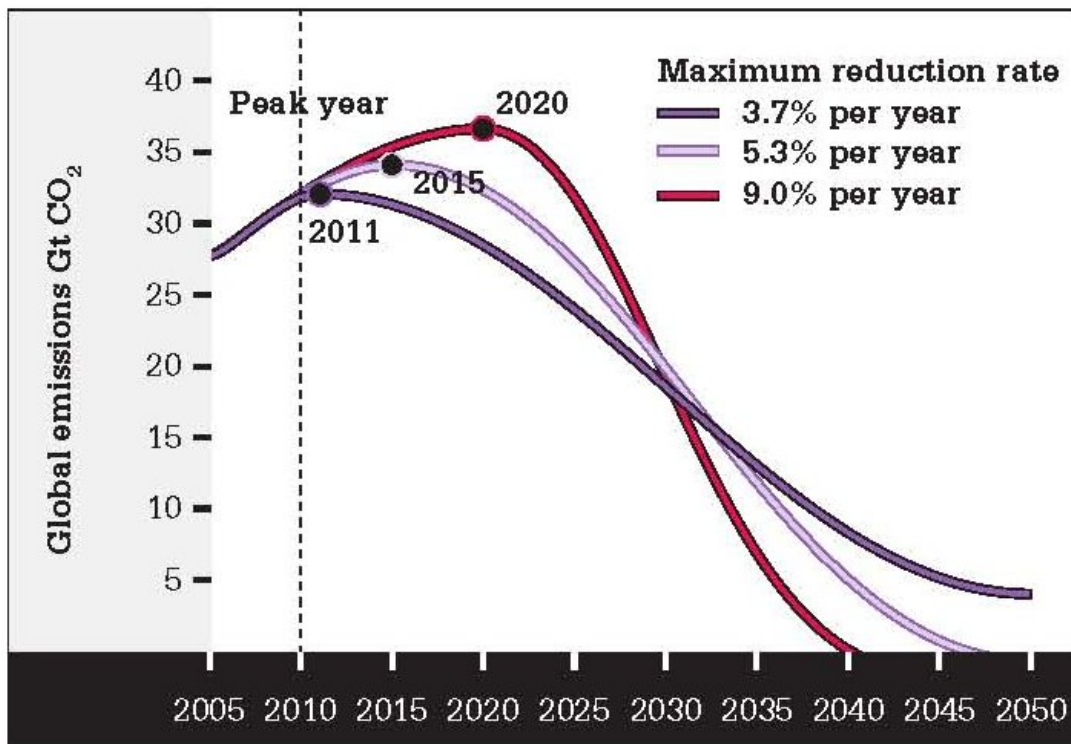


Figure 16. Three emission trajectories giving a 67% probability of limiting global warming to 2 °C. Leaving the peak year until 2020 will require subsequent reductions of 9% each year, which would be very difficult and very costly; 2020 is just eight years away. Taken from reference 66(a).

"Two degrees is not enough – we should be thinking of 1.5C. If we are not headed to 1.5C we are in big, big trouble."

With a 0.8 degree temperature increase already here and an equivalent rise on its way even if green house gas emissions stop tomorrow, the prospects for avoiding a 2 degree global temperature rise, let alone a 1.5 degree rise, and dangerous and costly climate change at best look bleak. In a report addressing this concern[105], heightened by last year’s record emissions, the IEA says *“This significant increase in CO2 emissions and the locking in of future emissions due to infrastructure investments represent a serious setback to our hopes of limiting the global rise in temperature to no more than 2°C,”* The comments were made by Dr Fatih Birol, who is the Chief Economist at the IEA and oversees the annual World Energy Outlook, the Agency’s flagship publication. Australia is a member country of the IEA.

Recent scientific assessments indicate global warming of four degrees or more is increasingly likely.[106(a-j), 66(d)] The CSIRO this month released research into the consequences of a four degree temperature rise for the Australian climate[106(f,g)], which would include:

- Temperature increases of about 3°C to 5°C in coastal areas and 4°C to 6°C in inland areas
- Likely declines of annual rainfall in southern Australia, particularly in winter, of up to about 50% but uncertain rainfall changes in other regions
- Marked increases of potential evaporation of about 5% to 20%
- More droughts in southern Australia

Four degrees would lead to increases in record high temperatures and rainfall, extreme fire weather, large hail events on the east coast and more intense (but less frequent) cyclones. Australia will increasingly see summer temperatures approaching or passing 50 deg. C. as this century progresses. The consequences for the catchment and environmentally fragile areas of the Illawarra and Wollondilly, and indeed across NSW, would be severe. Disturbingly, recent research suggests global warming is currently being dampened by the high level of sulfur particulates being emitted into the atmosphere from coal fired power stations in Asia.[33] Without this inadvertent shielding, global warming would have already passed two degrees .[106(b)] Also of grave concern is the increasing evidence that climate modelling is underestimating the rate of heating being caused by anthropogenic green house gas emissions.[107] These emissions are occurring at a greater rate than forecast by the IPCC[106(c), 108] and at a rate up to ten times that of anytime in the past 56 million years.[109] Figure 17 shows the current rate of temperature rise relative to the last period of rapid global warming.[109(k)]

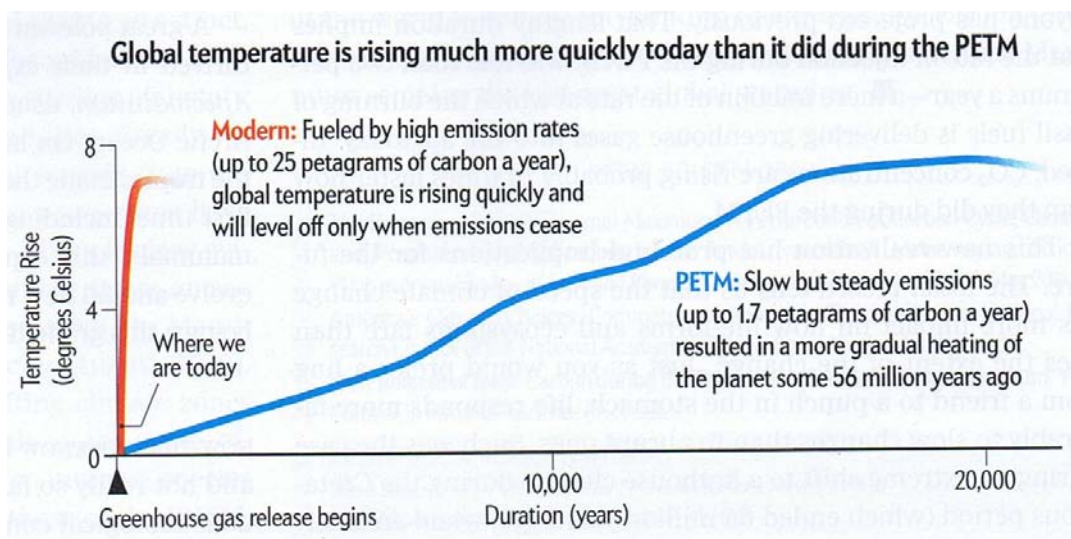


Figure 17. The rate of release of carbon into the atmosphere and the associated global temperature rise today is nearly 10 times as fast as during the Paleocene-Eocene Thermal Maximum (PETM), 55.9 million years ago. The PETM is the best analogue we have for current global warming, according to an international team of geologists; see references 109(k).

Disturbingly, recent research suggests global warming is currently being dampened by the high level of sulfur particulates being emitted into the atmosphere from coal fired power stations in Asia

Extreme weather events made 2010 a costly year[110] and the UN recently warned of the very high costs of delaying effective action on climate change.[104] Oxfam estimates that some 21,000 deaths in 2010 were the result of climate change driven extreme weather events[111]. The UN recently released a report calling for urgent action: “A comprehensive global energy transition is urgently needed in order to avert a major planetary catastrophe.”.[112]

In order to allow a reasonable chance of keeping global warming below two degrees, green house gas emissions must peak within this decade.[66] The 2011 Climate Commission report states that leaving the peak year until 2020 will require subsequent reductions of 9% each year which is “... impossible on anything but a wartime footing.”[66(a)] Locking-in gas as an energy source is not a

prudent response to the science of climate change; NSW should instead set a course to be Australia's leading renewable energy driven state.

3(ii). NSW as the leading renewable energy state

The IEA and other groups have pointed to the dire global warming consequences of a global transition to gas (see section 1.f(ii)). One of the arguments the industry makes in presenting its case to the NSW government is that developing gas resources here provides energy independence from Queensland and Victoria, and that doing otherwise would result in increased costs to consumers. Minister Hartcher has echoed this point of view.[157] There are indeed already signs the burgeoning export industry in Queensland will increase domestic costs.[113] Its clear however that a transition from coal to gas as the world's energy demand increases with increasing population will significantly add to the green house gas burden (see sections 1.f(i) and 1.f(ii)) and increase global warming. Beginning a transition to gas at the start of the critical decade for climate change is not in the best interest of NSW, or the National interest. Committing resources to the deployment of new gas powered energy infrastructure in NSW is inconsistent with the increasingly need for green house gas emissions to peak before 2020.

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NSW contributes about 28% of Australia's greenhouse gas emissions.[114] Some in the community argue that at around 1.5% of global greenhouse gas emissions Australia's contribution to global warming is trivial and there is no need for urgent if any action to curb emissions. However Australia is in the top 20 of global emissions by country (see Fig. 18) and has the highest per capita emission level of the developed economies. A compelling argument can be made that Australia then has a greater responsibility in lowering its emissions and should move to a zero carbon economy as quickly as possible; ideally by 2020.[115]

Queensland is now deeply committed to gas as a fuel and revenue source and, like NSW, other states are set to follow. With gas currently being a very small part of the NSW energy market[116], NSW has an opportunity to leap-frog over gas and distinguish itself from the other states by taking the lead in developing a renewable energy economy and market. Doing so is in the short, medium and long term public interest of NSW.

A University of Newcastle report[117] predicts 73,800 jobs in NSW in renewable energy and energy efficiency if the state government invests in a green energy future. That is more than ten times the number of jobs in coal-fired power stations and the coalmines that support them. Focusing on wind and concentrated solar energy, the Beyond Zero Emissions Plan for NSW[118] predicts 16,405 jobs. The benefits to NSW would include:

- Defining an upper limit on rising electricity prices by de-coupling electricity generation from volatile fossil fuel prices and their inevitable on-going cost increases;
- Reducing the impact of any carbon price on NSW businesses and residents by providing emission-free electricity;
- Protecting trade-exposed industries by enabling them to run on emission-free electricity;

- Creation of a dynamic new manufacturing industry based on renewable energy technology, generating thousands of new jobs and the potential to export knowledge and expertise in a new, rapidly-expanding international market.

The 2011 AEMO Electricity Statement of Opportunities[119] shows that with declining demand in NSW, there is no need for new baseload infrastructure until at least 2020. This provides NSW with a window in which to deploy renewable energy and energy efficiency infrastructure, and gain a lead in these new markets.

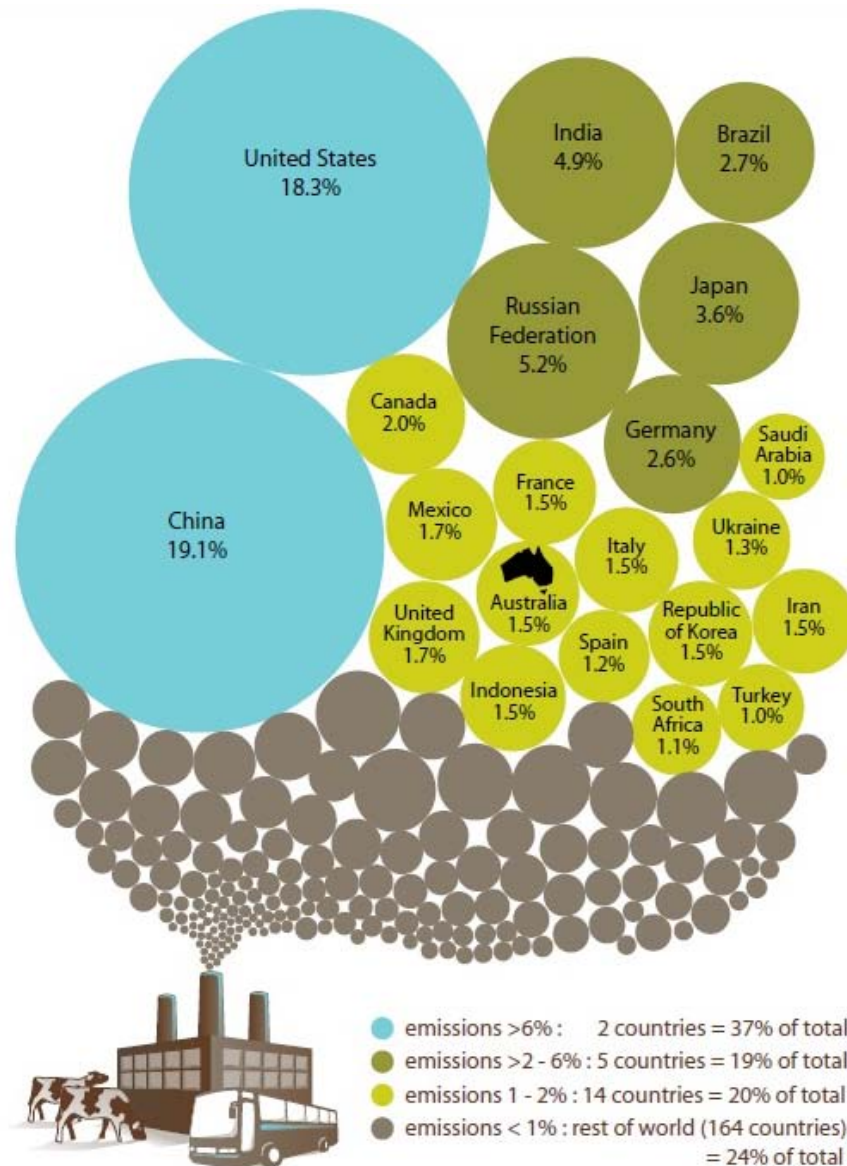


Figure 18. Depiction of Australia’s carbon dioxide emissions in the global context. As a developed economy with the highest per capita emissions, Australia has a responsibility to ensure its emissions peak before 2020 and rapidly reduce to zero.

3(iii). Renewable energy sources are ready now

The installed capacity of Australia's electricity generators is 50,815 MW in grid-connected infrastructure, about half being baseload, and a further 5,168 MW in embedded and non-grid capacity.[120] Coal provides more than 75% of that total and all of the 25 MW or so of baseload capacity.

Contrary to fossil fuel industry assertions, baseload capable renewable energy technology is deployable now.[121] Sharp cost reductions are expected for renewable energy over the coming decade[91,122]. Innovator David Mills suggests "*Costs are dropping so quickly that we may be able to very soon construct an inflexible plus flexible combination from solar and wind at much the same levelised cost as current coal plus natural gas combined cycle systems in the USA, and perhaps for Australia as well,*" says Mills. "*Wind is already there.*"[123]

Renewable energy is being deployed on a large scale in Europe, the US and China, and the voting public is increasingly aware that this is the case. Solar thermal now feeds over 700MW of renewable electricity to the Spanish grid with 10,000 MW expected by 2020.[91(b)] Overall renewable energy provides 42 percent of electricity demand in Spain, with wind being the largest provider of electricity.[124] The world's largest solar thermal and wind plants are being built in the US, with a 1000 MW parabolic trough solar thermal plant, a 350 MW solar tower thermal plant and 1,550 MW wind farm currently under construction.[125]

Solar thermal now feeds over 700MW of renewable electricity to the Spanish grid with 10,000 MW expected by 2020.[91(b)] Overall renewable energy provides 42 percent of electricity demand in Spain, with wind being the largest provider of electricity.

The widely acclaimed Zero Carbon Australia plan establishes a detailed pathway to a renewable energy powered Australia.[121(a)] Minister Ferguson is incorrect in asserting that gas is "*... really only form [sic] of alternative clean energy in Australia at the moment.*" [80(d)] Concentrated solar thermal with molten salt heat storage is as dispatchable as gas.[118] Australia is enviably rich in renewable energy waiting to be embraced by a government with vision; NSW should lead the way forward. Regrettably the NSW government remains focussed on fossil fuel, with Minister Hartcher recently stating "*So we will need three times more gas to fuel these power stations and to supply greater consumption of gas in households and our commercial and industrial sectors,*"[157] The twenty year demand growth he refers to could easily be met with renewable energy sources.

Germany, with a land area just under half of that of NSW and a population of 81 million, has 27,214 MW of installed wind driven generator capacity, with 108 MW of that installed offshore.[126] This year German wind industry expects new installations of about 1,800 MW, including up to 300 MW of offshore wind. Renewable energy supplied a record 20.8% of Germany's electricity in the first half of 2011. Germany expects to have 35% of its electricity supplied from renewable sources by 2022 and will remain a net exporter of electricity after the closure of its remaining nuclear plants by that date.[165] Spain has just over half the land area of NSW, with a population of 45 million. In March this year, wind power became the largest source of electricity in Spain, with 21 MW of wind capacity providing 21% of Spain's electricity generation, with coal at just 12.9%.[127] A rapid rise in British wind power capacity will gradually cut returns for operators of gas and coal plants over the next three years.[166]

Germany, with a land area just under half of that of NSW and a population of 81 million, has 27,214 MW of installed wind driven generator capacity. NSW, with a population of around 7 million currently has about 150 MW of wind power capacity.

The surge in renewable energy is credited with driving down the price of electricity in Germany[165] and a recent IEA policy study highlights wind having the same impact in Ireland.[91(b)] Wind has had the same influence on electricity costs in South Australia, where wind delivered 21% of the supply in 2010.[167, 91(d)] Australia has some of the world’s best wind resources, yet the total operating wind capacity at the beginning of 2011 was 1991 megawatts or 2 per cent of Australia's overall electricity needs.[128] South Australia provides about half of that total. NSW, with a population of 7 million and a land area more than twice that of Germany has 150 MW of installed wind capacity, or less than 1% of the States 18,000 megawatts (MW) of installed electricity generation capacity.[116, 128(b)] Gas provides some 6% of the electricity in NSW.

Australia has the highest average solar radiation of any continent in the world. NSW has around 300 MW of solar powered electricity generation, almost all of it roof-top solar PV, which is less than 2% of its total generation capacity.[129] Clearly NSW lags well behind the deployment of renewable energy in other developed and developing countries. Given the deployment examples overseas, the 2011 AEMO Statement of Opportunities[119] makes it clear that NSW does not need gas powered electricity in meeting its electricity needs to 2020 and beyond. The experience in Europe and South Australia makes it increasingly clear that there are significant costs benefits from the early deployment of renewable energy sources.

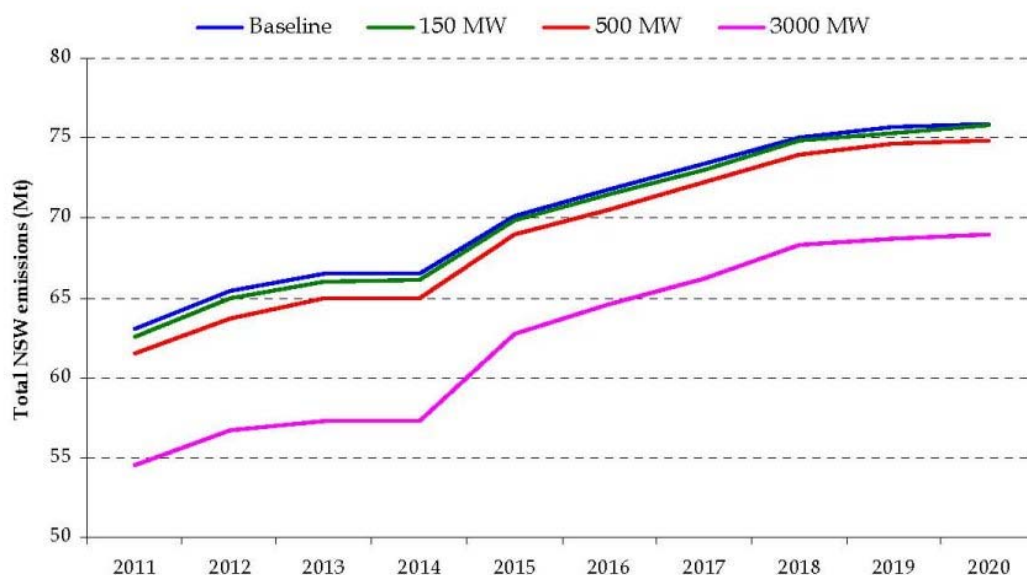


Figure 19. Total emissions from power generation in NSW by scenario. Taken from reference 130.

Wind power provides the cheapest and quickest entry path for the supply of renewable energy. A 2010 study[130] prepared for the then Department of Environment, Climate Change and Water

(DECCW), now Office of Environment and Heritage (OEH), by McLennan Magasanik Associates shows the significant impact the deployment of 3000 MW (roughly 17% of the total current NSW generation capacity) of wind power will have on NSW greenhouse gas emissions. Though small by international standards, a deployment of 3000 MW will more than meet new electricity demands for NSW to at least 2020. Disturbingly, 3000 MW is not sufficient to ensure the State's emission peak before 2020 (Fig. 19). More is needed, much more. Displacing and delaying the deployment of renewable energy with new gas fired power is not in the public interest.

The previous government identified six Renewable Energy Precincts across NSW in areas with the best-known wind resources: New England Tablelands, Upper Hunter, Central Tablelands, NSW/ACT Border Region, South Coast and Cooma-Monaro. The Renewable Energy Precincts are intended to prioritise and focus the delivery of renewable energy projects. In 2010 the NSW Department of Environment, Climate Change and Water commissioned AMR Interactive to survey community attitudes to wind power in the Precincts.[131] The large majority of residents across the Precincts indicated they would support wind farms being built both in NSW (85%) as well as in their local region (80%).

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A recent Galaxy survey shows 68 per cent of Australians support a moratorium on the coal seam gas industry until the full health and environmental impacts are known.

Support remains high at 60% for wind farms being built 1-2 kilometres from residences. Residents opposing wind farms being built 1-2 kilometres from their residence were much more likely than supporters to identify concerns about noise and the impact on the landscape, and much less likely to identify benefits of wind farms such as reducing pollution, and improving the community and economy. Notably though, over two thirds (68%) of residents opposing wind farms at 1-2 kilometres still saw an overall benefit of wind farms to the local region.

Only 13% of those surveyed oppose wind farms, including when at 1-2 kilometres from residences. There is far less community concern for the deployment of wind than there is for the development of coal seam gas. A recent Galaxy survey shows 68 per cent of Australians support a moratorium on the coal seam gas industry until the full health and environmental impacts are known. [132]

There is a campaign in Australia to oppose wind farms, and this was explored in a recent edition of the ABC programme Four Corners.[133] While there are anecdotal statements of adverse health impacts, none are unequivocally established. In 2010 the National Health and Medical Research Council (NHMRC) published a statement that concludes "*concludes that there is currently no published scientific evidence to positively link wind turbines with adverse health effects.*"[134(a)] A more recent publication[134(b)] reports a review of the peer-reviewed scientific literature, government agency reports, and the most prominent information found in the popular literature.

In 2010 the National Health and Medical Research Council (NHMRC) published a statement that concludes "*concludes that there is currently no published scientific evidence to positively link wind turbines with adverse health effects.*"

The review confirms “*no peer reviewed articles demonstrate a direct causal link between people living in proximity to modern wind turbines, the noise they emit and resulting physiological health effects.*” The study re-affirms that “*... that wind turbines can be a source of annoyance for some people.*” The report concludes “*... annoyance appears to be more strongly related to visual cues and attitude than to noise itself, self reported health effects of people living near wind turbines are more likely attributed to physical manifestation from an annoyed state than from wind turbines themselves.*” That is, some people simply do not like wind turbines and the paper comments that there will be the case “*.. with any number of projects that change the local environment*”. It would seem reasonable to expect that if there were serious health problems associated with wind turbines, a European epidemic would by now be well established, given the level of deployment and its population density.

Nonetheless, the NSW Premier recently publically expressed a personal disdain for wind power, saying “*... I'm told no new applications have been lodged, we haven't approved any applications - and if I had my way, we wouldn't,*”[135] A clear signal to an industry NSW needs if the State is to contribute to reducing Australia’s green house gas emissions. Wind and solar power both require a substantial area of land, but their location is not dictated by a need for underlying coal seams and they do not threaten aquifers, catchments or prime agricultural land.

4. The interaction of the Act with other legislation and regulations, including the Land Acquisition (Just Terms Compensation) Act 1991

In January this year the NSW Parliamentary Library Research Service published an informative briefing document entitled ‘*Regulation of the coal seam gas industry in NSW*’.[136] Coal seam gas project approvals may be subject to the Environmental Planning and Assessment Act 1979 (NSW), the Protection of the Environment Operations Act 1997, the Water Management Act 2000 , Water Management Act 2000; Protection of the Environment Operations Act 1997; National Parks and Wildlife Act 1974; Heritage Act 1977; Native Vegetation Act 2003; Threatened Species Conservation Act 1995; Pipelines Act 1967; Sydney Water Catchment Management Act 1998 and the Commonwealth Environment Protection and Biodiversity Conservation Act 1999.

As mentioned earlier, the SMCMA areas contain assets recognised by the Australian Government as being of National Environmental Significance and subject to the Commonwealth Environment Protection and Biodiversity Conservation Act of 1999. They include the National Parks, the Dharawal Nature Reserve and the wetlands of the O'Hares Creek Catchment. The Garawarra State Conservation Area has National Heritage listing and the NSW government is committed to establishing the Dharawal National Park.

The Upland Swamps of the Woronora Plateau appear to be encompassed by the definition of ‘Temperate Highland Peat Swamps on Sandstone’, an ecological community listed as endangered under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999. In April of 2011, the NSW Scientific Committee, established by the Threatened Species Conservation Act, made a Preliminary Determination[2] to support a proposal to list Coastal Upland Swamp in the Sydney Basin bioregion as an endangered ecological community on Part 3 of Schedule 1 of the Act. The listing of Endangered Ecological Communities is provided for by Part 2 of the Act.

Section 74 of the Petroleum (Onshore) Act 1991 states that in deciding whether or not to grant a petroleum title, the Minister is to take into account the need to conserve and protect:

- (a) the flora, fauna, fish, fisheries and scenic attractions, and

(b) the features of Aboriginal, architectural, archaeological, historical or geological interest Approving an industrial CSG field that would stretch across the surface of the SCA Special Areas and be surrounded by National Parks, Nature Reserves, a National Heritage listed State Conservation Area and the Illawarra Escarpment, and located under the Sydney airport flight path, would counter both considerations of the Act.

Viewed from the air on a Sydney Airport flight-path , a Chinchilla like landscape (Fig. 10) adjacent to national parks, including the Royal National Park, and Woronora and Warragamba Dams would provide an incongruous and unappealing contrast for domestic and international air travellers. The same would be true for tourists on the ground.

The Environmental Planning and Assessment Act 1979 (NSW) has several objectives, one of which is to encourage ecologically sustainable development (ESD). The definition of ESD is given in the 1987 Brutland Report from the United Nations World Commission on Environment and Development.[138] The definition includes “ ... *development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*” The principles of ESD include the ‘Precautionary Principle’, which dictates the following[137]:

- When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.
- In this context the proponent of an activity, rather than the public, should bear the burden of proof.
- The process of applying the Precautionary Principle must be open, informed and democratic and must include potentially affected parties. It must also involve an examination of the full range of alternatives, including no action.

That is, where there is doubt - don’t do it. Considerations of Ecologically Sustainable Development and the application of the Precautionary Principle coupled with the applicability of the relevant legislation summarised above, should have precluded any consideration of CSG exploration, a preclude to mining, in the SCA Special Areas, the SMCMA areas and Sydney Basin bioregion more generally.

Considerations of ecologically sustainable development and the application of the Precautionary Principle coupled with the applicability of the relevant legislation summarised above, should have precluded any consideration of CSG exploration, a preclude to mining, in the SCA Special Areas, the SMCMA areas and Sydney Basin bioregion more generally.

The 2009 approval of the Metropolitan Coal Mine expansion (the Metropolitan Coal Project) under Part 3a of the Environmental Planning and Assessment Act 1979, with a supportive Planning Assessment Commission (PAC) report, provides an example of a project approved without due regard to ESD and the Precautionary Principle. The PAC report documented numerous uncertainties and environmental risks. Most notably, the PAC recognised that there would be further subsidence damage to the Waratah Rivulet. Nonetheless the project was allowed to proceed, subject to monitoring requirements. That is, the Precautionary Principle was effectively inverted and subsidence damage has continued. The evidence suggests a reduced “ ... *ability of future generations to meet their own needs*”, with lower flows in dry conditions and degraded water quality. The Metropolitan Coal Project would not have passed the test of having a neutral or beneficial effect on water quality.[172]

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In contrast, as mentioned above in section 1.a, the Precautionary Principle was explicitly applied in the PAC considerations of the Bulli Seam Operations (BSO) project. The PAC states “*The principle is triggered when two pre-conditions exist:*

- *a threat of serious or irreversible environmental damage*
- *scientific uncertainty as to the environmental damage.”*

The PAC recognises that both trigger pre-conditions are met in the BSO proposal; they are also met in the threats and uncertainties of coal seam gas exploration and mining. It would not be possible to demonstrate without doubt that the threats posed by coal seam gas either do not in fact exist or are negligible. It is likely that at some point, one of more of those threats would be realised.

The PAC report for the BSO project recognises that damage of the kind inflicted on the Waratah Rivulet can no longer be tolerated. The report cautions “*The consequences of allowing the project to proceed in these areas are potentially very significant: the various protections for significant natural features are ‘turned off’ by the Part 3A process,*” Part 3a has been repealed and, while the role and character of the revised Part 4 remains unclear, future projects of significance will be determined by the PAC. Proposed legislation reforms appear to address community concerns that members of the PAC have been too closely associated or aligned with the mining industry and that this has been reflected in past recommendations. As reflected in the comments of the Campbelltown City Council, the role of the Department of Planning and Infrastructure (DoPI) in project determinations is of concern. The DoPI approval recommendation for the additional Apex Energy CSG bore on SCA land, in opposition to the views of the SCA, OEH and public submissions, illustrates the basis for that concern.

The BSO report comments on the weakness of the Environmental Assessment provided by the proponent, and observes “*The Panel also concludes that there is a problem with allowing the Proponent to assess what is of ‘special significance’ and what is not.*”. A community criticism of the approval processes to date, is that project proponents choose the environmental consultants that provide the assessment reports, and this induces a pro-development bias reflecting a conflict of interest. That is, a consultant delivering a negative report reduces its subsequent engagement prospects. The environmental assessment process should be separated from the project proponent, and the OEH should have a stronger role in project assessments. In the case of major projects in sensitive areas more than one EA should be sought and EAs should be peer reviewed.

The BSO report comments on the weakness of the Environmental Assessment provided by BHP, and observes “*The Panel also concludes that there is a problem with allowing the Proponent to assess what is of ‘special significance’ and what is not.*”.

The Federal Senate Inquiry into the management of the Murray Darling Basin has highlighted the concern that State governments and their agencies act under a conflict of interest. That is, the adjudicator and regulator is also the recipient of revenues from project proponents. Senator Edwards asks an industry spokesperson “*how long do you think it is going to be before the community*

expects there to be an independent umpire for regulation of this industry and what have you with regard to the current problem where the recipient of significant royalties and benefits from the coal seam mining—gas explosion in terms of growth—is also the regulator of all the environmental and community issues? We are here because there has been a failure somewhere—that is why this inquiry is going.” [59(e) page 44]

Given the clear intention of the NSW parliament in establishing the Sydney Catchment Authority, its powers should be strengthened with respect to the approval of projects and the granting of access to the lands it administers on behalf of Greater Sydney. Where projects might impact or be proposed for SCA Special Areas, the representations of the SCA should be given greater weight than those of the Department of Planning. Given the damage done to the catchments of the Southern Coalfields, its recommendations should override those of the Department of Planning. It’s bewildering that the SCA should need to resort to seeking listing as a registered land-holder in order to carry out its duties under the Act.[139] It is bewildering that the DoPI would recommend approval for a project that is opposed by the SCA.

“how long do you think it is going to be before the community expects there to be an independent umpire for regulation of this industry and what have you with regard to the current problem where the recipient of significant royalties and benefits from the coal seam mining—gas explosion in terms of growth—is also the regulator of all the environmental and community issues? We are here because there has been a failure somewhere—that is why this inquiry is going.” – Senator Edwards. Murray Darling Inquiry 2011

5. The impact similar industries have had in other jurisdictions

The US experience with the use of hydraulic fracturing to extract gas from shale triggered community concern and alarm in Australia. Dymock and Bradford County in Pennsylvania in particular has attracted US and international attention because of persistent media reports of environmental and health problems associated with shale gas mining. The award winning movie length documentaries Gasland[140], heavily criticised[141] by the industry and associated groups, and Split Estate[142] have galvanised public opposition to fracking. Among print media the New York Times has provided rich coverage, largely supporting and reinforcing the concerns raised by Gasland.[143] An ongoing investigation by Pro Republica that started in 2008 found court and government documentation of more than 1,000 cases of water contamination in Colorado, New Mexico, Alabama, Ohio and Pennsylvania. Pro Republica have catalogued individual and community case studies on the dangers of fracking, including environmental violations and contamination.[144] The Web site for the group Physicians Scientists & Engineers for Healthy Energy provides a considerable amount of information[145], as does the Web site for the community group that inspired Gasland, the Damascus Citizens for Sustainability.[146] In June this year the US NGO Food and Water Watch published a review of fracking, with an extensive reference list, that recommends banning[160(a)] this mining technique. The SBS programme Dateline canvassed the gas mining concerns in the US on Sunday September 18 2011.[147]

Industry denials have failed to abate or quell community concerns, which are now being addressed by draft and proposed state and federal legislation in the US. After acquiring Chesapeake Energy holdings in the Fayetteville shales the US earlier this year, BHP Billiton has been served with a series of class actions as landowners allege extraction techniques used in the group's shale gas business are causing earthquakes, poisoning water sources and dangerously polluting the soil and air.[148] The earthquakes are believed to be caused by the reinjection of produced water, prompting calls for reinjection to be banned.[148(b)]

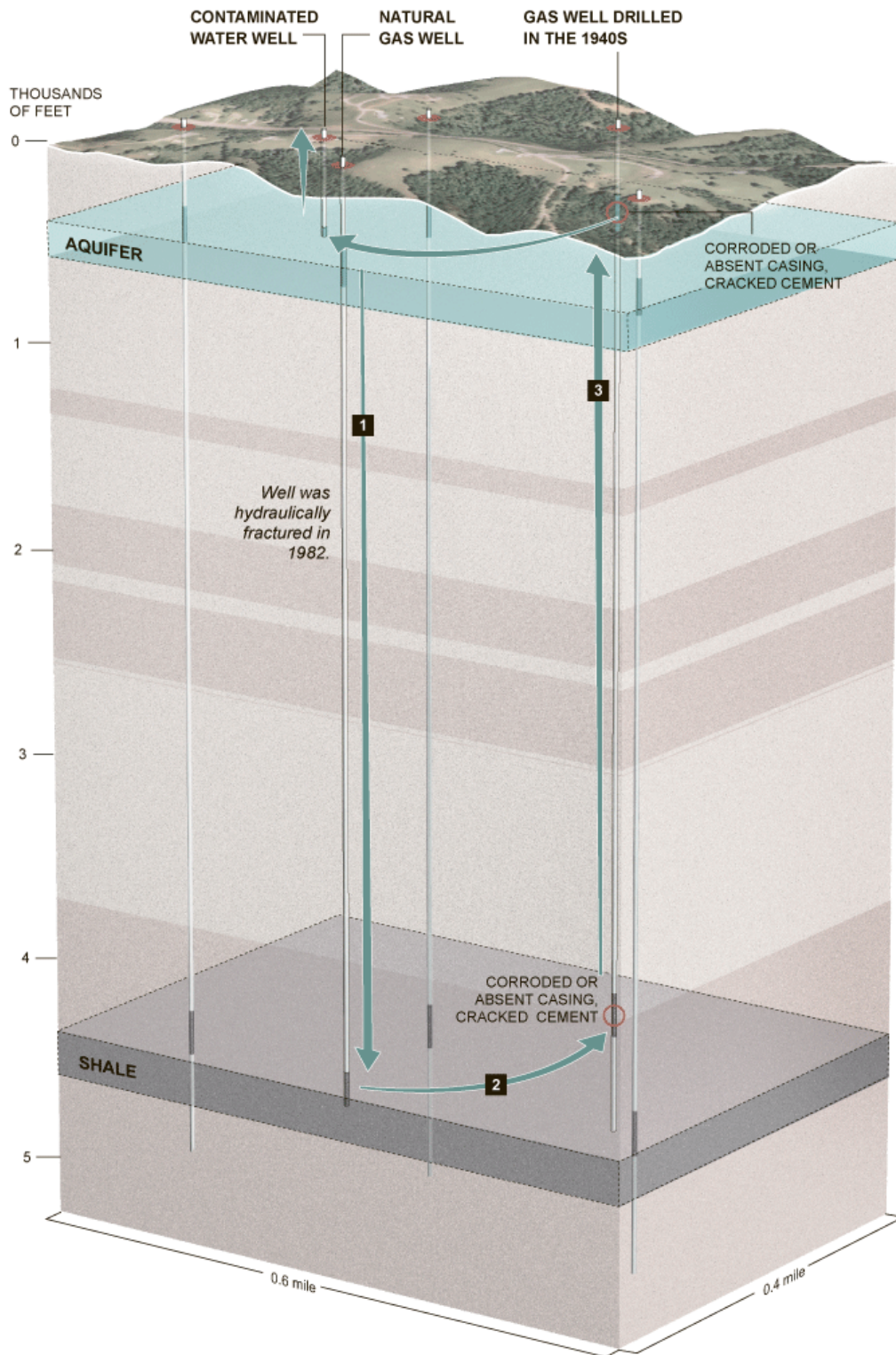


Figure 120. Depiction of aquifer and water well contamination from hydraulic fracturing in the US in 1982.[146] The US gas industry has consistently denied that it has been responsible for water contamination.

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The New York Times recently published a substantial number of documents showing that US Environmental Protection Agency concerns date back to 1987.[149] The Environmental Protection Agency in 1987 concluded that a water well in Jackson County had been contaminated with fluid used in hydraulic fracturing (see Figs. 20 and 21). Some drilling experts say that older wells in the area could have served as pathways for the fluid. The US industry has consistently denied allegations that it has been responsible for water contamination. The documents released by the New York Times include an industry study[150] that give insight into fracture propagation from fracking.

The Shale Gas Subcommittee of the Secretary of Energy Advisory Board has just released a report outlining recommendations intended to reduce the environmental impacts of shale gas production.[151] The New York Department of Environmental Conservation (DEC) has recently drafted regulations[152] that would prohibit gas mining activity in certain areas and impose several new regulations on the process in other areas. The draft regulations provide the following;

- ban hydraulic fracturing in the watersheds supplying New York City and Syracuse, and within 4000 feet of those watersheds,
- ban drilling within primary aquifers,
- ban surface drilling within state-owned parks and other lands,
- ban surface drilling within any 100-year flood plan,
- place a moratorium on drilling within 2000 feet of any public drinking water supply well until regulators can evaluate three years of experience elsewhere with hydraulic fracturing,
- require disclosure of all fracking water additives to regulators, and provide for public disclosure of all additives that do not constitute trade secrets, and
- require an intermediate well casing (well pipe) that would be placed between the outer "surface casing" and the inner "production casing" in order to provide additional protection against migration of gas at the well itself.

The DEC provide a brief summary of key lessons from mining in Pennsylvania, including problems with well casing and cement.[152(b)] The EPA has just released proposed regulation to reduce fugitive emissions from gas mining.[153] The US Geological Survey has recently dramatically reduced downwards the estimated reserves of gas in the US, prompting speculation of industry exaggeration of prospective yields.[154] Haliburton, who pioneered the use of fracking for gas, have now conceded that the quantities of water used for fracking are a concern that needs to be addressed.[155]

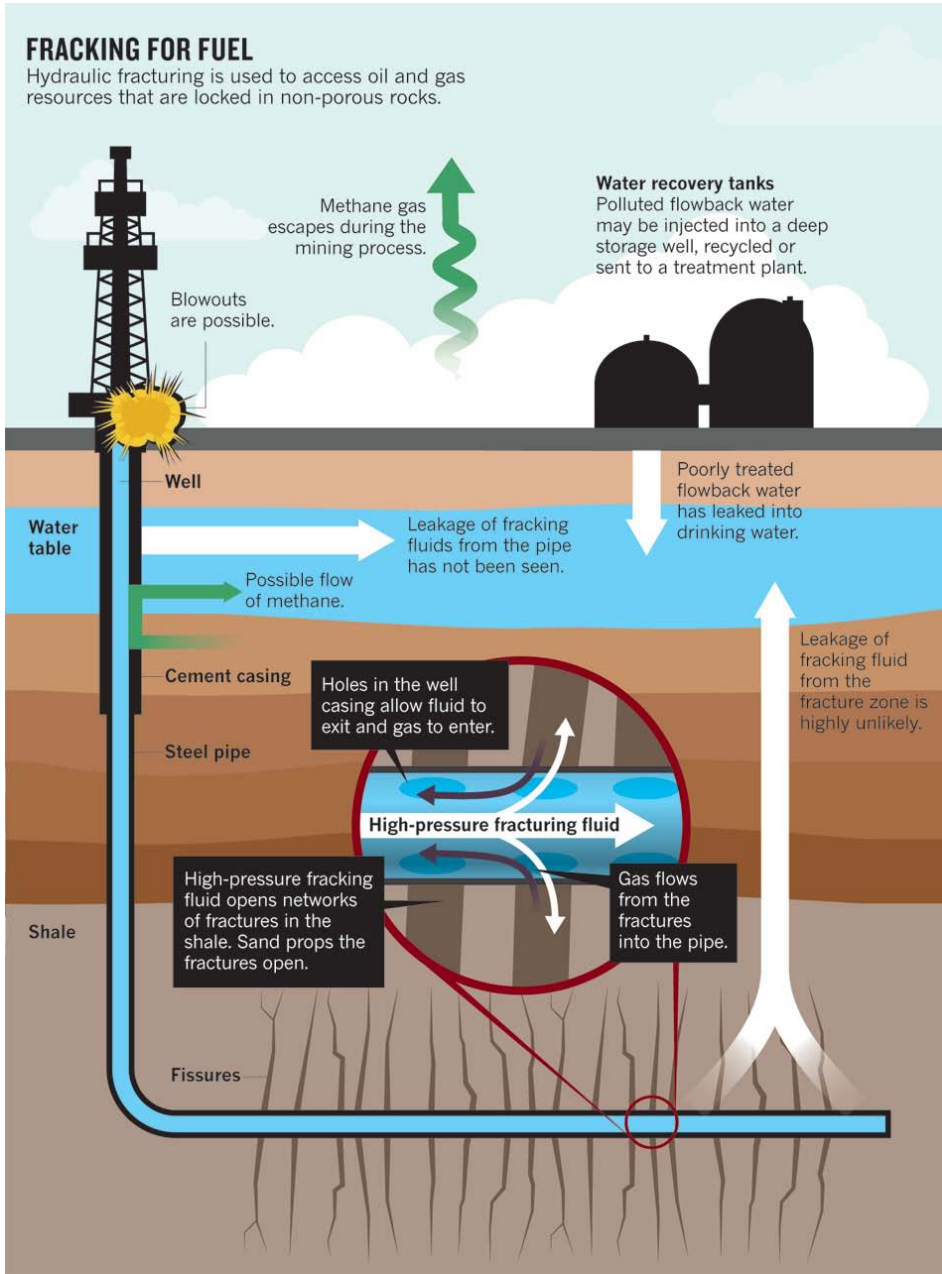


Figure 21. Figure depicting the risks associated with shale gas mining, from a commentary published in September 2011 in the science journal *Nature*. [160(b)] Similar risks are posed by mining ‘tight gas’ low permeability coal seams. A paper published earlier in the year in the US journal the *Proceedings of the National Academy of Sciences (PNAS)* suggests that while fracking fluids will not migrate from the seam to shallow aquifers, methane can. [30] In active gas-extraction areas (one or more gas wells within 1 km), average and maximum methane concentrations in drinking water from shallow aquifers were 17 and 58 times higher than in similar aquifers where gas mining was not taking place. Methane will also be escaping into the atmosphere.

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