Environmental and Groundwater Issues and AGL's Hunter Coal Seam Gas Project

Final Report to Hunter Valley Protection Alliance

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Key Summary Findings

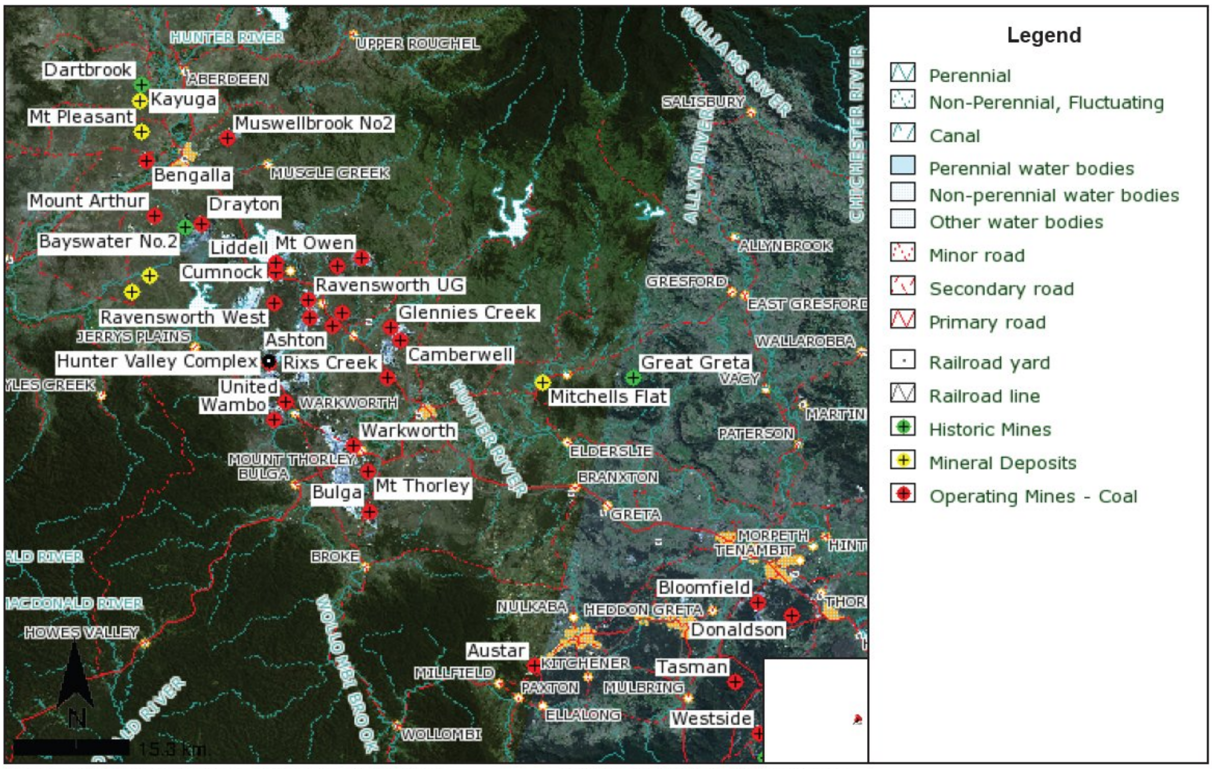
This report has reviewed a number of key groundwater and environmental issues with respect to ongoing coal seam gas exploration by AGL in the Broke-Fordwich region of New South Wales. Key summary findings include:

- groundwater in the Broke-Fordwich area is complex, with insufficient data to properly characterise flow and the extent of hydraulic connections (if any);
- recent work by consultants for AGL has provided tentative evidence of minimal vertical interconnections between shallow alluvial aquifers and coal seams, though this was only one pump test and cannot reliably be extrapolated to larger scales or time periods without significant uncertainty;
- the CSG industry in NSW is significantly under-regulated with respect to groundwater issues, since Camden fails to even monitor groundwater and the environmental assessment for the proposed Gloucester CSG project failed to include thorough baseline groundwater studies;
- a major issue is the potential for combined groundwater impacts from longwall coal mining and coal seam gas extraction, which requires detailed cumulative impact assessment (including any potential geothermal energy project, if that develops).

In summary, there remains significant uncertainty about the extent of possible future impacts on groundwater resources and the environment around Broke-Fordwich, with a key requirement being ongoing monitoring, co-operation between all parties involved and especially pro-active environmental assessment of all cumulative potential impacts.

1. Introduction

The Broke region in the southern Hunter Valley, New South Wales, is an important wine district, and contains a number of commercial vineyards, associated industry (eg. ecotourism) and local communities. Another major industry in the region is coal mining, stretching from 3km north of Broke (the Bulga mine), north to Singleton and throughout the Hunter Valley. A location map is given in Figure 1.



Coordinate System: Geocentric Datum of Australia 1994 (GDA94) Map Centre: 32° 32' 13.8" S, 151° 11' 23.1" E

Figure 1: Regional map of Broke and the Hunter Valley region (courtesy AMA, 2009)

The Broke region is presently being explored by AGL Energy Ltd ('AGL') for coal seam gas ('CSG'), known as their Hunter CSG Project. Interest in CSG has increased over the past decade as demand for natural gas continues and technological progress and economic conditions make CSG extraction projects potentially attractive. CSG projects are also known as 'coal bed methane' (CBM) projects, especially in the United States.

There are a range of significant environmental issues associated with CSG projects, especially with respect to groundwater resources and project water management. This report to the Hunter Valley Protection Alliance (HVPA) presents the findings of review work on the potential groundwater and broader environmental implications of CSG exploration and/or development for the Broke region arising from AGL's Hunter CSG project.

The primary review work has included:

- review of AGL consultation documents, or their consultants' reports;
- review of the hydrogeological sections of the environmental impact statement for the "Bulga Coal Continued Underground Operations", July 2003 (BC, 2003);
- compilation and assessment of major reports or studies on Australian CSG projects, especially those in operation at Camden, south-west of Sydney (owned by AGL) or Fairview-Scotia, north-west of Brisbane (owned by Santos Ltd);
- search and review of United States literature on CSG projects and impacts;
- critique of environmental and groundwater issues as relevant to the Broke-Fordwich region.

The report structure covers a brief review of groundwater resources around Broke, followed by relevant comments on the recent Bulga Coal EIS, and finally a critique and comments on specific Australian and United States CSG projects and their environmental management. All findings relevant for the Broke-Fordwich region are presented and discussed.

2. Brief Review of the Groundwater Resources of the Broke Region

The groundwater resources, or hydrogeology, of the Broke region is complex, characterised by high spatial and temporal variability. To date there appears to have been very few studies specifically in the immediate Broke region, with most work to the north associated with monitoring the potential and actual impacts from coal mining (eg. Bulga).

There are several aquifers (or rock layers containing groundwater), present in the broader region, which can be simplified as being alluvium associated with the Wollombi Brook, underlain by coal measures. In addition, there are aquifers in the Narrabeen Group Sandstones, though these appear to be rarely used at present.

Based on the work of consultants to AGL, a conceptual model of the aquifers, groundwater resources and system behaviour for the Broke region is shown in Figure 2.

This conceptual representation of groundwater behaviour in the Broke area is fairly typical, and would be based on bore logs (showing different soil and rock types at different depths), experience from mining projects, water resources studies, monitoring data and theoretical considerations of groundwater flow in such rocks (eg. coal seams, alluvium). The movement of water between different parts of the environment, such as from runoff to soil infiltration and hence groundwater recharge, is often difficult to measure and monitor accurately. This leads to the necessity of making several assumptions about the systems' behaviour – the only remedy being long-term monitoring data. As new information becomes available, this conceptual model of the groundwater system can be updated and refined, but only if good data is continually obtained and used to inform the conceptual model.

The main uses of groundwater in the Broke region are associated with vineyards, agriculture, domestic use and/or coal mining. A critical issue which arises from Figure 2 is the apparently strong interaction between surface and groundwater in the alluvium associated with the Wollombi Brook. Based on Figure 2, it would appear that the Wollombi Brook is behaving as a 'losing stream', whereby the water level in the stream is higher than surrounding groundwater and thereby flows downwards into the alluvium to recharge groundwater. Furthermore, since the Wollombi Brook consists of alluvium, such as sands and gravels, it can be expected that periodic floods would also be important for recharging the alluvium.

At present, it appears that surface and groundwater monitoring is not directed towards monitoring these complex interactions, leaving a key weakness in discerning the cause and extent of potential future impacts from coal mining (eg. subsidence from South Bulga longwall mining), any potential CSG project or local extraction.

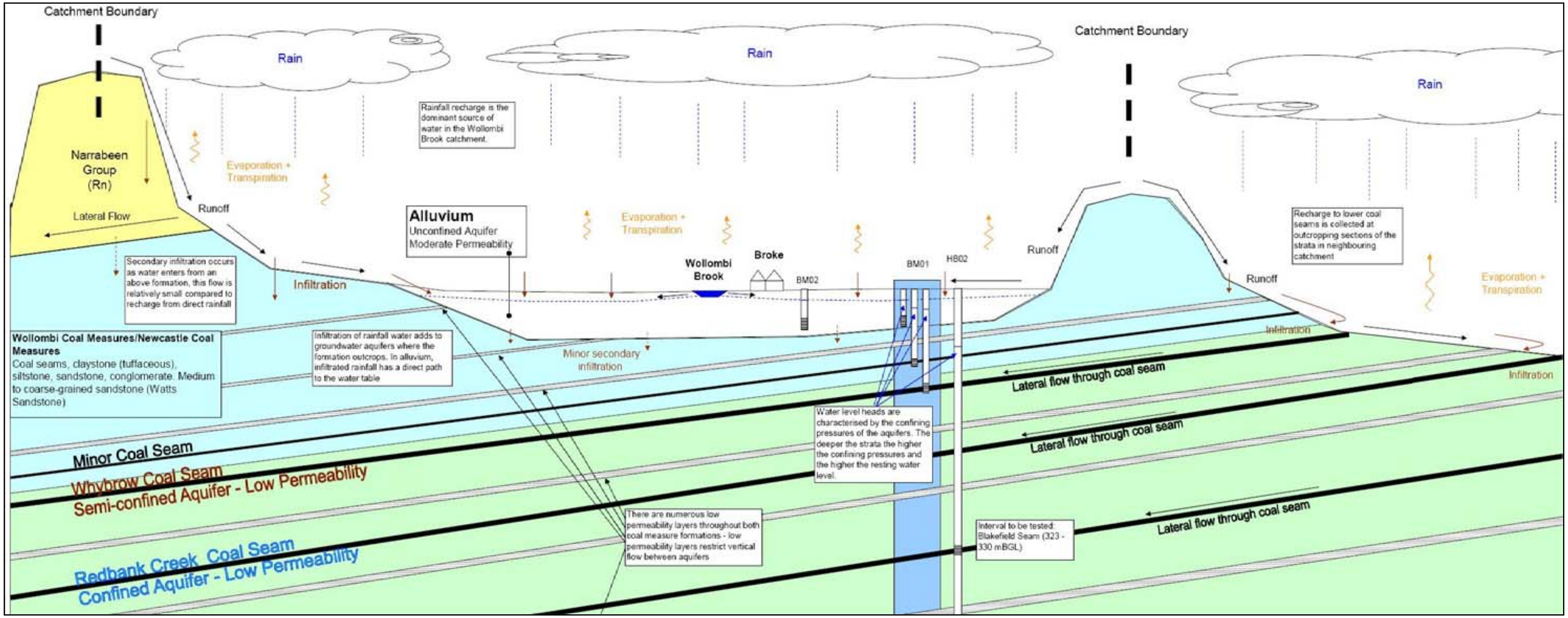


Figure 2: Conceptual model of the aquifers and groundwater resources in the Broke (adapted from PB, 2009)

At present, the main groundwater study to date is that by Mackie Environmental Research for the 2003 Bulga Coal EIS (Mackie, 2003). A number of key issues stand out as being of relevance for CSG projects and Broke:

- although groundwater monitoring has been in progress since the 1980s, most data is relatively recent and was mostly within 5 years (eg. Figures B2 to B7) (future work aims to compile as much historical data as possible to help redress this situation);
- the frequency of monitoring is poor with respect to key and groundwater recharge processes (as shown in Figure 2), such as alluvial floods or climatic variability (eg. wet/dry conditions). For example, if the groundwater level increases or decreases in a given bore, is that due to recharge (increase), mine depressurisation (decrease) or dryer climatic conditions (decrease) ? Monitoring needs to be ***at least monthly*** on key bores to ensure a sufficient quality of data matching assumed groundwater flow, climatic or other processes (especially recharge rates);
- key trends in the data are insufficiently explained in the report, such as why at the same bore, P5, two very different responses are found in late 2001 when groundwater level increases in P5A but decreases in P5B. Declining trends in other bores can be related to mining impacts (eg. groundwater pumping and depressurisation), but the period of monitoring is relatively short to observe groundwater responses to processes such as subsidence which can take several years or more (especially the case for the Beltana area with just months of data);
- the quality of groundwater is indicated in Mackie (2003) through electrical conductivity ('EC'), a measure of the salt dissolved in the water, and pH, a measure of acidity or alkalinity. Although these are useful indicators of water quality, other issues such as heavy metals are just as critical, especially with respect to domestic or agricultural use and environmental impacts. Complete water quality analyses are required to ensure that the sources of impacts can be accurately ascribed to their cause (eg. mining, over-pumping, etc.), especially since some trace metals can be valuable as indicators or 'signatures' of different aquifers;
- according to Mackie (2003), there is evidence of stratification of water quality in the alluvium, meaning that shallow groundwater is often fresher than deeper groundwater (page 9). The implications of this are ***VERY SIGNIFICANT***, since activities which create pathways or opportunities for these normally separate zones to flow and mix could impact on the shallower high quality water resources. Such activities could be exploration drilling for CSG, groundwater bores, or subsidence from underground longwall coal mining (such as the recently developed Bulga South, or Beltana, mine just north of Broke).

Given the lack of specific studies for the environs of Broke, it is not surprising that the above issues arise – they are relatively common for most groundwater resources of Australia.

3. Camden CSG Project, NSW

The Camden CSG project, south-western Sydney, is presently owned by AGL but was originally developed by Sydney Gas and delivered its first gas in May 2001 (Stage 1), and was expanded again in November 2004 (Stage 2). AGL took over Sydney Gas in early 2009. A range of reports on the Camden CSG project have been reviewed, including recent assessment studies for further project expansion and environmental performance reports.

3.1 Environmental Performance Reports (2006/07 & 2007/08)

AGL make available via their website two recent annual environmental performance reports (AEPRs) for the Camden CSG project, covering the financial years 2006/07 and 2007/08 (AGL, 2007, 2008). Unfortunately, gas production figures are not provided, since they are considered commercially sensitive. Some relevant notes and comments on these reports:

Water Generation (sections 4.5.1 or 4.6.1 in 2006/07 and 2007/08, respectively):

- this is a key issue in CSG, with respect to both the amount of water extracted but also its quality (clear definitions or explanations of different water types are not given).
- "Produced water" in 2006/07 was 2,723,000 litres (ie. 2.7 million L or 'ML') of brackish (mildly saline) water from Stage 2 CSG wells. In addition, 25,000 L of water was extracted from gas lines, 0.86 ML from the gas plant and 0.6 ML of grey water and sewage water.
- "Produced water" in 2007/08 was 6.1 ML of brackish water, excluding recycled water. The increase was due to more wells. In addition, 25,000 L of water was extracted from gas lines, 0.87 ML from the gas plant and 0.54 ML of grey water and sewage water.
- No detailed water quality analyses are provided in either reports for the above waters.
- Water quality monitoring of the evaporation pond showed widely varying salt levels, traces of hydrocarbon contamination and minor turbidity (although occasional exceptionally high turbidity values can be recorded after a storm event).
- There is no annual site water budget presented which details groundwater pumped, water recycled or stored waters. This lack of data makes comparison to other CSG projects impossible.

Groundwater Pollution (sections 4.6 or 4.7 in 2006/07 and 2007/08, respectively):

- this is a fundamental issue in CSG, as the protection of groundwater resources and the surrounding environment is obviously critical to ensure sustainable ecosystems and communities.
- In both reports, the following quote is used to justify assertions about perceived groundwater pollution risks:

  > *"A previous technical assessment of the groundwater regime found that as the entire casing of each well is cemented from top to bottom, connection between the Illawarra coal measures and overlying aquifers is not possible. The potential for cross contamination between aquifers during the production life of a well is therefore extremely unlikely."*
  >
  > (pages 4-14 and 37 of AGL, 2007 and 2008, respectively)

- Ignoring the issue of the 'technical assessment' not being cited at all (making it impossible to check this study), the fact that there is (apparently) no actual monitoring data to validate this claim is ***very concerning***. If the assessment is correct, then it should be easy to obtain ongoing groundwater monitoring data over time to continually prove that this claim is valid. Sound data is critical, as cements and bore casings can fail over time, especially since issues such as corrosion have long lag times.
- There is also ***no presentation*** of any groundwater level or quality data from operations in these sections. Although AGL are arguably complying with their licence conditions, this again shows that statutory regulation is accepting assertions of low risk rather than relying on regular monitoring to validate such claims.

Overall, the level of data and information in the water sections of AEPRs is very minimal, and does not provide a high level of confidence in claims about the lack of impacts. Although this is a poor reflection on the Camden CSG project, it is especially pertinent for regulators for not requiring such critical field-based evidence to be mandated to underpin claims of minimal impacts.

3.2 Independent Environmental Audit 2004-2006

A formal environmental audit of the Camden CSG project was undertaken in 2007 (URS, 2007). For the Stage 1 licence, 3 of 124 licence conditions were in non-compliance, while for the Stage 2 licence 14 of 319 licence conditions were in non-compliance and a further 20 conditions remained indeterminate. Overall, the audit concluded acceptable performance and "no significant ongoing environmental issues" (eg. page 3-6). With respect to surface and groundwater management, however, the following issues or points should be noted:

- Based on Schedule 3 of the conditions, which cover numerous environmental aspects, there appears to be no formal requirement to actually monitor groundwater levels and water quality in adjacent aquifers. This is a major statutory weakness and explains why the AEPRs do not contain such data.
- Although monitoring of possible surface subsidence associated with CSG operations is required (Clause 74, page 30 of 42 in Schedule 3; see URS, 2007), this is done only in a minimal manner:

  > *"Subsidence is reportedly not a significant issue for gas extraction. Trenched areas are monitored after rehabilitation."*
  >
  > (page 75 of PDF version, URS, 2007)

- As noted for previously, the lack of groundwater data is very concerning. Although this may be true, given the potential for risks such as subsidence and the consequences in a peri-urban area such as Camden, it is imperative to obtain real data to verify such assertions. Such data is relatively inexpensive, and relative to the potential costs if unexpected subsidence does occur, should be considered sound science and provides high quality assurance on such risks.

3.3 Camden Stage 2 Expansion Environmental Assessment Report

In September 2007, an extensive environmental assessment study was released for a proposed expansion of the Camden Stage 2 CSG project (HLA-E, 2007). The specific sub-sections on groundwater are very small, and contain only assertions about the lack of interconnectedness between the deeper coal measures and overlying aquifers (eg. page 8-60). The lack of actual monitoring data – ***again*** – is very stark, and prevents confidence in claims about low risks and impacts.

3.4 Pollutant Emissions

The Camden CSG project reports certain pollutant emissions through the 'National Pollutant Inventory' (see NPI, 2010). The NPI lists numerous known environmental pollutants, and emissions above certain thresholds to air, land and/or water require reporting to the Australian Government. A summary of recent reporting of air emissions from 2004/05 to 2007/08 is given in Table 1. No emissions of listed NPI pollutants to land or water were reported.

Table 1: Pollutants emitted to air at the Camden CSG project

	2004/05	**2005/06**	**2006/07**	**2007/08**
Carbon monoxide (as kg CO)	11,000	37,000	29,000	51,000
Nitrogen oxides (as kg NO_X)	15,000	28,000	17,000	15,000
Sulfur dioxide (as kg SO_2)	95	260	400	250
Total volatile organics (kg)	49	52	130	480
Particulate matter (<10 µm; kg)[#]	7	72	27	1,700

[#] A µm is a micro-metre, or one millionth of a metre. Note: all data is sourced from the NPI online database (www.npi.gov.au).

Although most pollutants show a rising trend, nitrogen oxides being the exception, this also corresponds to the period when Camden was expanded with Stage 2. Emissions also need to be considered in conjunction with air quality monitoring data and the recent audit, which show that statutory limits for pollutant concentrations in air are being met. Due to the lack of production data and the lack of proposed project scales for the Broke region (at present), it is not possible to infer the potential significance of such pollutant emissions at Broke.

4. Coal Seam Gas Projects, Queensland

At present, there is little public information available on the environmental management and impacts from coal seam gas projects in Queensland, especially with respect to groundwater. A compilation of projects is given in Table 2, showing gas and water production (although the basis for estimating water volumes is not included). The largest CSG projects are at Spring Gully, Fairview, Berwyndale South and Moranbah, with the variability in unit water costs being very high, ranging from '0.0' (Scotia, reportedly) to 629 ML/PJ (Argyle East). Unit water costs also vary over time, often being higher initially and declining over time (PB, 2004).

Table 2: Operating coal seam gas projects, Queensland (2008) (QME, 2009)

Project	Company	Gas (PJ)[#]	Water (ML)	Unit Water (ML/PJ)
Dawson River	Anglo Coal Australia	0.5	5.5	11.0
Moura	Anglo Coal Australia	0.6	1.4	2.3
Mungi	Anglo Coal Australia	0.3	0.6	2.0
Nipan	Anglo Coal Australia	0.9	9.8	10.9
Daandine	Arrow Energy	4.7	969.6	206.3
Kogan North	Arrow Energy	3.3	1,027.5	311.4
Moranbah	Arrow Energy	13.5	512.4	38.0
Tipton West	Arrow Energy	8.3	2,496.5	300.8
Peat	Origin Energy	4.1	17.7	4.3
Spring Gully	Origin Energy	37.2	2,064.3	55.5
Talinga	Origin Energy	1.2	526.0	438.3
Argyle	Queensland Gas Company	1.3	262.0	201.5
Argyle East	Queensland Gas Company	0.2	125.8	629.0
Berwyndale South	Queensland Gas Company	17.2	1,397.4	81.2
Kenya	Queensland Gas Company	3.6	1,380.4	383.4
Coxon Creek	Santos	0.5	45.9	91.8
Fairview	Santos	25.8	1,719.1	66.6
Scotia	Santos	8.9	'0.0'[§]	0.0
	TOTALS	132.1	12,561.9	95.1

[#] A PJ is measure of the amount of energy, with P = 10^{15} and J a 'joule' (ie. 1 PJ = 1,000 million million joules).

[§] This is the value given by QME (2009), although it is possibly an error.

Two aerial photographs are provided in Figure 3 below. They show the scale of such water management facilities and the challenges associated with them. The scale of water involved (as suggested in Table 2), and especially water quality and salt loads, are readily visible in Figure 3. These were key issues of concern raised in the recent Australian Senate inquiry into the impacts of mining in the Murray Darling Basin (ECARC, 2009).

Figure 3: Evaporation pond (top) and salt-storm (bottom), CSG projects, Queensland (courtesy Polglase, 2009)

The Fairview CSG project reports certain pollutant emissions through the 'National Pollutant Inventory' (see NPI, 2010). A summary of recent reporting of air emissions from 2001/02 to 2007 is given in Table 1. Minor emissions of listed NPI pollutants to land or water were reported, though not consistently for all years. The high variability from year to year is evident, as well as the significant load of emissions at some hundreds of tonnes.

Table 3: Pollutants emitted to air at the Fairview CSG project

	2001/02	**2002/03**	**2003/04**	**2004/05**	**2005**	**2006**	**2007**
Carbon monoxide (as kg CO)	72,000	31,000	500,000	310,000	170,000	560,000	190,000
Nitrogen oxides (as kg NO_X)	260,000	*no data*	1,100,000	1,700,000	67,000	3,800,000	910,000
Sulfur dioxide (as kg SO_2)	55,000	39,000	1,300	1,000	1,300	3,800	1,300
Total volatile organics (kg)	350,000	15,083[§]	660,000	3,500	690,000	390,000	240,000
Particulate matter (<10 μm; kg)[#]	11,000	20,000	16,000	11,000	6,100	8,800	3,100

[§] Includes ethylbenzene, phenol, polycyclic aromatic hydrocarbons, toluene, total volatile organic compounds and xylenes.

[#] A μm is a micro-metre, or one millionth of a metre. Note: all data is sourced from the NPI online database (www.npi.gov.au).

5. CSG/CBM in the United States

Since the late 1980's, the United States has become a major producer of coal seam gas (or 'coal bed methane'), mainly in the mid-western states of Colorado, New Mexico, Wyoming and Utah, as well as Alabama in the south. The rapid growth in the 1990's is shown in Figure 4, including a comparison to Queensland and New South Wales. This section provides a brief summary of the main environmental issues of concern, especially in Wyoming where such problems are well documented. Typical production values of CSG projects in the USA are summarised in Table 4, again confirming the highly variable nature of unit water costs for CSG production.

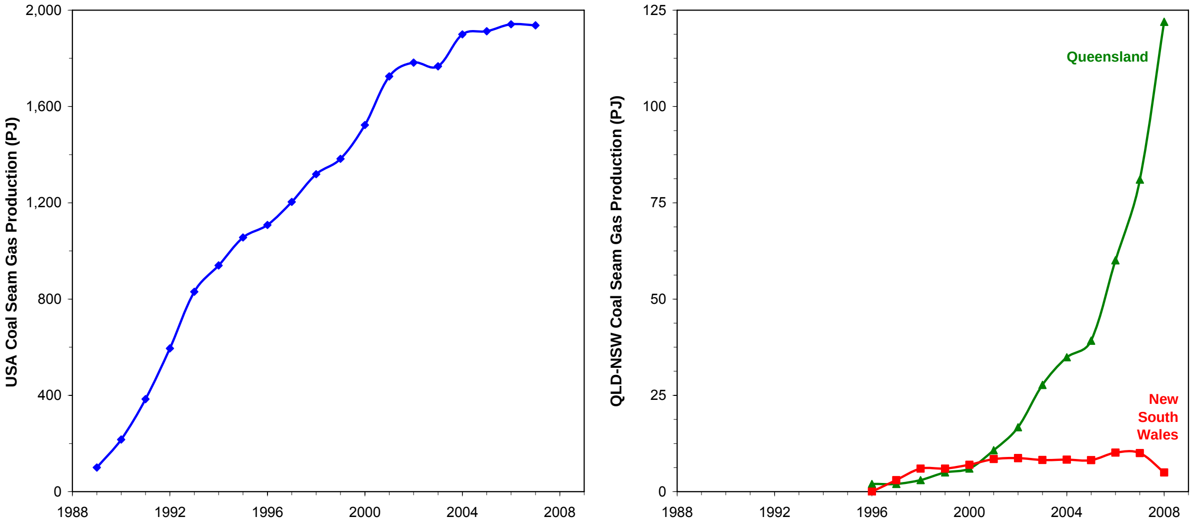


Figure 4: Recent growth in coal seam gas production – USA, Queensland and New South Wales (data from EIA, 2009; ABARE, 2009; QME, 2009; GA, 2006)

Table 4: Select production data for coal seam gas basins, USA (PB, 2004)

Geologic Basin	**No. of Wells**	**Average Water (L/day/well)[§]**	**Unit Water (ML/PJ)[§]**
Back Warrior	2,917	9,222	63.5
Powder River	2,737	63,600	317.5
Raton	459	42,294	154.7
San Juan	3,089	3,975	3.6
Uinta	393	34,185	48.5

[§] Converted from USA (imperial) to metric units for consistency, also assuming 39 MJ/m^3 of gas (based on ABARE, 2009).

5.1 CSG in Wyoming, USA

The mid-west state of Wyoming is a major energy producer, providing coal, uranium and coal seam gas to numerous regions of the United States. The Powder River Basin, the dominant geologic system in Wyoming, is the home to a large CSG industry – and, of course, large associated water resources and environmental problems. As shown in Table 3 above, the Powder River Basin produces the most water for every PJ of CSG (317.5 ML/PJ). Curiously, many of the coal seams targeted by CSG also serve as aquifers for groundwater supply (Young, 2005). Water quality from CSG operations is variable, and can range from reasonable to brackish and saline. Historically, when water is of acceptable quality, it has been discharged into nearby streams, while poorer quality water is commonly held in large evaporation or infiltration ponds (RIENR, 2005). Other options in minor use include managed irrigation, deep groundwater injection, and reverse osmosis or ion exchange treatment.

The recent plateau in production over 2003 to 2004 is in part due to difficulties in managing increasing amounts of poorer quality water, although other factors could be declining CSG production from older fields, the lag in production from new wells while they extract sufficient water to facilitate gas flow, or regulatory requirements delaying new fields (RIENR, 2005).

In some areas of Wyoming, there has arguably been some benefit due to the ability to use reasonable quality water for agriculture (RIENR, 2005). However, large scale and long-term impacts on surface water and groundwater quality, soil resources and ecosystems have also been well documented. For example:

- Soil quality impacts near Juniper Draw, north-eastern Wyoming, were leading to long-term sodium increases and changes in biodiversity as a result of salt tolerant weed species invading, suggesting a long-term problem for agricultural production and adjacent water quality (Stearns *et al.*, 2005);
- The continued expansion of the CSG industry could lead to a significant impact on aquifers and prior pumping uses (Young, 2005);
- Construction of roads, wells, pipes and processing facilities can lead to significant land disturbance, such as soil erosion, vegetation loss or even wind erosion (Young, 2005);
- Evaporation or holding ponds increase the potential for mosquitos to breed and spread West Nile virus (Young, 2005; RIENR, 2005);
- Spread of invasive weed species and reduction in vegetation quality and biodiversity (Bergquist *et al.*, 2007).

The debate over existing regulatory standards and approaches, as well as future management options for the expanding CSG industry, is proving very contentious – leading to a possible view that CSG is unique in its characteristics and requires special regulation (RIENR, 2005).

Although there are many key geological and environmental differences between Wyoming, Queensland and New South Wales, the complex challenges faced by Wyoming in trying to balance agriculture, coal seam gas extraction, local communities and the environment are a salutory lesson in the need for strict regulation and standards, comprehensive baseline studies and thorough environmental monitoring.

6. Proposed Australian Projects

6.1 Gladstone Liquified Natural Gas Project (GLNG), Queensland

The Gladstone LNG project is an export-oriented CSG project being developed by Santos Ltd (60%) and partner Petronas Ltd (40%). The proposal includes a major expansion of CSG extraction fields in central Queensland, pipelines to facilities in Gladstone for conversion to liquified natural gas (LNG) and subsequent export – hence the name of the Gladstone LNG Project. The proposed production levels are a total of 544 PJ/year, being developed in three equal stages of about 163 to 218 PJ/year. The multi-billion dollar project is presently undergoing environmental impact assessment (GLNG, 2009), with comments on the surface water and groundwater issues of the CSG fields made below.

Surface water (section 6.5):

- Existing surface water hydrology is reviewed, including water quality and flows. A detailed and thorough study is provided in Appendix O1.
- Overall, numerous risks such as accidents or floods, are addressed and plans proposed.

Groundwater (section 6.6):

- Although detailed descriptions of all aquifers are provided (which are mainly alluvium, sandstones and some fractured rock aquifers), no cross-sections of the hydrogeology are provided in the main EIS report (no geological cross-sections are even provided earlier in section 6.3). Some qualitative discussion of water levels, pumping yields and quality is given, but very little data. A detailed study and assessment of groundwater is instead provided in Appendices P1 and P2, and is certainly a thorough study.
- Potential risks identified include flow of poor quality groundwater from low-yielding aquifers and flow along fault lines and rock fractures (critical for local stock watering sources).
- Overall, the EIS predicts limited impacts on groundwater resources during and after CSG field operations with respect to both water quality and groundwater levels.

6.2 Gloucester Basin CSG Project, New South Wales

In November 2009, AGL released an environmental assessment of a 'Concept Plan' for the staged development of the Gloucester CSG project, about 100 km north of Newcastle and initially producing about 30 PJ/year (Aecom, 2009). Although it might appear to be an extensive study, with specific chapters on surface water and groundwater issues, some critical comments are important to note.

Surface water (chapter 12):

- Flood risks are considered, though largely in a qualitative manner.
- Quantitative data on the hydrology of the project area are ***completely missing***.
- Water quality data are ***completely missing***. This also makes it impossible to assess the current status of water quality and compare this to relevant guidelines, such as the freshwater guidelines (ie. ANZECC & ARMCNAZ, 2000).
- Although risks such as sedimentation, turbidity, salt and other contaminants (eg. fuel) are acknowledged, the lack of baseline data completely prevents any assessment

Groundwater (chapter 13):

- No cross-sections of the hydrogeology are provided (no geological cross-sections are even provided later in chapter 17).
- Despite data being obtained from trial pumping and gas extraction over 2004 to 2008 which allegedly shows no changes in alluvial aquifers, this data is not provided in graphical or other format – leaving one to merely believe the assertions in the report.
- The report proposes that groundwater monitoring and assessment be developed as part of the overall environmental management plan if NSW government approval is given. This makes it impossible to assess the accuracy and suitability of the monitoring program, especially given the lack of quantitative data and hydrogeological cross-sections.
- The report acknowledges the risks of connections between shallow alluvial, shallow bedrock and deep bedrock aquifers, especially due to fractures, but overall it argues that impacts on alluvial aquifers are most likely to be minimal (if at all). ***Given the lack of data and hydrogeological cross-sections, such confidence is not scientifically sound.***

Such critical gaps in surface water and groundwater data and impacts are extremely poor practice.

7. Current AGL Work Around Broke

In the latter months of 2009, AGL's hydrogeological consultants, Parsons Brinkerhoff (PB), presented their ongoing results of groundwater studies, including the pump test at HB02. This work has been directed at providing new evidence to support the conceptual model of groundwater flow and behaviour, shown previously in Figure 2, as well as allowing AGL to test behaviour with respect to gas generation rates. A primary issue which the work has been designed to help address is the potential for flow of groundwater between the shallow aquifers, such as the alluvium of the Wollombi Brook, and the deeper coal measures being dewatered for gas extraction. The majority of the results from this work were presented to the Broke Community Consultative Committee (BCCC) on 30 November 2009 (Ross, 2009), although the final report, including all data, analyses and interpretations, is yet to be finalised as of the BCC meeting of 1 February 2010.

The groundwater level in pumping bore HB02 is shown in Figure 5, including an inset location map of Broke and HB02. The groundwater level monitoring data for nearby bores, including data for the past several months, is shown in Figure 6. Although other results for other monitoring bores are also given by Ross (2009), these show similar behaviour and are not included herein.

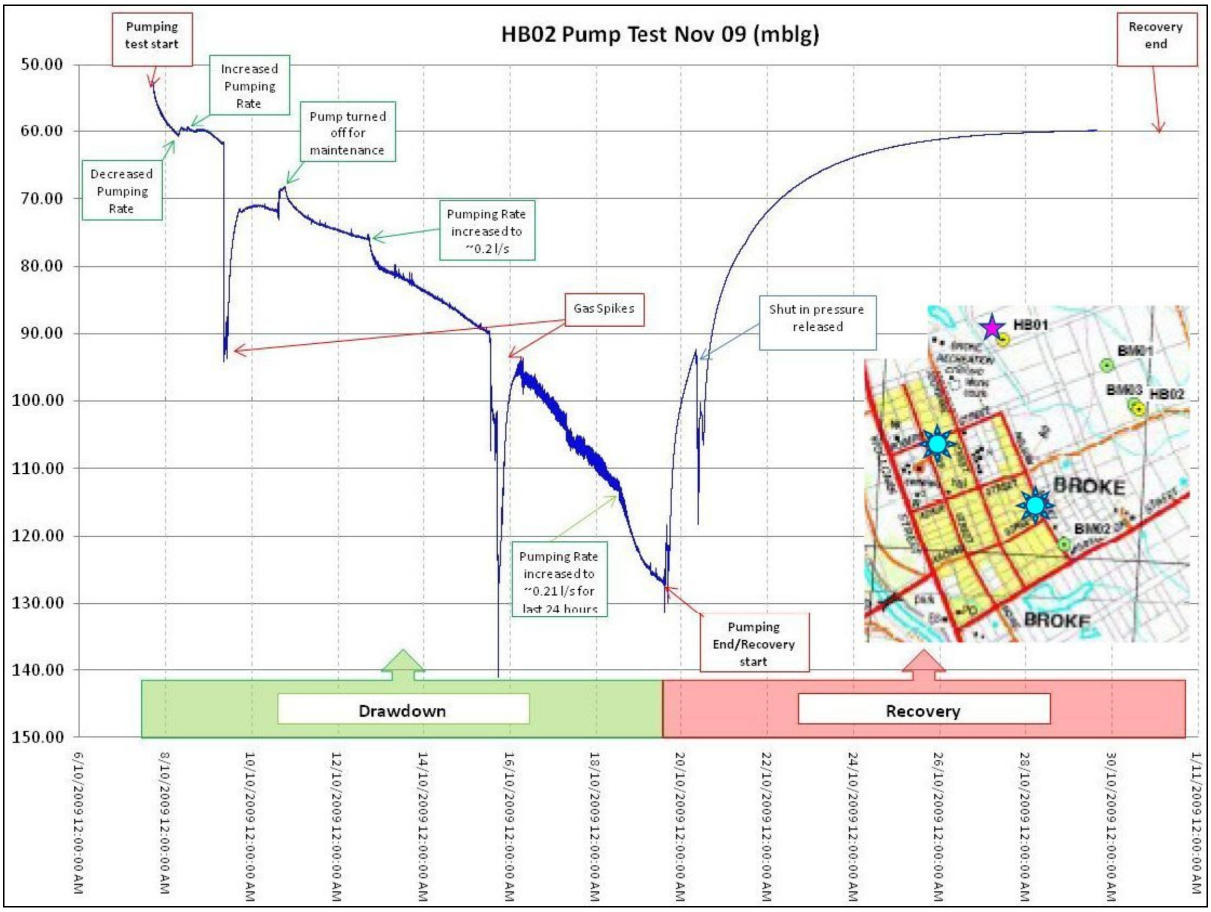
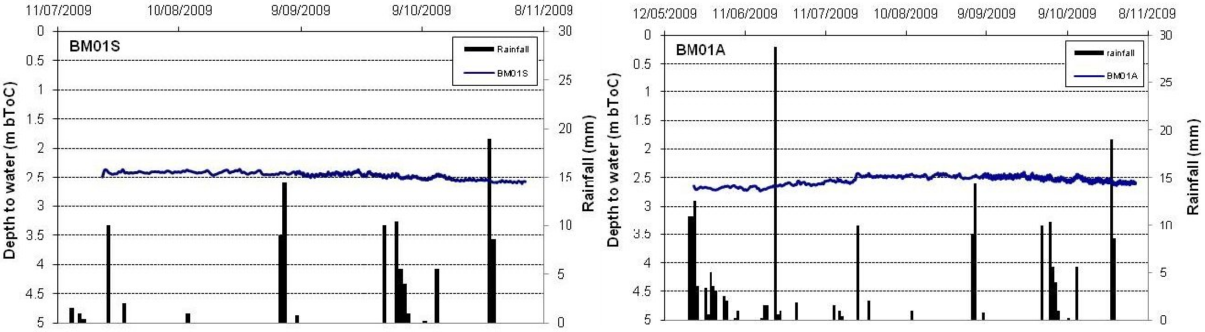
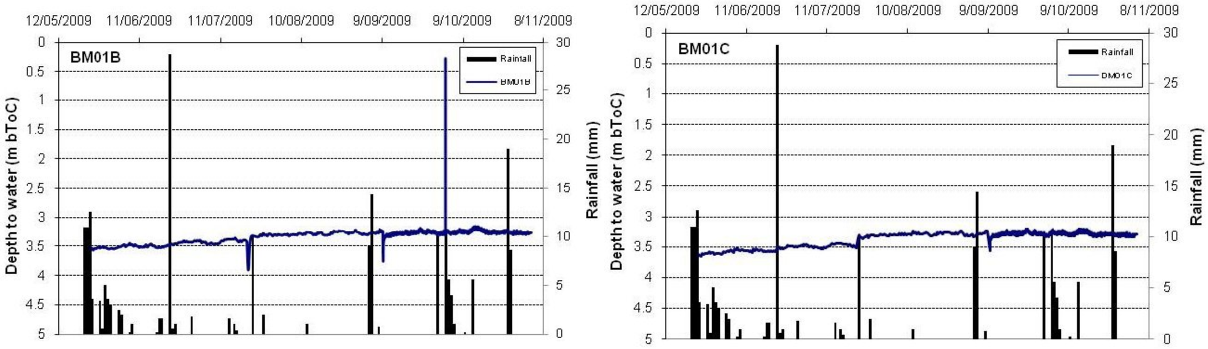


Figure 5: Groundwater levels during the HB02 October 2009 pumping test, including an inset location map (adapted from Ross, 2009)



Shallow alluvial aquifer, bore screen: 1.5-6 m *Deeper alluvial aquifer, bore screen: 6-10 m*



Shale/sandstone aquifer, bore screen: 56-68 m *Coal seam aquifer, bore screen: 160-220 m*

Figure 6: Groundwater levels in monitoring bore BM01 during the HB02 October 2009 pumping test (adapted from Ross, 2009)

All groundwater levels are presented from the 'Top of Collar' (ToC), which is the top of the bore casing as it sticks out of the ground. Ideally, all results should be converted to relative levels, such as elevations with respect to the Australian Height Datum (AHD) – giving a precise view of the relative groundwater levels of each aquifer or layer independent of the height of each bore collar above ground. The results therefore need to be viewed carefully (especially since pumping bore groundwater levels are metres below ground; the different should be small but it still needs to be accounted for). However, the results do suggest that at present, the groundwater levels in the alluvial aquifers associated with the Wollombi Brook are slightly higher (~1 m) than those in underlying aquifers and seams. The dry period in the latter months of 2009 was arguably beginning to have an effect on alluvial groundwater levels, since they were declining slightly by September.

The difference in groundwater levels suggests a minimal hydraulic gradient (ie. pressure difference) between the shallow and deeper aquifers, with a downward direction. This needs to be considered not just in a one-dimensional view of results at BM01, but with respect to the three-dimensional nature of the geology and hydrogeology. That is, it is important to understand the sources of groundwater levels – what are the locations and geologic features that control these pressures? Is it mostly a reflection of very low permeability barriers between shallow and deep aquifers? Or is this apparent downward gradient a result of the existing impacts from longwall mining which has led to minor head declines in deeper groundwater? It is not possible, on the extent of evidence available so far, to extrapolate the finding of a minimal hydraulic gradient without significant uncertainty. That is, although it is suggestive of minimal vertical groundwater flow, groundwater behaviour needs to be further investigated, understood and assessed in its full three-dimensional characteristics.

The water quality testing presented by Ross (2009), using dissolved salts and some isotope analyses (including additional results presented to the BCCC on 1 February 2010; Ross, 2010), also suggests some evidence for the lack of mixing or vertical flow between aquifers.

The salt content of water from the HB02 pump test was 3.6 g/L (Ross, 2009). If we assume this figure is representative of all future groundwater extracted by CSG activities, every ML of water pumped to the surface would include 3.6 tonnes of salt. If a CSG project in the Broke area were to extract 1 GL of water per year (ie. similar to Queensland CSG projects), this would entail 3,600 tonnes of additional salt per year which has to be managed in the surface environment. Experience in Queensland, as well as in combatting salinity problems across Australia has shown that such challenges are very significant and often hard to solve.

The remaining question is the degree to which the pumping test can be considered representative of any future extraction scenario. A major issue with any such extrapolation is that the test was only a single bore – compared to potential production scenarios which would require numerous bores. Further comment can be provided once the PB report is completed.

8. Other Relevant Issues

At present, there are two additional issues concerning groundwater in the immediate environs of Broke.

First, the potential for overlap of impacts on groundwater from nearby longwall mining and any future CSG project is very significant. Based on reviewing Australian and overseas projects, it is unclear if large scale CSG extraction has ever been attempted so close to active (or even historic) longwall coal mining operations. Subsidence from longwall mining can lead to impacts on groundwater levels through opening up new cracks, fractures and pathways which previously did not exist. This could lead to significant risks when combined with the substantive groundwater extractions and changes due to any future CSG project. That is, the combined impacts on groundwater could be greater than each project alone.

Although it is possible to identify and mitigate much of the potential subsidence and groundwater impacts from longwall coal mining, given the potential seriousness of overlapping longwall and CSG impacts, extensive and methodical investigation and risk assessment is required to identify and mitigate likely impacts, but also to make sure that appropriate monitoring is in place to ascertain causes and discern responsibilities.

Second, the increasing prospects for further development in the region requires more thorough environmental assessment than a project by project study (which is the traditional case for such developments). In this regard, it is critical to examine the opportunity for cumulative impact assessment of existing and future developments in the vicinity of the Broke-Fordwich region.

At present, there are extensive vineyards and coal mines, possible future expansions to coal mining (open cut and longwall), CSG exploration and prospective development, and more recently even geothermal energy exploration by Geodynamics Ltd. A cumulative impact assessment would allow a more complete and holistic view of total environmental and community impacts to be compiled, as well as a more strategic view of future development scenarios.

9. Summary: Major Findings

This report has reviewed a number of key groundwater and environmental issues with respect to ongoing coal seam gas exploration by AGL in the Broke-Fordwich region of New South Wales.

Significant findings with respect to groundwater resources and behaviour include:

- there is only sparse data on groundwater in the immediate Broke environs.
- the conceptual model for groundwater resources and behaviour suggests a complex system, but also that current monitoring appears to be insufficient to accurately demonstrate and quantify important processes, especially for the Wollombi Brook and associated alluvial groundwater resources.
- the recent pump test and monitoring by AGL just east of Broke has provided tentative evidence of minimal vertical groundwater flow between the various aquifers or layers, although this is only valid under the conditions of the pump test and cannot be extrapolated to larger scales or time frames without significant uncertainty.
- given the stratification of shallow groundwater quality in the alluvial aquifers of the Wollombi Brook, with most bores being shallow and close to the surface, this means any reduction in groundwater levels leads to a high risk of impacts on existing users.
- considerably more investigation and monitoring is required to more fully characterise groundwater flow and behaviour in three dimensions before sufficient confidence in the lack of vertical groundwater flows can be developed.

Significant findings with respect to groundwater and CSG projects include:

- every CSG project can be substantially different with respect to the volumes and quality of groundwater involved.
- although the CSG industry in Australia is relatively young, it is clear that groundwater often remains under-assessed and regulated.
- at Camden, NSW, there is no statutory groundwater monitoring, meaning that claims of no impacts cannot be verified with ongoing field data.
- water reporting for Camden does not appear to be consistent with known water volumes for other CSG projects in Australia or the USA.
- the environmental impact assessment for AGL's proposed Gloucester CSG project failed to include detailed groundwater data and processes, largely relying on claims about low impacts rather than providing field data to prove claims – in stark contrast to the extensive studies for Santos' proposed Gladstone CSG project in Queensland.
- it remains unclear at present the extent to which water issues might constrain or govern any future AGL activities in the Broke region, especially possible water management and treatment options.

Significant findings with respect to CSG projects and pollutant emissions include:

- reported emissions of pollutants listed through the National Pollutant Inventory show relatively low levels for Camden but much larger levels for Fairview.

Significant findings with respect to CSG projects and potential cumulative impacts with nearby projects include:

- the closeness of existing and future longwall mining to potential CSG developments raises significant risks of overlapping groundwater impacts – a serious issue which requires careful and thorough investigation.
- There is a strong basis and need for a thorough cumulative impact assessment of all present and future activities in the Broke-Fordwich region, including coal seam gas, coal mining, existing vineyards and geothermal energy, to ensure that the environment and community remain protected, as well as all industries operating within appropriate conditions and total impact limits.

In summary, there remains significant uncertainty about the extent of possible future impacts on groundwater resources and the environment around Broke, with a key requirement being ongoing monitoring, co-operation between all parties involved and especially pro-active environmental assessment of all cumulative potential impacts.

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