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Barrington-Gloucester-Stroud
Preservation Alliance Inc.
(Incorporated under the Associations Incorporation Act, 1984)
Incorporation No. INC9885807

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15 November 2011

RECEIVED
17 NOV 2011

The Hon Robert Brown, MLC
Chair
Legislative Council Inquiry into Coal Seam Gas
Parliament House
Macquarie Street
Sydney NSW 2000.

Dear Sir,

TAREE HEARING 31 OCTOBER – The Committee's request for details of reports referring to methane gas migration and to coal mining at the northern end of the Gloucester Valley

I ask if I may submit one further document in regard to the above matter. This was omitted from our initial response dated 10 November but is highly relevant to the questions asked by the Committee and should have been included at that time.

The document is:

8. Anthony Berecry, 2010, *The Implications and Risks of Coal and Coal Seam Gas (csg) Extraction Industries and their Cumulative Impact on Gloucester's Clean Water from a Geological Perspective.*

The document is relevant to the matter throughout and we ask that it be read in its entirety. This is the only professionally written document available that specifically considers the impact of coal seam methane gas mining on the geology of the Gloucester Valley and brings to a head the geological data contained in the various reports and studies available to date.

While we ask that it be read in its entirety, we extract for the committee's reference several relevant sections and have highlighted these in the report.

- Page 1. Introduction notes;
  'Most geological academic information on coal seam gas extraction tends to refer to areas having 'flat simple' geology like at Broke, NSW and areas in Queensland. The geological structure of the Gloucester – Stroud Basin is not flat, layer cake geology. It is folded, irregular, heavily faulted with large displacements, jointed, and steeply dipping.

  This discussion considers the unique geological structure of the Gloucester-Stroud valley and the possible impact that both coal mining and coal seam gas (CSG) extraction on the finely balanced systems of surface water and underground aquifers.

  It is in the Government's interest to understand the relationship between the basin's geology and its water system and to be proactive rather than relying on a reactive management strategy. The problems from pollution of the Gloucester-Stroud, Karuah and Manning catchments that may arise in the near future will certainly diminish the profits the Government receives from the mining companies.

There is a real possibility that mining could destroy the water quality in this area'.

- Page 4 Structural Features of the above Geological Maps comments: 'Unlike other areas where the geology is essentially flat or horizontal, the sedimentary rocks, which contain the coal beds, have been folded and are very steeply dipping with numerous north-south and east-west trending faults'.

- Page 6 Water Sources for the Stroud-Gloucester basin considers: 'There appears to be a complex relationship with the ground water systems due to the complex geological structure in the Syncline. Most water storage and movement knowledge derives from the 'flat geology' districts that have virtually no correlation with the Stroud-Gloucester basin'.

- Page 6. 3 RISKS reports that: Gloucester recently had a forum on air, water, coal and health presented by the Clean Air Society of Australia and New Zealand. This included seven academic speakers on several topics but the common theme from all of them was that they did not know anything about the Stroud-Gloucester valley and all their examples came from outside the area. Garry Willgoose, University of Newcastle, gave a talk on coal seam gas, water and fraccing and continually referenced his experience in 'flat geology' Broke, NSW where AGL is establishing a coal gas extraction mine. Willgoose refrained from commenting on the Gloucester-Stroud Syncline claiming no knowledge of the area..

- Page 7 Coal Mining – Gloucester Coal Limited noted in relation to the geological characteristics that: 'Talking to geologists involved in the exploration drilling for the Stratford Coal Mine, faulting was one of the major problems encountered. It caused difficulties in the correlation of seams during exploration drilling'.

- Page 9 Cumulative Risks to the Whole System: 'Water is essential for our wellbeing and survival. The cumulative risks that could affect our water security and environment also have to consider all the aspects of increased activity requiring water in the valley. Both coal mining and CSG Extraction put heavy demands on the system principally on drawing down the existing water tables. The new exploration areas involve the eastern boundaries which are one of the main recharge areas for coal seam and jointed rock aquifers. However the reduction of water will impact local dairy farmers and other agricultural activities which will probably need to take more from the river systems. Extended dry periods will exacerbate this supply and the whole picture sees the Gloucester water system out of balance. Before mining started this balance in underground water and the streams and rivers maintained equilibrium. However mining and CSG extraction could impact on the valley to render it a dust bowl or at least turn it into a salt basin thereby reducing food production'.

- Page 10 SUMMARY AND RECOMMENDATIONS recommends that coal seam gas extraction in the Gloucester valley should be rejected.

We sincerely urge that this report be given the Committee's most serious consideration.

Yours sincerely,

Garry Smith

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Documents supplied by the Barrington-Gloucester-Stroud Preservation Alliance Inc

to

LEGISLATIVE COUNCIL GENERAL PURPOSE STANDING COMMITTEE NO. 5

following the hearing at Taree, Monday 31 October 2011.

Document 8

Report

Anthony Berecry, 2010, The Implications and Risks of Coal and Coal Seam Gas (csg) Extraction Industries and their Cumulative Impact on Gloucester's Clean Water from a Geological Perspective.

THE IMPLICATIONS AND RISKS OF COAL AND COAL SEAM GAS (CSG) EXTRACTION INDUSTRIES AND THEIR CUMULATIVE IMPACT ON GLOUCESTER'S CLEAN WATER FROM A GEOLOGICAL PERSPECTIVE by Anthony Berecry, 2010.

1. INTRODUCTION

Most of the geological studies on the Gloucester-Stroud Basin were completed in the early 1970s. There is little known compared to too much not known on the relationship between the Gloucester-Stroud basin's geological structure and its associated ground water systems. This lack of up-to-date scientific knowledge and understanding sets the scene for disagreement and misuse of facts by all parties, i.e. extractive companies, governments, council and the residents of Gloucester, as well as the water users down stream, (Karuah and Manning catchment areas). Most geological academic information on coal seam gas extraction tends to refer to areas having 'flat simple' geology like at Broke, NSW and areas in Queensland. The geological structure of the Gloucester – Stroud Basin is not flat, layer cake geology. It is folded, irregular, heavily faulted with large displacements, jointed, and steeply dipping.

This discussion considers the unique geological structure of the Gloucester-Stroud valley and the possible impact that both coal mining and coal seam gas (CSG) extraction on the finely balanced systems of surface water and underground aquifers.

It is in the Government's interest to understand the relationship between the basin's geology and its water system and to be proactive rather than relying on a reactive management strategy. The problems from pollution of the Gloucester-Stroud, Karuah and Manning catchments that may arise in the near future will certainly diminish the profits the Government receives from the mining companies.

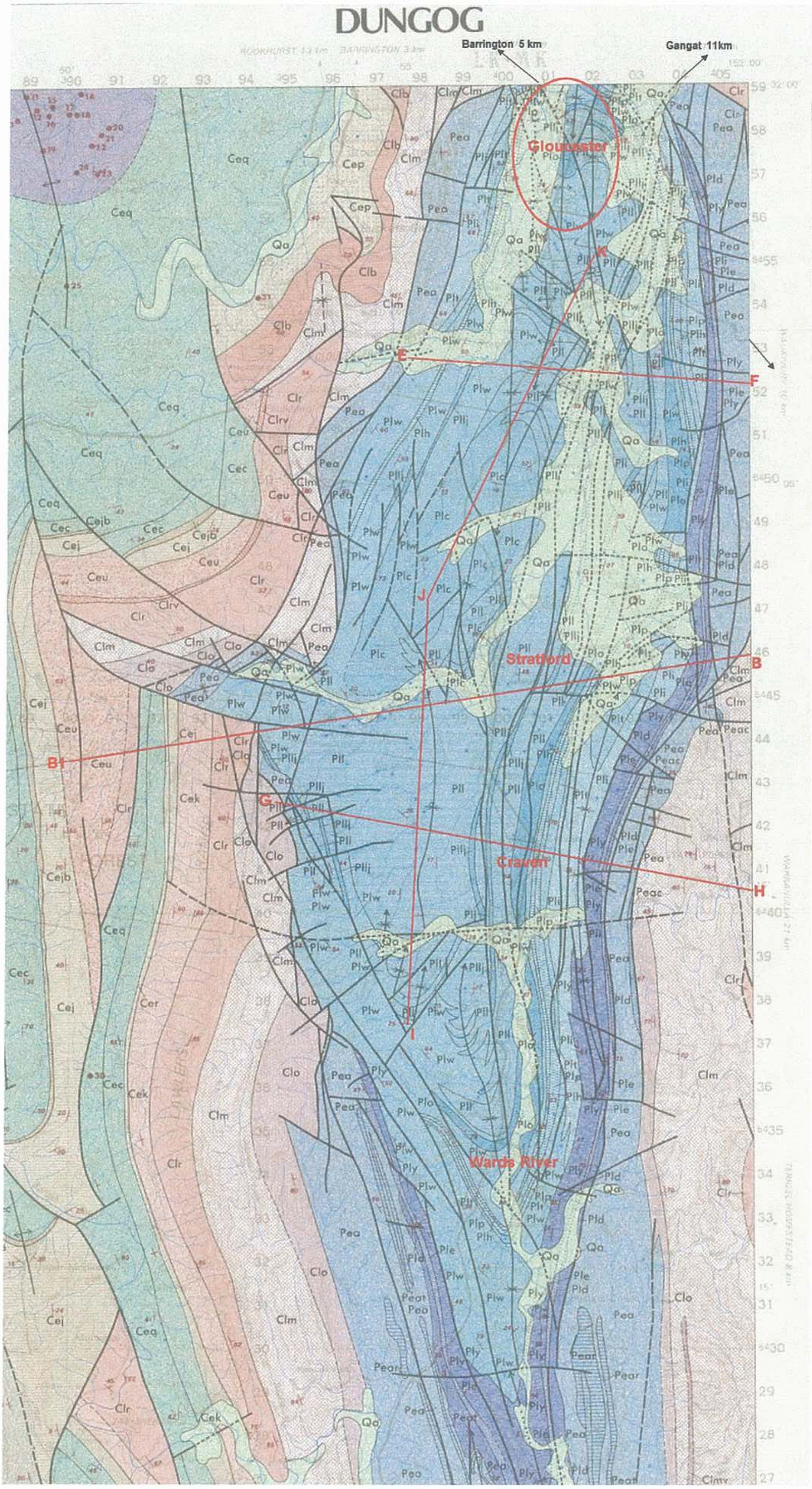
There is a real possibility that mining could destroy the water quality in this area.

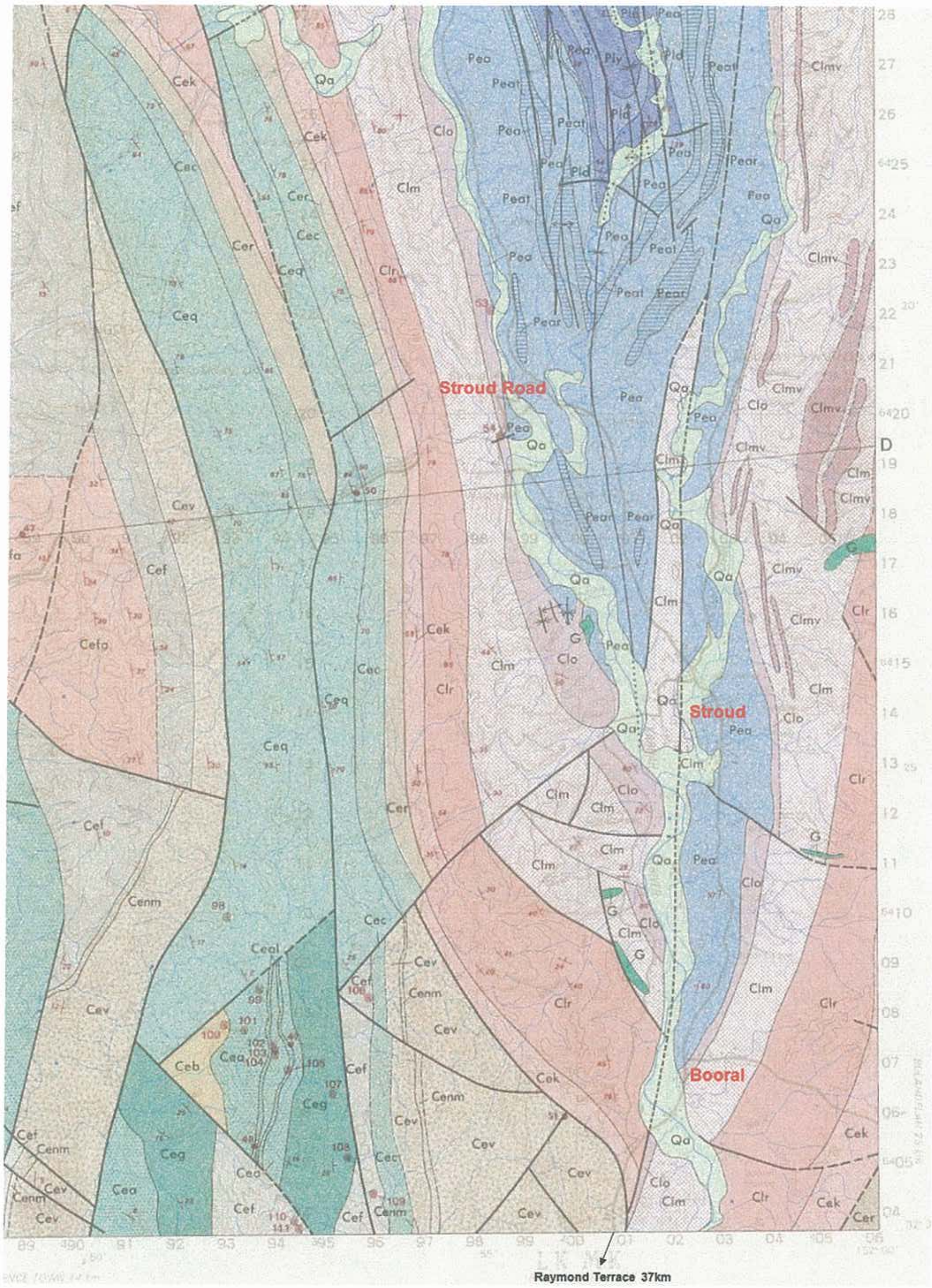
2. GEOLOGICAL STRUCTURE OF THE GLOUCESTER – STROUD SYNCLINE.

The following map and cross section extracts (1:100,000 Dungog Geological Series Sheet 9233) are from the Geological Survey's website and show the complexity of the structure in the Gloucester Basin. The red lines highlight the cross section locations and the towns for reference.

This shows the geology and structural features of the Gloucester – Stroud Syncline.

The map is split into two sections, the northern and southern halves to assist with fitting on A4 pages and to help with clarity. The black lines on the map represent faulting in the basin which are mapped in the field by geologists and interpretation from aerial photos and by no means represent all the faults in the valley.


DUNGOG
Barrington 5 km
Gangat 11km
Gloucester
Stratford
Craven
Wards River
E
F
K
J
B
B1
G
H
I



Structural Features of the above Geological Maps.

The Stroud - Gloucester Syncline is a narrow feature which can be envisaged as a canoe-like structure having closures at Stroud and just north of Gloucester.

The lighter blue colours on the map represent the Gloucester Coal Measures which contains the Avon, Bowens Road and Cloverdale and other seams that are currently being mined to the east of Stratford. The darker purple colours represents the Dewrang Group that contains the Weismantel and Clareval seams that are being mined at Duralie near Stroud Road, and also now being explored along the eastern boundary of the valley close to Gloucester town. GCL are drilling northwards to Fairbairns Road and

Risks of Coal and CSG Mining in the Gloucester Valley

Gloucester Resources Limited (GRL) are drilling north of Fairbairns Road to somewhere north of Jacks Road.

Unlike other areas where the geology is essentially flat or horizontal, the sedimentary rocks, which contain the coal beds, have been folded and are very steeply dipping with numerous north-south and east-west trending faults. The maps show the many faults and their directions. The faulting increases in intensity between Craven and Gloucester. The cross sections display the steeply dipping rock strata. Cross section B-B1 shows a large throw reverse fault to the east of Stratford which displaced the Dewrang Group 400metres vertically. The strata near the centre of the syncline axis has its sedimentary rocks dipping at angles of between 30 to 50 degrees and can be more than 60 degrees at the edges of the basin and in some cases nearly vertical.

The geological map shows just how complex this syncline structure is and geologists have classified the various fault types into six categories:

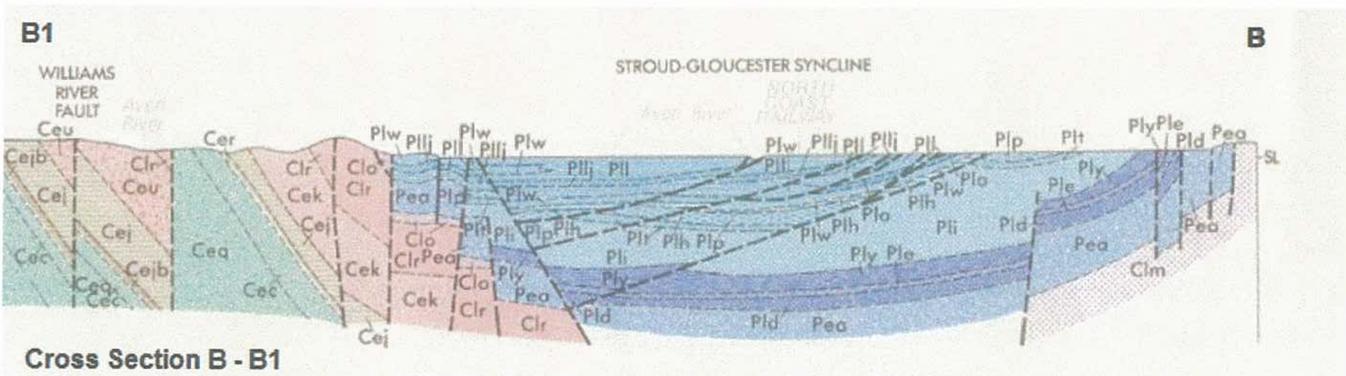
1. Most of the major faults are along the axis (approximately north-south), along the Syncline and are related to the folding.
2. North-south low angle thrust faults dipping to the west
3. North westerly Strike Slip faults.
4. Reverse faults (trending along the axis)
5. East-west Normal Faults
6. Shearing and/or Normal Faults (trending in north easterly direction).

Associated with the folding, the sedimentary rocks would also have undergone fracturing and jointing. It is these joints and fractures that allow rocks with low porosity to store underground water which is mentioned later.

(For a more detailed structural explanation - see Reference Section for Extracts from the Explanatory Notes which accompany the Dungog Sheet by the Geological Survey of NSW).

Structural Features of the above Geological Cross Sections.

The cross sections are not to scale but are included to demonstrate the combination of complex faulting and steeply dipping strata in the Stroud-Gloucester Syncline.

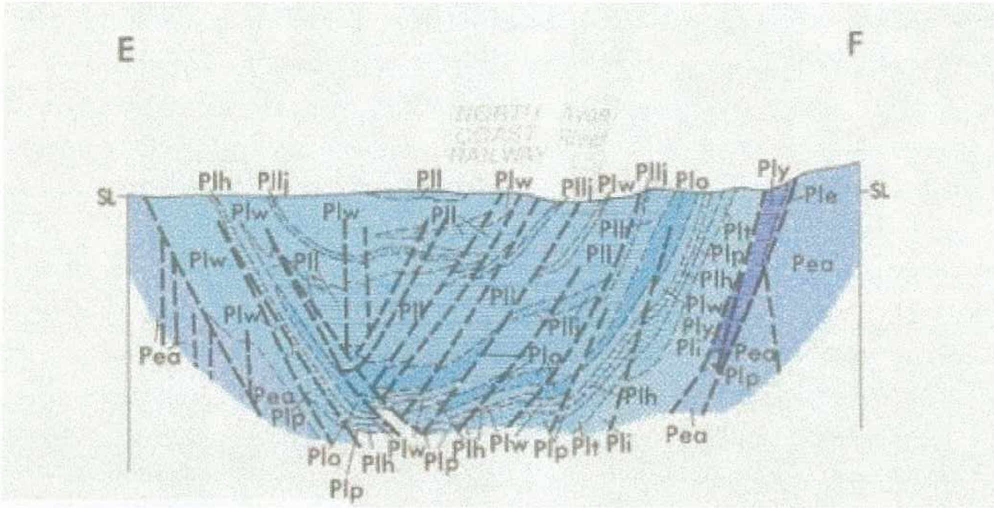


Cross Section B - B1

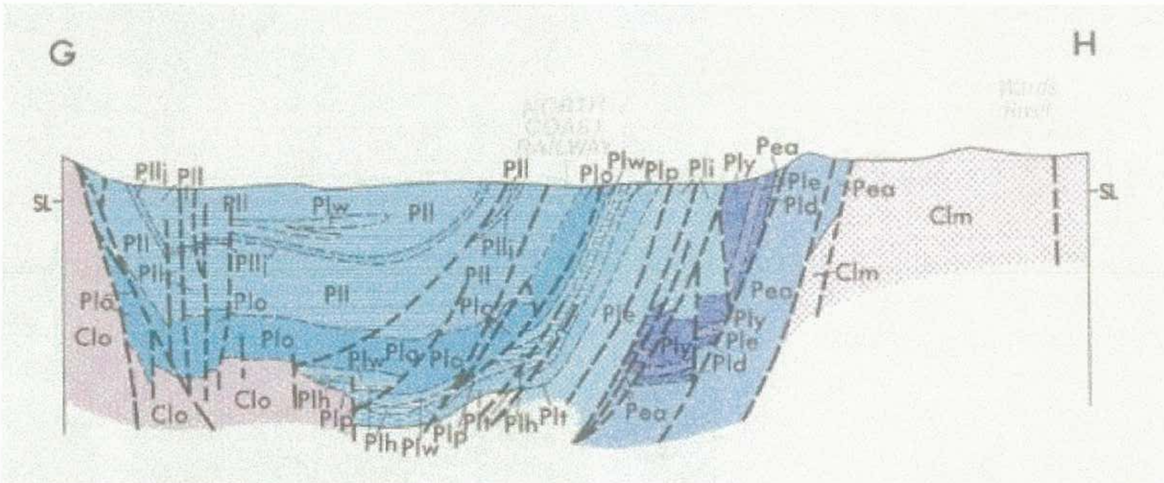
Cross section B-B1 cuts across the widest part of the Syncline near Stratford. Towards the east there is a fault that shows the large throw reverse fault which displaced the top of the Dewrang group in the order of 400 metres.

From B-B1 we can estimate the approximate depths to the coal measures towards the centre of the basin. The Weismantel is approximately 1.8km deep and the Avon Sub Group (containing the main seams being mined to the east of Stratford by GCL), and their depth varies from 800 to 900 metres.

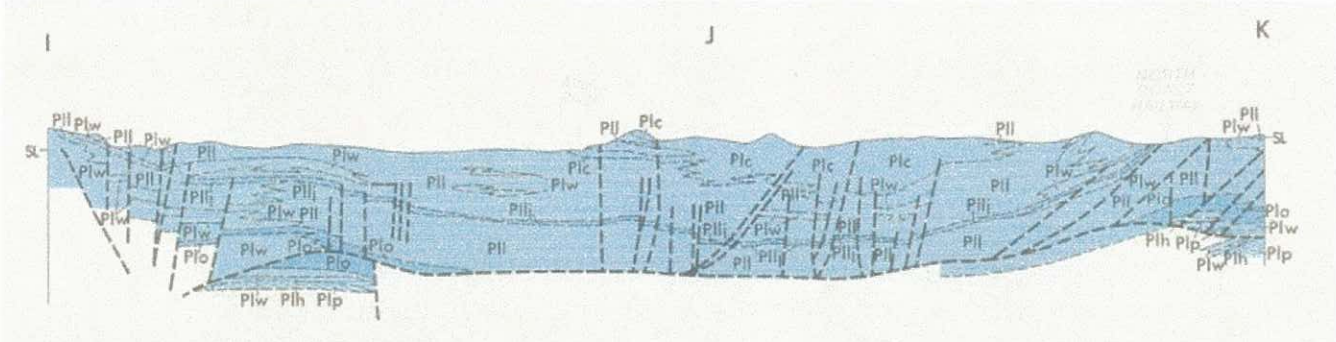
Cross Section F-E is east-west direction through the basin approximately 2kms south of Jacks Road, Gloucester.



Cross Section H-G approximately cuts east-west through Craven.



B-B1, F-E and H-G show the numerous north-south trending faults and very steeply dipping strata which concentrates mainly on the Eastern boundary of the valley. It is this section that contains most of the accessible coal and coal seam gas deposits. It appears from these sections that most of the coal is on the eastern side of the syncline. However, Gloucester Resources Limited (GRL) are currently exploring the western limbs of the Syncline on Woods Road and Upper Avon road near Craven.



North - South Cross Section: I - J - K

Cross Section K-J-I runs from Jacks Road, Gloucester to about 3kms north of Wards River and generally follows the axis line of the Stroud-Gloucester Syncline. This section shows the east-west faulting which seems to be concentrated near Gloucester, around Stratford and south of Craven.

Water Sources for the Stroud – Gloucester basin.

Water generally exists above ground as streams, creeks and rivers and underground as aquifers. The aquifers consist of clean water in alluvial sediments, fractured and jointed rocks below the alluvial sediments and as saline water in the coal seams. (See explanatory notes in the reference section).

There is a relationship between the creeks and the alluvial aquifers where the creeks charge the alluvial ground water. During extended dry periods the alluvial ground water flows into drying creeks. The underground rock and coal aquifers are recharged by rain on the edges of the basin through faults and subcrops. Water also seeps down into the rock structure from the alluvial deposits.

There appears to be a complex relationship with the ground water systems due to the complex geological structure in the Syncline. Most water storage and movement knowledge derives from the 'flat geology' districts that have virtually no correlation with the Stroud-Gloucester basin.

(See Reference Section for Extracts from the Explanatory Notes which accompany the Dungog Sheet by the Geological Survey of NSW).

3. RISKS:

Coal Seam Gas {CSG}– AGL

Gloucester recently had a forum on air, water, coal and health presented by the Clean Air Society of Australia and New Zealand. This included seven academic speakers on several topics but the common theme from all of them was that they didn't know anything about the Stroud-Gloucester valley and all their examples came from outside the area. Garry Willgoose, University of Newcastle, gave a talk on coal seam gas, water and fraccing and continually referenced his experience in 'flat geology' Broke, NSW where AGL is establishing a coal gas extraction mine. Willgoose refrained from commenting on the Gloucester-Stroud Syncline claiming no knowledge of the area.

AGL continue to say that this is a safe area to practice CSG extraction. It was said that AGL (or the then Molopo/Lucas) had several problems with exploration drilling. On encountering fractured rock circulation was lost, producing costly exploration outcomes . Subsequently, they ceased exploration drilling and conducted a three dimensional seismic survey to locate areas where the drilling wouldn't encounter the Gloucester-Stroud Syncline's geological complexities.

Basically, CSG extraction, involves two stages. First is drilling to the bottom of the coal bearing strata and fraccing the target seam. This involves pumping water, sand and some chemicals into the coal seam. Secondly to extract the gas the water table has to be drawn down by pumping water out of the hole. This reduces the pressure on the liquid gas methane associated in the coal and allows it to gasify and escape up the well. The CSG extraction can only work by reducing pressure on the deep coal seams and to do this they draw down the water table 300 to 600 metres or more..

Garry Willgoose showed a diagram of a horizontal coal seam and explained how the fraccing only runs horizontally along the seam due to tectonic stresses applied to an area relating back to tectonic plate movements. He didn't offer any advice about fraccing coal seams in areas with seams dipping 50 degrees in a heavily faulted valley.

Risks associated in coal seam gas extraction process are:

- Dust pollution from the large number of truck movements required to remove 'production' water and deliver clean water, sand and chemicals over dirt access roads.
- Holding and disposal of large quantities of production water (**unfit for consumption by humans and animals** – see Corkery Report) in waste water dams and turkey nest dams, could allow spill events into the catchment during heavy rain events.
- Possible **escape of fraccing chemicals from the target coal seam** escaping into the surrounding aquifers. Also there is no mention by AGL of what happens when fraccing is close to fault zones. It is likely that the fraccing energy and chemicals will spread out in all directions into the fault zone into other aquifers. (refer to Maps and Cross Sections)
- Possible migration of saline coal seam water being forced out into the clean water aquifer and consequent escape into alluvial aquifers and streams and rivers.
- **Large scale draw down of the water table** during the gas extraction phase of the wells life time. AGL plans something like 110 holes spaced about 600 metres apart which could impact community and farming access to water. It poses a risk of upsetting the balance in the ground water systems for an unknown time into the future.
- Migration of fraccing chemicals or saline water through poorly prepared and not properly sealed well holes allowing these liquids the chance to mix with clean aquifers.
- Mishaps occurring during the production phase due to faults in equipment or perhaps movement in geological conditions.

Coal Mining – Gloucester Coal Limited

Talking to geologists involved in the exploration drilling for the Stratford Coal Mine, faulting was one of the major problems encountered. It caused difficulties in the correlation of seams during exploration drilling.

Most of GCL's mine planning is designed around or up to fault planes which proves the complexity of mining in the area. When they complete a working pit they then pump waste water from the washery into the excavated pit and these toxic wastes have direct access to joints, fault zones with possible ingress to the ground water system.

Risks of Coal and CSG Mining in the Gloucester Valley

During exploration drilling one of the geologist's tasks is to measure the water flows at the rig to give an estimation of the ground water at the site. To do this they use a 'V' notched weir placed at the overflow from the drilling rig. At Gloucester it was commented that there was so much ground water produced that it was impossible to measure the flows and only rough guesses were attempted. These geologists commented at the time that this will be a difficult area for open cut mining. To overcome the water and to allow open cut mining the water table has to be lowered by pumping out the ground water to at least 75 metres to prevent the pit filling up.

Toxic Elements associated with Coal

Some of the potentially toxic elements that are found in coal include mercury, beryllium, asbestos, cadmium, arsenic, lead and fluorine presently. All these elements have undesirable physiological effects on plant and animal life.

Pyrite is the common mineral found in coal. The Weismantel coal seam is a high sulphur coal, predominantly pyrite, which makes it unsuitable for steaming coal and has to be brought by rail from Duralie to the Stratford washery plant for processing and blending. The process concentrates the Duralie waste at Stratford.

The mineral pyrite, or iron pyrite, is an iron sulfide with the formula FeS_2 and is the most common of the sulfide minerals. Pyrite is usually found associated with other sulfides in coal beds. Gold and arsenic also occur as a coupled substitution in the pyrite structure.

Pyrite exposed to the atmosphere during mining and excavation reacts with oxygen and water to form sulfate, resulting in acid mine drainage held in the waste water holding dams.

Risks associated with coal mining are:

- Open cut coal excavation requires a draw down of the water table to about 80 meters to allow removal of the overburden and coal. This water contains contamination from mine blasting chemicals and residues, diesel from equipment, released heavy metals from the broken rock and drill rig chemical aids. The water is pumped to holding dams and stored for release into creeks, large scale irrigation on to land and now there is an investigation into mist sprays to speed the evaporation process. All of these processes risk contaminants getting into the ground water and streams. These processes are not monitored for environmental impacts.
- Overtopping dams through heavy rainfall events allow contaminants to flow into the river system.
- Concentrating toxic waste from the coal preparation plant and coal washery into open pits where it has access to the ground water system. This waste combines toxic waste from the high sulphide coals and chemicals from the washery process. Pyrite is a big contaminant in coal from Duralie (Weismantel Seam). The toxic elements, arsenic, lead, cadmium, mercury, beryllium, fluorine and asbestos are concentrated in the washing plants and pumped into old pits and managed with limestone to neutralize the pH of the water. The old pits have fault and shear zones in them which may allow migration of these concentrated elements into surrounding aquifers and hence into streams.
- Coal washery plants also use chemicals in the process of coagulation/flocculation process involving some type polyacryamide based flocculant and this washery waste also ends up in the holding pits. These chemicals pose a real threat if released into the waterways to plants and aquatic life.
- Higher throughputs with increased tonnage have put pressure on waste water management and possibly require greater draw down of the water table.

Risks of Coal and CSG Mining in the Gloucester Valley

- Large scale irrigation on mine owned lands of waste water is a very real risk to run off. Heavy rain periods move the waste products into creeks and ingress into the alluvial and lower aquifer systems. This could possibly sterilize the lands future use for agriculture.
- Planned release of toxic waste water into our river system, even if managed could still cause problems down stream.
- Proposed misting of waste water into the atmosphere to speed evaporation will direct pollution over all the people, settle into the water system and house water tanks.
- Overburden piles are currently seeded and grassed. The overburden piles are mountains of crushed rock dug up from up to 80 meters depth and are free draining and no structural water table. There is a risk that in the future these overburden piles won't sustain the new plant life and become barren.
- GCL is the largest owner of agriculture land. John Williams, the NSW Natural Resource Commissioner, at a forum in Sydney (17/05/2011), says the laws need to be changed to ensure mining exploration companies face the same controls as other land users. "What I'm arguing for is that the acts for mining exploration be consistent with our acts for native vegetation management and water management". Agricultural landholders have to meet strict legislation and authority rules including Native Vegetation Act, Catchment Management Authority and Private Native Forestry Act and others. Under the Mining Act of 1992, mining is pretty much exempt from these restrictions.

Mining and Its Potential Impacts Downstream to the Manning River and the Karuah River

Craven, located around the centre of the Gloucester-Stroud Syncline, marks the valley water shed. Surface water flows north from Craven into the Avon, then Gloucester and finally out into the Manning Catchment area. Water flows to the south of Craven into the Mammy Johnston Creek and into the Karuah River Catchment areas.

Polluting these river systems will have a large geographical reach affecting a large population of unwary people relying on clean water.

There is a number of ways these rivers can be polluted:

- Direct out flow of contaminated water from GCL and AGL holding dams into the rivers.
- Toxic waste held in dams or completed open cut pits which allow chemicals to leach into the ground water system via faults, jointing and shear zones.
- Fraccing chemicals that escape the coal seam being targeted. Consideration should be given to what happens when fraccing near to faults and steeply dipping coal seams.
- Air pollution (PM10 and PM2.5) from open cut mining, blasting operations (explosive residues), diesel combustion wastes, conveyor transportation to washery and/or coal loader, these dusts can transfer onto ground surfaces and washed into streams and rivers.
- Large scale irrigation to empty holding dams.
- A new technique being investigated where waste water is sprayed as a fine mist into the atmosphere with the objective of fast evaporation.

Cumulative Risks to the Whole System:

Water is essential for our wellbeing and survival. The cumulative risks that could affect our water security and environment also have to consider all the aspects of increased activity requiring water in the valley. Both coal mining and CSG Extraction put heavy demands on the system principally on drawing down the existing water tables. The new exploration areas involve the eastern boundaries which are one of the main recharge areas for coal seam and jointed rock aquifers. However the reduction of water will impact local dairy farmers and other agricultural activities which will probably need to take more from the river systems. Extended dry periods will exacerbate this supply and the whole picture sees the Gloucester water system out of balance. Before mining started this balance in underground water and the streams and rivers maintained equilibrium. However mining and CSG extraction could impact on the valley to render it a dust bowl or at least turn it into a salt basin thereby reducing food production.

4. SUMMARY AND RECOMMENDATIONS

The geological maps and cross sections show a complex mix of faulting and steeply dipping beds which gives a deep concern as to just how safe this area is for CSG extraction and implies that GCL and any new mines could easily affect the waterways with toxic and saline solutions.

- Start some scientific physical, chemical and biological testing of boreholes and the streams around Gloucester to develop bench marks and then be in a position to ring the alarm bells if any extractive industry has any affect on the ground water and rivers water quality. Results could be used to evaluate the explorer's Environmental Impact Studies (EIS), and to be in a position to monitor production wastes and their impact on the environment.

- A scientific study of the prevailing wind strengths and directions should be completed for the valley which would allow for an intensive particulate matter including PM10 and PM2.5

- Water Security Monitoring Streams and Rivers for Clean Water. (Where is the Catchment Management Authority (CMA) and where is Mid Coast Water?)

- Reject coal seam gas extraction in the Gloucester valley

- Mining be subject to the same environmental laws as every other Australian citizen.

- Mining to manage their waste responsibly and demonstrate this by transparent monitoring and assessment by independent persons.

- Exploration Licences should be revisited. They have a large impact on the landholders and in the case of GCL, who have been able to hold there licences for over 40 years with no consideration for the landholders, something should be done about paying some type of rental for the inconvenience. A Fairbairns landholder spoke to the new GCL CEO's assistant about their plans for drilling on his property. He asked if the exploration showed that if there wasn't an economic recourse would they relinquish the exploration licence and let him get on with his life. GCL representative said no, the coal could be worth mining in 10 to 20 years, to which even he considered was unfair. Perhaps a rental paid to the landholders would put pressure for the mining companies to shelve off unwanted land more effectively and quickly.

6. REFERENCE SECTION

The Explanatory Notes to accompany the Dungog 1:100,000 Geological Sheet, Geological Survey of NSW.

The Stroud-Gloucester Syncline is a fault-bounded trough, being about 55km long and 24km in width at its widest part. In overall outline the syncline trends northwards between Stroud and Stratford and then swings a bit more to the east from Stratford to Gloucester. The axial plane is inclined slightly towards the east, and the syncline is a tight, canoe-like structure, having closures at either end. The notes continue to state that some blocks to the north east are overturned and generally the limbs dip at more than 60' and often nearly vertical. Dips of the structure closer to the Syncline axis are of the order of 30 to 50'.

The Syncline structure is complex and can be reduced to six components:

1. Synclinal folding with the axis approximately north-south. Most of the major faulting are axial faults related to the folding. The most important of these is the 'Williams River Fault' which forms the western margin of the Myall Block, (containing the Stroud-Gloucester Syncline).
2. Low angle, west-dipping, broadly north-south thrust faults
3. North westerly Strike Slip faults.
4. Reverse faults (trending along the axis)
5. East-west Normal Faults
6. Shears or Normal Faults striking 040' to 060' (north easterly direction)

The Dungog 1:100,000 Geological Sheet shows the basin structure with its major faulting. The cross sections show for example of a large throw reverse fault just east of Stratford which displaces the top of the Dewrang Group 400m vertically. The syncline sedimentary infill has been controlled by near vertical north-northwesterly trending strike slip faults which locally have substantial vertical components.

"Note the Dewrang Group of Permian sediments contain the Weismantel and Clareval coal members which Gloucester Coal Ltd mine to the south at Duralie Mine. The Gloucester Coal Measures contain coal seams like Avon and Bowens Road which are mined at Straford by GCL. However the Weismantel and Clareval also run along the western boundary of the syncline and are currently being explored by both GCL and GRL. These seams subcrop up the hills which form the eastern edge of the Gloucester valley and form part of the ground water recharge areas. Open cut mining of these areas will be in full view from Gloucester township and The Bucketts Way". (Authors note)

So the eastern margin of the Permian section of the syncline is controlled largely by meridional reverse faults, many with substantial throws. The south-west has also been controlled by meridional reverse faults and the interior sedimentary infill has been controlled by near vertical north-northwesterly trending sinistral shears (strike slip faults). The extreme northern edge of the syncline is also controlled by sinistral shears, (the best exposed example is on the barrinton road. These were active during the depositional hiatus between the Alum Mountain Volcanics, (the volcanic rocks that form the hills to the east and the Bucketts to the west), and the Dewrang Group. The north western edge and the flexure in the syncline east of Stratford are controlled by north-northeasterly to northeasterly trending shears or normal faults.

Within the remainder of the syncline, sedimentation has been controlled by meridional reverse faults, east-west normal faults, and by northeast striking shears and normal faults.

Ground water within the Stroud-Gloucester Syncline occurs in aquifer systems within either fractured (and including jointed / faulted) rock or unconsolidated sediments.

Fluviatile Environment. (Shallow alluvial aquifer)

There are significant groundwater resources associated with the Gloucester and Avon Rivers. The thickness of these sediments vary and rarely greater than 10 metres.
Groundwater levels in the alluvium are generally shallower than 7 metres and are mostly slightly above or at river bed level. Stream flow is the main source of recharge to the alluvial aquifers. The direction of groundwater flow is dominantly down-valley with a component to or from the stream, depending on relative levels of the stream and groundwater table.
Stream flow and rainfall readily recharge these sediments and the salinity of the groundwater is generally much lower than that occurring in the underlying fractured rock. Deterioration in water quality is often noticeable at times of low stream flows.

Fractured Rock.

1. Shallow weathered bedrock aquifer with associated colluvial deposits.
These rocks have been subjected to considerable folding and faulting. A network of joints joints and fractures enables them to store and transmit water. Groundwater generally enters fractures near the surface in topographically high areas, and drains through the open fractures and joints until it discharges into the surface drainage system.
Standing water levels in boreholes in low lying sites often have water levels only a few metres below ground surface.
2. Permian Coal Measures aquifer of which the coal seams are the prime water bearing strata.

**Extract from 'GLOUCESTER RESOURCES LIMITED - 40 - REVIEW OF ENVIRONMENTAL FACTORS.
R. W. CORKERY & CO. PTY. LIMITED'**
(Referring to a report from - Gloucester Coal Exploration Program Report No. 806/05 – July 2010)

Coal Seam Aquifers

Studies undertaken for the Stratford Coal Mine EIS indicate that the coal seams are the main continuous aquifers in the basin. The Permian strata can therefore be categorised into two hydrogeological units.

1. Hydrogeologically "tight" and hence very low yielding to essentially dry sandstone and lesser siltstone that comprise the majority of the Permian interburden / overburden.

2. Low to moderately permeable coal seams which are the prime water-bearing strata within the Permian sequence.

The coal seams are recharged by direct rainfall in outcrop areas or, as discussed, via leakage from the regolith or overlying colluvial deposits. The pristine water table/piezometric surface is a subdued reflection of the topography and groundwater levels are likely to vary from 15m to 20m below surface in higher elevated areas, to 2m to 6m below the floodplain level.

Groundwater flow is to the west-northwest with potential for discharge to the basal alluvial aquifer along the creek/river system, via fractured overburden.

The coal seams are extensively faulted with the faulting reported to compartmentalize groundwater flow. The hydraulic parameters of the coal seams can vary over a number of orders of magnitude depending on the depth of burial of the seam and degree of jointing and cleat density. Rising and falling head permeability tests indicate that the hydraulic conductivity of the coal seam aquifer ranges between 1.2 x 10-7m/sec to 3.3 x 10-5m/sec.

Groundwater in the coal seams is generally saline, highly mineralized and hard with a slightly alkaline to acidic pH **unsuitable for domestic consumption and in some cases unsuitable for stock / irrigation.** The Electrical Conductivity (EC) of the coal seam groundwater increases with depth, that is as it moves away from the recharge source, with increases from 1395µS/cm at near surface, to 3070µS/cm at 97m. Similarly total hardness increases from 300mg/L to 730mg/L. Groundwater monitoring of bores around the Stratford Coal Mine pits indicates that the groundwater is slightly acidic in the general range pH 6.2 to 7.0 and that the EC is in the general range 2000-9000µS/cm (AEMR 2009).

Inflow to the Stratford Open-cut Mine from the coal seams was estimated at between 25-40L/s in the initial years of development reducing over time to about 4L/s (126ML/year). The Stratford Mine AEMR (2009) reports that for the year 2008 groundwater inflow to the Roseville Extended and West Pits was 142ML and to the Bowens Road North Pit 193ML.

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