Appendix A

Director-General's Requirements

Major Projects Assessment
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Mr Girish Yadwad
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Locked Bag 4
NEW BERRIMA NSW 2577

Our Ref: 10/02259

Dear Mr Yadwad

Berrima Colliery Project (MP 10_0172)
Director-General's Requirements

The Department has received your application for the Berrima Colliery Project.

The Director-General's requirements for the project are attached. These requirements have been prepared in consultation with relevant agencies, based on the information you have provided to date. I have also attached a copy of the agencies' comments for your information.

Please note that the Director-General may alter these requirements at any time.

If your proposal is likely to have a significant impact on matters of National Environmental Significance, it will require an approval under the Commonwealth *Environment Protection Biodiversity Conservation Act 1999* (EPBC Act). This approval is in addition to any approvals required under NSW legislation. It is your responsibility to contact the Department of Environment, Water, Heritage and the Arts in Canberra (6274 1111 or http://www.environment.gov.au) to determine if the proposal requires an approval under the EPBC Act. If it is subsequently determined that an approval is required under the EPBC Act, please contact the Department of Planning immediately as supplementary Director-General's requirements may need to be issued.

I would appreciate it if you would contact the Department at least two weeks before you propose to submit your EA for the project. This will enable the Department to:

- determine the applicable fee (see Division 1A, Part 15 of the *Environmental Planning and Assessment Regulation 2000*); and
- confirm the number of copies (hard-copy and CD-ROM) of the Environmental Assessment (EA) that will be required for exhibition purposes.

Once it receives the EA, the Department will review it in consultation with the relevant agencies to determine if it adequately addresses the Director-General's requirements, and may require you to revise it prior to public exhibition.

The Department is required to make all the relevant information associated with the project publicly available on its website. Consequently, I would appreciate it if you would ensure that all the documents you subsequently submit to the Department are in a suitable format for the web, and arrange for an electronic version of the EA to be hosted on a suitable website.

If you have any enquiries about these requirements, please contact Clay Preshaw on 9228 6305 or Clay.Preshaw@planning.nsw.gov.au.

Yours sincerely

DKitto 8/10/10

David Kitto
Director
Mining and Industry Projects
As delegate for the Director-General

Director-General's Requirements

Section 75F of the *Environmental Planning and Assessment Act 1979*

Application Number	MP 10_0172
Project	The proposed Berrima Colliery Project, which includes: • continuing underground mining operations using the bord and pillar mining method; • extracting up to 460,000 tonnes of coal a year for a period of up to 8 years; • transporting unwashed coal by road to various customers, including Berrima Cement Works, Maldon Cement Works, Waurn Ponds Cement Works, limestone kilns at Marulan and Galong Limestone Mines and Port Kembla Coal Terminal; and • using existing surface infrastructure with the possibility of upgrades in the future.
Location	Berrima Colliery, approximately 7 kilometres north-west of Berrima.
Proponent	Boral Cement Limited
Date of Issue	8 October 2010.
General Requirements	The Environmental Assessment of the project must include: • an executive summary; • a detailed description of the project, including: - need for the project; - alternatives considered, including justification for the proposed mine plan; and - various stages of the project; • a risk assessment of the potential environmental impacts of the project, identifying the key issues for further assessment; • a detailed assessment of the key issues specified below, and any other significant issues identified in the risk assessment (see above), which includes: - a description of the existing environment, using sufficient baseline data; - an assessment of the potential impacts of the project, including any cumulative impacts, taking into consideration any relevant guidelines, policies, plans and statutory provisions (see below); and - a description of the measures that would be implemented to avoid, minimise and if necessary, offset the potential impacts of the project, including detailed contingency plans for managing any significant risks to the environment; • a statement of commitments, outlining all the proposed environmental management and monitoring measures; • a conclusion justifying the project on economic, social and environmental grounds, taking into consideration whether the project is consistent with the objects of the *Environmental Planning & Assessment Act 1979*; and a signed statement from the author of the Environmental Assessment, certifying that the information contained within the document is neither false nor misleading.

Key Issues	• **Subsidence** – including: - accurate predictions of the potential subsidence effects of the proposed mining; and - a detailed assessment of the potential impacts and environmental consequences of these subsidence effects on both the natural and built environment. • **Groundwater and surface water** – including: - an assessment of the potential impacts of the project on the quantity and quality of the surface and groundwater resources in the project area, including an explanation of site water balance and groundwater drawdown; - an assessment of the potential impacts of mine water discharge on the Wingecarribee River and its tributaries, paying particular attention to downstream uses of the water; - a description of measures that would be implemented to prevent adverse impacts on the Wingecarribee River and its tributaries; and - a detailed description of surface water management at the pit-top and Loch Catherine; • **Heritage** – including the potential impacts of the project on Aboriginal and non-Aboriginal heritage, both within the surface infrastructure areas and the proposed mining areas; • **Biodiversity** – including an assessment of the potential impacts of the project on any terrestrial and aquatic threatened species or populations or their habitats, or endangered ecological communities; • **Transport** – including a detailed assessment of the potential impacts of the project on the safety and performance of the road network, specifically along Medway Road and at its intersections with the Hume Highway and Old Hume Highway; • **Noise** – including on-site construction and operational noise and off-site road noise and vibration impacts from the haulage of coal along Medway Road; • **Air Quality** – including a consideration of the impacts that surface infrastructure operations and coal haulage by trucks could have in the local air shed; • **Greenhouse Gas** – including: - a quantitative assessment of the potential scope 1, 2 and 3 greenhouse gas emissions of the project, and qualitative assessment of the potential impacts of these emissions on the environment; and - a detailed description of the measures that would be implemented on site to ensure that the project is energy efficient; • **Waste** – including: - estimates of the quantity and nature of the potential waste streams of the project, including details on any waste water management systems; and - a detailed description of the measures that would be implemented to minimise, reuse, recycle and dispose of any waste produced on site; • **Hazards** – paying particular attention to public safety; • **Rehabilitation** – including a detailed description of the proposed rehabilitation strategy for the mine, taking into consideration any relevant strategic land use planning or resource management plans or policies, including: - identifying post-mining land use options; - clearly defining project rehabilitation objectives; - outlining mine sealing works and general rehabilitation methods and procedures; and - a conceptual final landform design; and • **Social & Economic** – including the costs of rehabilitation, remediation and repair, and socio-economic benefits for the NSW community. • **Hazards** - including bushfires.

References	The environmental assessment of the key issues listed above must take into account relevant guidelines, policies, and plans. While not exhaustive, the following attachment contains a list of some of the guidelines, policies, and plans that may be relevant to the environmental assessment of this project.
Consultation	During the preparation of the Environmental Assessment, you should consult with the relevant local, State or Commonwealth Government authorities, service providers, community groups and affected landowners. In particular you must consult with the: • Department of Environment, Climate Change and Water, including the NSW Office of Water; • Industry and Investment NSW; • Land and Property Management Authority; • Roads and Traffic Authority; • Wingecarribee Shire Council; and • Sydney Catchment Authority. The consultation process and the issues raised must be described in the Environmental Assessment.
Deemed Refusal Period	90 days

Policies, Guidelines & Plans

Risk Assessment	
	AS/NZS 4360:2004 Risk Management (Standards Australia)
	HB 203: 203:2006 Environmental Risk Management – Principles & Process (Standards Australia)
Soil & Water	
Soil	Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites (ANZECC)
	Rural Land Capability Mapping (DLWC)
	Agricultural Land Classification (DPI)
Surface Water	National Water Quality Management Strategy: Australian Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ)
	National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ)
	National Water Quality Management Strategy: Guidelines for Sewerage Systems – Effluent Management (ARMCANZ/ANZECC)
	National Water Quality Management Strategy: Guidelines for Sewerage Systems – Use of Reclaimed Water (ARMCANZ/ANZECC)
	Using the ANZECC Guideline and Water Quality Objectives in NSW (DEC)
	State Water Management Outcomes Plan
	NSW Government Water Quality and River Flow Objectives (DECC)
	Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (DEC)
	Managing Urban Stormwater: Soils & Construction (Landcom)
	Managing Urban Stormwater: Treatment Techniques (DECC)
	Managing Urban Stormwater: Source Control (DECC)
	A Rehabilitation Manual for Australian Streams (LWRRDC and CRCCH)
	Technical Guidelines: Bunding & Spill Management (DECC)
	Environmental Guidelines: Use of Effluent by Irrigation (DECC)
Groundwater	National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC)
	NSW State Groundwater Policy Framework Document (DLWC, 1997)
	NSW State Groundwater Quality Protection Policy (DLWC, 1998)
	NSW State Groundwater Quantity Management Policy (DLWC, 1998)
	Guidelines for the Assessment & Management of Groundwater Contamination (DECC, 2007)
	NSW Inland Groundwater Shortage Zones Order No. 2 (2008)
Noise	
	NSW Industrial Noise Policy (DECC)
	Environmental Criteria for Road Traffic Noise (NSW EPA)
	Interim Construction Noise Guideline (DECC)
Air Quality	
	Protection of the Environment Operations (Clean Air) Regulation 2002
	Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (DEC)
	Approved Methods for the Sampling and Analysis of Air Pollutants in NSW (DEC)
Biodiversity	
	Draft Guidelines for Threatened Species Assessment under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act) (DEC)
	NSW State Groundwater Dependent Ecosystem Policy (DLWC)

	Policy & Guidelines - Aquatic Habitat Management and Fish Conservation (NSW Fisheries)
	Policy & Guidelines - Fish Friendly Waterway Crossings (NSW Fisheries)
	State Environmental Planning Policy No. 44 – Koala Habitat Protection
Rehabilitation	
	Mine Rehabilitation – Leading Practice Sustainable Development Program for the Mining Industry (Commonwealth of Australia)
	Mine Closure and Completion – Leading Practice Sustainable Development Program for the Mining Industry (Commonwealth of Australia)
	Strategic Framework for Mine Closure (ANZMEC-MCA)
Traffic & Transport	
	Guide to Traffic Generating Development (RTA)
Heritage	
Aboriginal	Draft Guidelines for Aboriginal Cultural Heritage Assessment and Community Consultation (DoP and DEC)
	Aboriginal Cultural Heritage Consultation Requirements for Proponents
Non-Aboriginal	NSW Heritage Manual (NSW Heritage Office)
	The Burra Charter (The Australia ICOMOS charter for places of cultural significance)
Greenhouse Gases	
	National Greenhouse Accounts Factors (Australian Department of Climate Change (DCC))
	Guidelines for Energy Savings Action Plans (DEUS)
Hazards	
	State Environmental Planning Policy No. 33 – Hazardous and Offensive Development
	Applying SEPP 33 – Hazardous and Offensive Development Application Guidelines (DUAP)
	Hazardous Industry Planning Advisory Paper No. 6 – Guidelines for Hazard Analysis
Waste	
	Waste Classification Guidelines (DECC)
Social & Economic	
	Draft Economic Evaluation in Environmental Impact Assessment (DoP)
	Techniques for Effective Social Impact Assessment: A Practical Guide (Office of Social Policy, NSW Government Social Policy Directorate)

Appendix B

Berrima Colliery Environmental Management Plan 2010



Berrima Colliery
CCL No. 748

Environmental Management Plan 2010

South West 1 Panel, 406 Panel and 59 Panel

June 2010

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1. Introduction

The Subsidence Management Plan for Berrima Colliery was approved on 2 October 2009. In response to the approval a series of management plans were prepared and lodged in October 2009. Approval was subsequently granted for the subsidence monitoring program however Department of Industry and Investment advised on 4 March 2010 that further information is required for the remaining management plans. This report has been prepared in response to this advice.

Extraction will first commence in South West 1 Panel, then 406 Panel and 59 Panel. Given the flexible nature of mining at Berrima, one or more of these panels may be used for access to further mining areas and so may not be completely extracted. Details of mining progress and the proposed 12 month forward plan will be detailed in the Annual Environmental Management Report.

1.1 Scope

This report provides further details on Condition 13.

Condition 13 - Environmental Management

13 The Leaseholder must submit to the Director Environmental Sustainability for approval an Environmental Management Plan (EMP) for the panels that are the subject of this Approval. This plan must address subsidence impacts on:
(a) surface and groundwater (quality and quantity);
(b) surface cracking and slope stability;

The leaseholder must not operate other than in accordance with an Environmental Management Plan (EMP) approved by the Director Environmental Sustainability. This plan must address subsidence impacts above and must include:

a) a detailed monitoring programme;
b) trigger levels for subsidence impacts that require actions and responses;
c) the procedures that would be followed in the event that the monitoring indicates an exceedance of trigger levels;
d) measures to mitigate, remediate and/or compensate any identified impacts;
e) a protocol for the notification of identified exceedances of the trigger levels; and
f) a contingency plan.

This plan must be prepared in consultation with relevant landholders and government agencies. The Groundwater EMP must be consistent with the Department of Water and Energy's *"Draft Guidelines for Groundwater Monitoring"*.

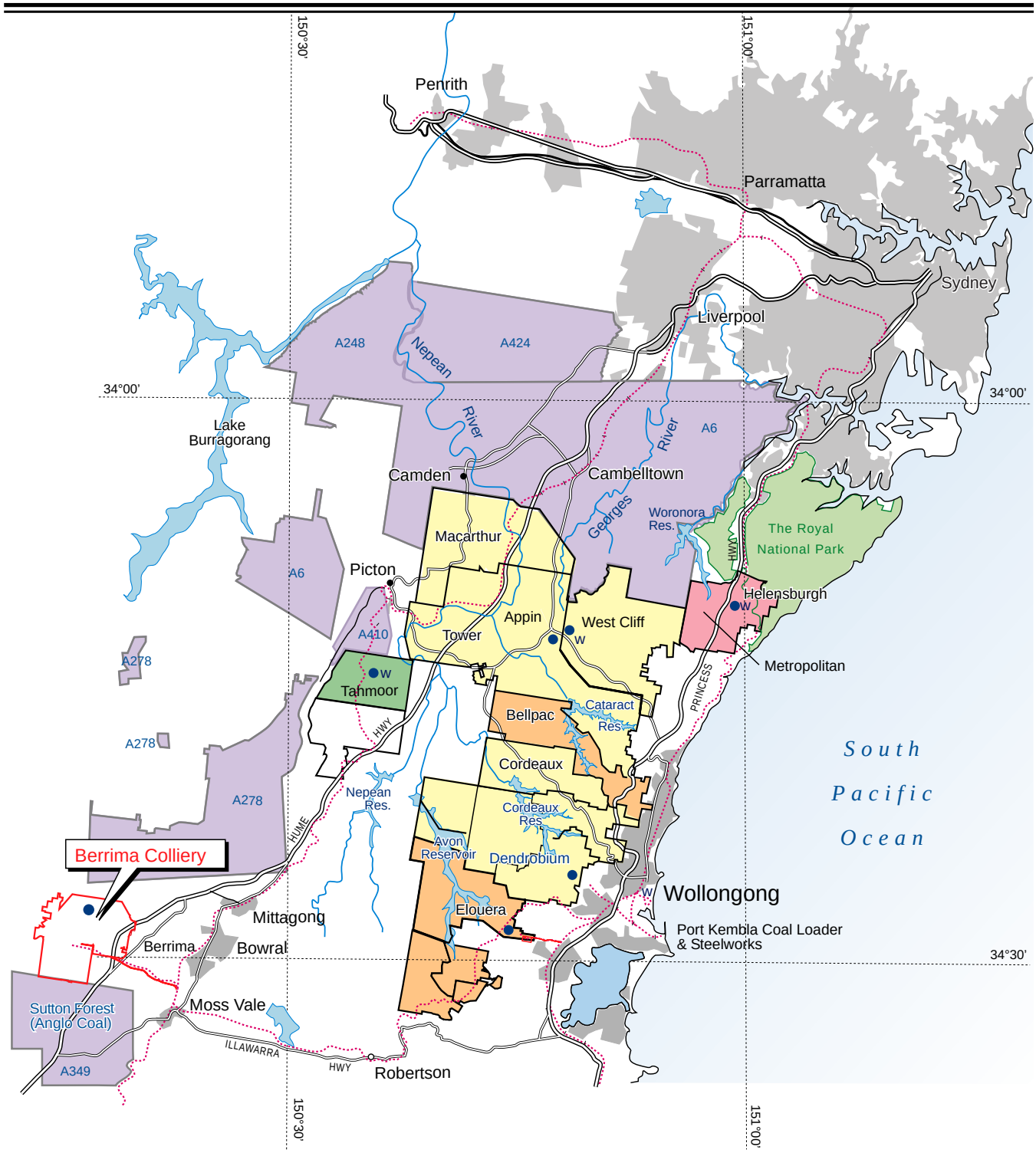


FIGURE 1
Berrima Colliery - Regional Location

Other conditions relating to environmental management provisions have also been updated. These conditions include:

Condition 14 - Infrastructure and Property Management

14 The Leaseholder must develop a management plan to ensure the safety and serviceability of any infrastructure that may be affected by subsidence arising from the extraction of the subject panels. The management plan must be implemented to the satisfaction of the owners/operators of the said infrastructure.

Condition 15 - Public Safety

15 The Leaseholder must prepare and implement a public safety management plan to ensure public safety in any structures, houses and surface areas that may be affected by subsidence, to the satisfaction of the Director, Mine Safety Operations.

The plan must include, but not be limited to:

a) identification of houses which are hazardous or could become hazardous due to subsidence impacts;
b) regular monitoring of areas or infrastructure/structures posing safety risks
c) measures to prevent, mitigate and promptly remediate hazards and safety risks referred to in (a) and (b) above;
d) erection of warning signs;
e) entry restrictions;
f) backfilling of dangerous surface cracks;
g) securing of unstable built structures or rockmass where required and appropriate; and
h) provision of timely notification of mining progress to the community and any other relevant stakeholders where management of public safety is required.

The above plans have been prepared for the entire SMP area. Berrima Colliery has adopted a risk-based approach to subsidence impact management and has incorporated:

- The tolerance of the surface topography and land improvements to withstand predicted subsidence;
- Avoidance of sensitive areas;
- Provision of mitigation strategies and Risk Management Zones;
- Remediation and rehabilitation initiatives coving residual impacts of subsidence should they occur.

The environmental monitoring program developed for Berrima Colliery recognises that further data is required to develop more accurate predictive models for subsidence and groundwater. This will enable a risk-based systems approach to managing future mining at Berrima Colliery. The key features of this approach are:

- To increase the information base used in predicting subsidence related impacts to enable more effective avoidance of unacceptable impacts;
- To better understand the groundwater regime in the mining area in order to reduce the future risk of landowners losing or having reduced supply from existing water bores;
- To maintain current working relationships with landowners within our mining lease area (shown on **Figure 2**);
- To provide improved reporting to government stakeholders as required by the SMP approval.

A key management tool has been the development of a series of Trigger Action Response Plans (TARPs). The TARPs have been developed in consultation with the Department of Industry and Investment but will be reviewed on an annual basis as the monitoring data set increases. As more data is collected, the trigger levels for water quality parameters may be adjusted in consultation with I&I NSW and other relevant agencies. The use of existing water quality guidelines such as the ANZECC Irrigation guideline, may be replaced with a site specific trigger level for each parameter once a sufficient data set is obtained.

1.2 Background to Berrima Colliery

Berrima Colliery is located at Medway in the Southern Highlands of NSW as shown on **Figure 1**. Berrima Colliery is operated under contract with Delta Mining. The lease holder is Boral Limited and the principle supply contract is held with Berrima Cement Works. The Mining Lease area is shown on **Figure 2**.

There has been a continuous (production) history of underground mining activity within the present boundaries of the Berrima Colliery holdings since 1926. Annual production is in the order of 250,000 tpa which is used for Cement manufacture at the local cement works at Berrima as well as opportunity sales to other domestic and export markets.

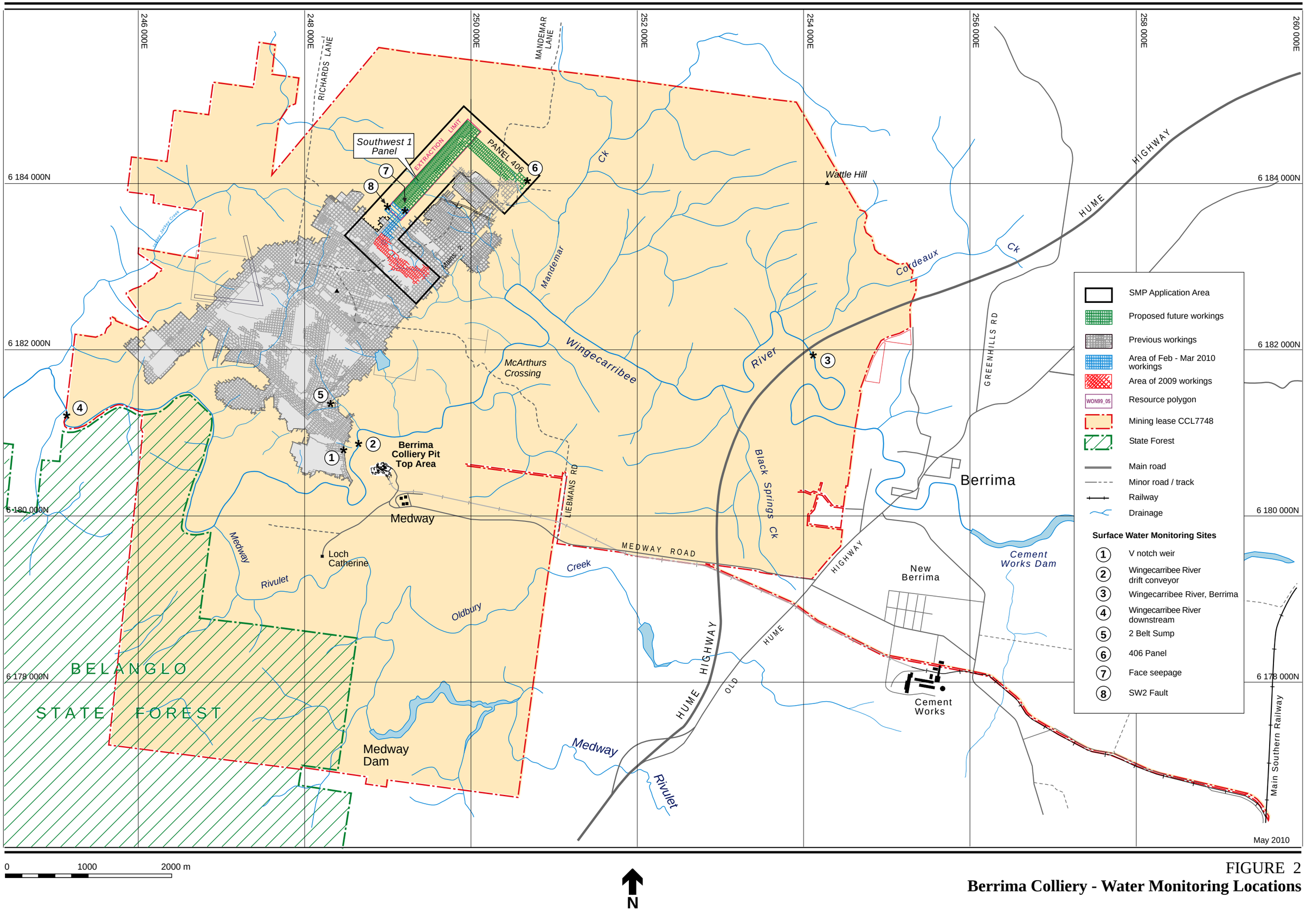


FIGURE 2

Berrima Colliery - Water Monitoring Locations

2. Subsidence Monitoring Program

This section provides details of the methods to be implemented to monitor subsidence movements and effects as a result of coal extraction. The Program also provides a series of management responses required to rectify damage resulting from subsidence impacts.

2.1 General

The SMP has provided for two subsidence protection categories:

- Subsidence Protection Zones (SPZs) which are defined by a 26.5° angle of draw to provide a conservative setback distance from pillar extraction;
- Risk Management Zones (RMZs) which are defined by a 35° distance from the feature. These zones represent areas where more intense monitoring is to occur in order to detect any impacts as mining progresses closer to a SPZ.

2.2 Monitoring and Inspection Regime

In general, subsidence monitoring will be conducted monthly of the panel crosslines and centrelines, Renahan Property structure and large dam stations after mining commences in South West 1 Panel, with fortnightly surveys proposed while second workings encroaches within 35° (125 m) from the features within the RMZ.

Monitoring of the slopes adjacent to the Renahan and Belbin properties will also be undertaken and will occur by default once mining enters the RMZ.

Monitoring of subsidence and the condition of the Belbin and Alcorn properties will continue during extraction of 406 and SW1 Panels as well.

If movements greater than the survey accuracy limits of 5 mm are detected (or the residents advise the MSB) at either of the Alcorn, Belbin or Renahan buildings, then weekly monitoring of these sites will be required and inspection of the houses undertaken by the MSB until the movements cease.

2.3 Layout of Monitoring Points

The proposed new subsidence lines are described below and shown on **Figure 3**:

(i) Extension of 404 Centreline to a distance of 70 m past the extraction limits of 406 panel;

(ii) Extension of 403 and 406 Crosslines to a distance of 85 m past the extraction limits of SW1 panel;

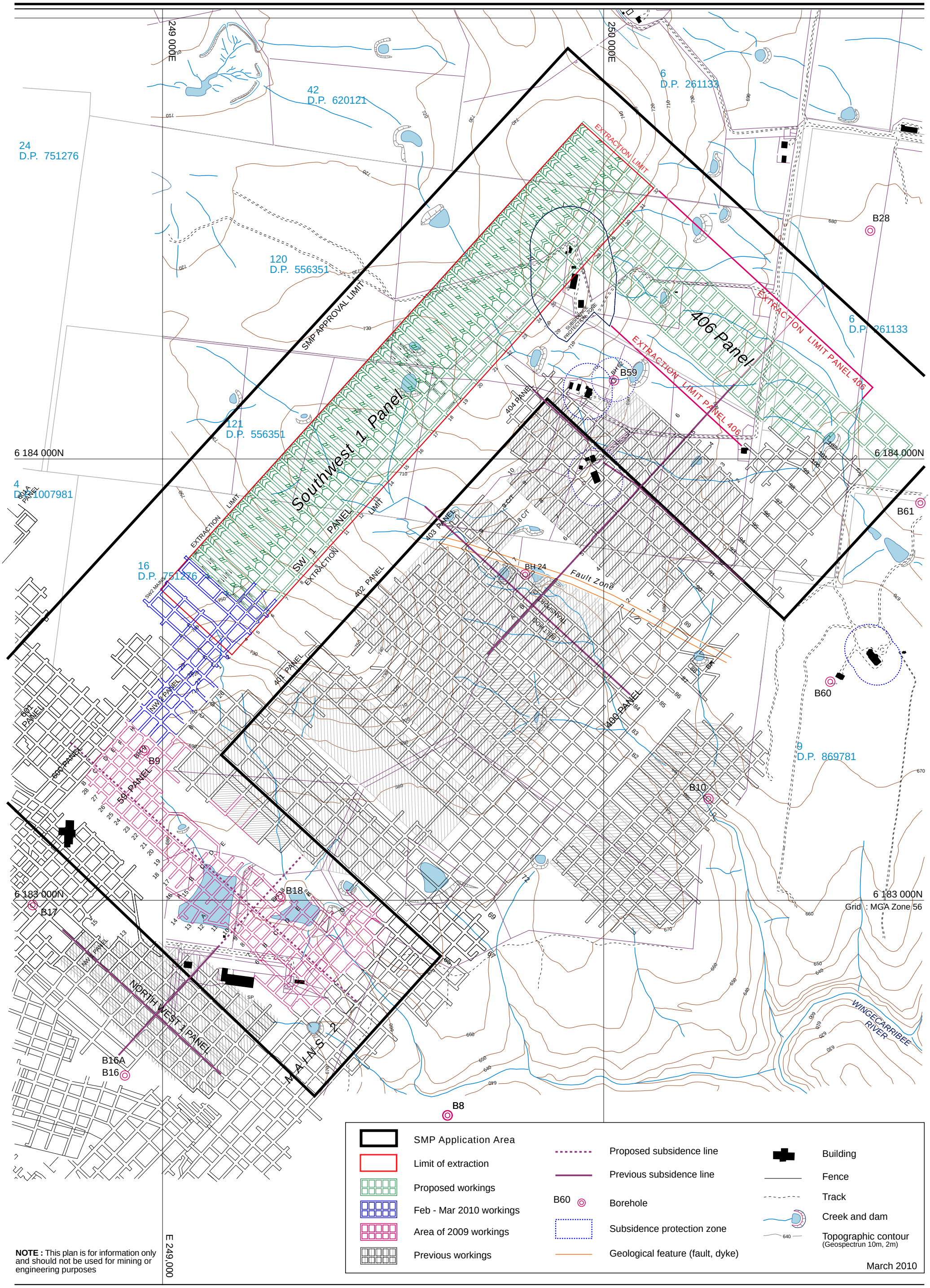


FIGURE 3

Berrima Colliery - Proposed Mining

(iii) Installation of a centreline down the middle of 59, 406 and SW1 Panels for a minimum distance equal to half the cover depth beyond each end of the proposed mining limits;

(iv) Install a minimum of 4 pegs in the ground at the corners of each of the Renahan structures and along the crests of Dams 1 and 2 above 59 Panel; and

(v) Monitoring of utility infrastructure may also be necessary and proposed monitoring of the power poles, conductor clearances and loss of signal/service will be discussed with Integral Energy and Telstra prior to subsiding these features.

The above monitoring layout proposed is intended to allow the comparison between predicted and measured subsidence parameters for the panels and at a sensitive feature.

The survey pegs will be driven to refusal in soil or drilled and installed securely into rock at a spacing of 10 m. At least one baseline survey will be undertaken before mine subsidence effects occur.

Survey lines may be installed in stages provided new pegs are installed and base line surveys completed before the advancing mining 'front' encroaches within a 35^{o} angle of draw from the station. The first subsidence line will cover South West 1 Panel as this will be the first panel to undergo full extraction.

2.4 Parameters to be Measured

Subsidence data will be collected in 3-D coordinates to determine vertical movement, strain and tilt parameters at each peg. The monitoring program will also include visual inspections and mapping of any damage to houses, machinery sheds, dams, fences and access roads before, during, and after mining is complete.

A photographic record will be maintained of the area being mined to determine if any soil erosion or cracking occurs.

2.5 Monitoring Methods and Accuracy

Subsidence and strains will be determined using total station techniques to determine 3-D coordinates, provided that the survey accuracy is suitable. Survey accuracy using EDM and traverse techniques from a terrestrial base line is normally expected to be +/- 2mm for level and +/- 7 mm for horizontal displacement (i.e. a strain measurement accuracy of +/- 0.7 mm/m over a 10 m bay-length).

Strain measurements using the steel tape method generally improve the accuracy to +/- 2mm (or 0.2 mm/m strain over 10 m) and will be the preferred method for measuring strain.

2.6 Timing and Frequency of Surveys and Inspections

The survey lines will be installed at least one month before secondary extraction occurs to allow at least one baseline survey to be completed. Surveys will then be carried out:

- Monthly when extracting outside any RMZ area;
- Fortnightly when extracting within any RMZ area;
- Weekly in the event that measured movement is greater than 5 mm at any residence or structures within a SPZ.

2.7 Recording and Reporting of Monitoring Results

The monitoring program will also include visual inspections and mapping of damage to houses, machinery sheds, dams, fences and access roads. Inspections will be conducted before, during, and after mining is complete.

Results will be reported to the Department of Industry and Investment quarterly. Both hard and soft copies will be provided and will include subsidence measurements in Excel format, details of visual inspections, copies of photographs and a mine plan showing areas extracted during the reporting period.

3. Environmental Management Plan

This section describes the environmental management systems required for the ongoing mining operation within SMP Approved Area. Mitigation measures are also described as well as triggers resulting in additional works. The plans have been updated to include Trigger Action Response Plans.

3.1 Mining Area Features

For the first 60 years of the mine, extraction was limited to the rugged forested terrain to the north of the Wingecarribee River. Neither the river nor any of its associated cliff lines were undermined and there has been no evidence of rock falls or cracking in any of its tributaries or rock outcrops.

Over the past 20 years, the mine has been progressively working in undulating cleared or partially cleared agricultural land. For the past 10 years mining has been almost exclusively within cleared agricultural land. The photo below shows the previous mining area including both the original forested land in the background and the cleared grazing land in the foreground. Berrima Pit Top can be seen in the middle of the photo.

The area to be mined by 59, 406 and South West 1 Panels lies entirely within privately owned and cleared agricultural land. The main roadways lie under flat partly cleared but regrowing pasture while 406 Panel crosses a cleared but relatively steep hill. This hill shows evidence of slumping indicating surface instability as shown in the photo to the right. The instability is a result of previous clearing and grazing practices. The current land owners are aware of the unstable surface and have fenced off sections to allow vegetation to re-establish. This instability is not related to mining but will be the subject of ongoing monitoring to establish if mining induced subsidence has any additional effect on the existing slopes. Subsidence monitoring stations have already been established along the face of this slope.



Properties within the mining area use both surface and groundwater to supply dams and stock watering stations. Depth of cover varies from 125 to190 m across the mining area and water bores tend to access the water from the seam and immediately overlying strata.

There are therefore two principle areas to be addressed with the ongoing mining operation, namely ground stability and water supply. Management responses to each of these issues are discussed below.

3.2 Groundwater Management

3.2.1 Berrima Colliery Pit Top

Groundwater seeps into the underground workings primarily through the coal seam roof. Current groundwater discharge is approximately 3 ML/d, but varies within usually no more than 6 ML/d. Operating experience suggests that the inflow rate is proportional to the area of seam roof exposed, and is relatively constant. The discharge from the mine is naturally occurring groundwater and the colliery does not alter the chemical nature of the water.

Mine water inflows are discharged under EPA License conditions, through old workings and an adit into the Wingecarribee River. Licence conditions require the monitoring of water discharged through the adit (Point 1). The TARPs provided in Appendix A provide details of management initiatives to ensure that the groundwater discharged from the mine meets EPA License conditions.

3.2.2 Monitoring Bores

Hydrogeological investigations to date have incorporated the development of a groundwater monitoring network. The monitoring bores record baseline water levels, enable ongoing water level monitoring and if required can be utilised for aquifer testing (formal pumping tests), hydraulic testing (permeability measurements), monitor production pumping cycles where appropriate and the collection of groundwater samples for a baseline set of geochemical data.

At this stage, monitoring is undertaken in the two registered private property bores (GW101581 and GW106150) and one 'old' coal resource exploration drill hole on private land ('Culpepper').

An attempt was recently made to install a water level data logger in the Renahan production bore but this failed because of insufficient available space in the upper part of the bore. The bore is presently equipped with a pump which is thought to be a venturi type jet pump. Unfortunately, the flanges or pipe connections in the upper part of the bore do not allow access below about 14.0 m. Attempts to measure the water level using a 'slimline' electronic water level dipper also failed at this level. In order to install a water level logger for long-term water level monitoring, the pump and pump line will need to be removed temporarily while the logger is lowered in the bore and positioned at the appropriate level. This would be an opportune time to assess the integrity of the pump for the owner and undertake any maintenance that may be required.

Automated *in situ* 'Level Troll' submersible Pressure and Temperature Data Recorders were installed in the three monitoring bores. These loggers are 'absolute' pressure transducers and were programmed to take measurements of water level and temperature at a sample frequency of four hours. The loggers are currently operational.

In order to compensate for fluctuations in local barometric pressure, a barometric logger is installed at the surface near Registered Bore GW101581 (production bore on the De Rosa property). This background barometric logger is also programmed to take measurements of pressure at a sample frequency of four hours.

3.2.3 Groundwater Monitoring

It is proposed to continue monitoring groundwater using the current network and if possible to expand the network to include the existing bore on the Renahan Property. The data will assist in determining the regional hydraulic gradient, the direction of groundwater flow and hydraulic characteristics of the groundwater regime. The hydraulic gradient is often described as the driving force for groundwater flow. It is essentially the difference in hydraulic head between two points which implies a hydraulic gradient where the gradient is along the direction of the lower head and the gradient direction indicates the potential for groundwater to flow in that direction.

The global gradient and direction of regional groundwater flow is expected to be to the east parallel to the shallow 1.5° dip of the Permian coal measures. Locally, the direction of flow will be influenced by such factors such as steep topography and geological anomalies such as massive volcanic intrusions, sheet-like intrusions and faults that may provide barriers to groundwater flow. The direction on the local scale may in places parallel the local topography.

On the mine scale, the gradients and flow directions will likely vary throughout the mine workings with a steepening of gradient expected in close proximity to some voids and changes near dyke structures.

3.2.4 Ongoing Groundwater Monitoring Program

Although the risk of significant impact on registered water users is considered to be variable and low in most areas, long-term water level monitoring will be required in the area overlying the advancing panel development in order to detect any potential impacts. Locations of monitoring bores are shown on **Figure 4**.

Measurements of water level will be continued in the monitoring network in order to build on the existing baseline database. It is noted that water level monitoring to date has provided a set of important water level data.

An ongoing long-term program of regular water level and water quality monitoring will be carried out. Measurements of water level will be collected using the existing installed automated water level data loggers and recorders in the representative monitoring bores.

The water level data loggers will be programmed to take and record measurements of water level in the representative monitoring bore at a sample frequency of one measurement every 4 hours.

Data download, sampling and testing of groundwater in the representative monitoring bores has been previously carried out on a three monthly basis, however under the advice of the Department of Industry and Investment, the downloading of

data will occur on a monthly basis. In this way, analysis of the results will establish any trends in water quality. Careful analysis and progressive assessment of the results may lead to the reduction of the number of analytes determined and the frequency of sampling. A set of indicator analytes will be developed which will alert the mine Environmental Officer of any significant changes in water quality that may require action.

The proposed monitoring program is summarised in Table 3.1 and the detail described in the following paragraphs.

Table 3.1 – Summary of Water Level and Water Quality Monitoring

Monitoring Type	Activity	Sample Frequency	Comment
Water Level	Automatic water level measurements in *'water level* data logger in monitoring bores	• Initial 4-hourly (1 sample every 4 hours) • Monthly download of data • Assess data after 12 months • Depending on results and trends, decrease frequency to 8-hourly (1 sample every 8 hours) in consultation with DII	This sample frequency is designed to provide adequate, real time good quality water level data, optimise the logger battery life and optimise logger memory.
Water Quality	Groundwater sampling in representative monitoring bores	• Initial 3-monthly (1 sample per bore every 3 months) for 12 months • Assess data after 12 months • Depending on results and trends decrease frequency to 6-monthly (1 sample every 6 months)	This sample frequency is designed to provide adequate water quality data to assess any significant changes in groundwater chemistry that may be due to the ongoing mining operations.
Rainfall	Automatic daily rainfall measurements from BOM station/s	• Daily	This sample frequency is designed to provide adequate, real time good quality rainfall data.

All water level data and groundwater quality monitoring results will be recorded, collated and duly reported in-house on an annual basis and reviewed by a qualified hydrogeologist. The aim is to assess any changes in water levels and identify reasons for the changes if they occur. The monitoring schedule will be reviewed annually and changed if deemed appropriate by the hydrogeologist.

Analysis of the data collected will be undertaken by a qualified hydrogeologist to establish the cause of any adverse trends and assess the degree of any impacts. That

is, any significant decrease in water level may be a consequence of several factors including but not necessarily limited to pumping interference from neighbouring bores, impacts from the advancing coal extraction operations, cumulative interference of mining and third party bore pumping or due partly to long-term environmental effects.

In addition, groundwater inflows into the underground mine will be monitored, with the flow / volume estimated and any change in activity noted by the mine manager.

3.2.5 Reporting

All water level data and any groundwater quality monitoring results will be recorded, collated and duly reported in-house on at least a six-monthly basis for the first 12 months, and on an annual basis thereafter. The data will be reviewed by a consulting hydrogeologist, with the aim of assessing any changes in water levels or groundwater chemistry and identify reasons for the changes if they occur. The monitoring schedule will be reviewed annually and changed if deemed appropriate by the hydrogeologist or by DII.

A complete set of results of the production and monitoring program will be formally reported to the Senior Hydrogeologist NSW Office of Water on an annual basis, if required, and included in the Annual Environmental Management Report (AEMR). This may be a condition of any agreement or plan.

The report will include, but not necessarily be limited to:

- A progressive record of the water level measurements in the monitoring bores;
- A figure showing the locations of the monitoring bore network;
- A set of hydrographs;
- Rainfall data correlations;
- Progressive assessment of any trends in water level fluctuations;
- Analytical results and progressive assessment of any trends in geochemistry; and
- Conclusions and recommendations.

3.2.6 Management Response

Although the risk of significant impact on registered water users is considered to be variable and low in most cases, long-term water level monitoring will be required in the area overlying the advancing panel development in order to detect any potential impacts.

If there is a scientifically demonstrated significant impact on any neighbouring water users in the mining area, for example, a fall in bore water level that can, with the available scientific data, be linked to coal extraction activities, the following options will be pursued subject to any agreement/s between the property owners and Boral Limited:

- Drill a new test bore on the Property for the owner in order to replace or improve the flow rate of the existing affected registered bore. The water quality must be similar to the existing bore water quality (or better), or suitable for the intended purpose;

- Compensate the owner of the Property by supplying groundwater supplies to the property/s with a minimum flow equivalent to the measured and documented losses with water quality commensurate with the present bore supply, or better; and / or

- Provide monetary compensation to the property owner for the measured and documented losses.

Following the experience at the Belbin Bore, redrilling to a greater depth below the Wongawilli Seam appears to have proved successful, however this strategy will need to be assessed in the longterm by continued monitoring and assessment.

3.3 Surface Water Management

3.3.1 Berrima Colliery Surface Water Management

The principle behind the surface water management plan for Berrima Colliery is to keep the clean and dirty water systems separate by interception and diversion of stormwater runoff from operational and non-operational areas. In this way, all dirty runoff is directed to sedimentation dams, of which there are three, two on the pit-top area, and one on the stockpile area (Lock Catherine), where it is retained for re-use on site. Clean runoff is directed to bushland outlets on the borders of the site.

Discharges from the pit top area are rare, and are in compliance with the licence conditions.

3.3.2 Regional Surface Water

While Berrima Colliery operates within a permanent, well managed and established pit top area, discharge of groundwater from the mine into the Wingecarribee River has the potential to impact on the water quality of downstream surface water systems.

Monitoring of surface waters away from the pit top area has included analysis of Wingecarribee River samples both upstream and downstream of the groundwater discharge point. The purpose of this is to monitor the existing background water quality of the system, and how the discharge of the groundwater changes the water quality downstream as it is mixed with the surface waters.

Triggers that may indicate an undesirable impact on receiving surface waters are provided in the TARPs contained in Appendix A, along with the contingency strategies to deal with any negative impacts on water quality.

3.4 Management of Surface Cracking and Slope Stability

To date there has been no evidence of surface cracking in any mining area at Berrima Colliery. There has also been no evidence of increased surface instability or erosion caused by mine subsidence. The predicted tilts for 406 and SW1 panels are expected to change existing slopes by 0.5° to 1° (i.e. 10 and 15 mm/m tilt or 1% to 1.5%). This would indicate that any near surface beds might have their dip increased from about 3° to 5° to a range of 4° to 6° on east facing slopes within the study area. Although this is unlikely to increase erosion risk, to ensure that impacts are not occurring and if identified are managed correctly, the following management and monitoring program will be implemented, and in accordance with the TARPs included in Appendix A.



A photographic record of the condition of the surface above each extraction panel will be made prior to secondary coal extraction occurring. The photographs will be included in the first report to the DII.

A visual inspection will be made at the same time as survey measurements are being made of the subsidence lines. The visual inspection is to include the hillslope section on the Renahan Property and the separate set of subsidence monitoring pegs that run between Renahan and DeRosa properties.

Should these inspections detect additional erosion, slumping or land movement at a time when mine induced subsidence is occurring, the following actions will be taken:

- Determine and record total movement;
- Determine distance from extraction areas;
- Make photographic record of any surface damage;
- Inform the property owners;
- Increase subsidence monitoring and inspections to fortnightly.

A report of the damage is to be prepared which is to include the above information as well as details of rainfall in the preceding week and advice from a geotechnical engineer and landowner. The report will be provided to DII and MSB and will include amelioration measures proposed. These measures may include, but not necessarily limited to the following:

- Land grading and reforming;

- Fencing off to exclude further grazing;
- Filling of any cracks that may occur;
- Implementing additional drainage controls;
- Revegetation works using comparable improved pasture seed as surrounding paddocks with potential to undertake tree planting with the consent of the property owner;
- On-going review and appraisal of any significant changes to surface slopes such as cracking along ridges, increased erosion down slopes, foot slope seepages and drainage path adjustments observed during second workings.

The timing of the works will be undertaken in consultation with DII, the geotechnical engineer and landowner. The work may be delayed or staged depending on future subsidence predictions.

249 000E

250 000E

6 184 000N

6 183 000N

Grid : MGA Zone 56

SMP APPROVAL LIMIT

EXTRACTION LIMIT

EXTRACTION LIMIT PANEL 406

406 Panel

SUBSIDENCE PROTECTION ZONE

B28

BH 62

B59

404 PANEL

Southwest 1 Panel

SW 1 PANEL

SW2 MAINS

SW1 EXTRACTION

LMH

601A PANEL

601 PANEL

NW PANEL

602 PANEL

BH 9

B9

59 PANEL

B17

B18

403 PANEL

402 PANEL

401 PANEL

400 PANEL

BH 24

Fault Zone

TRANSFER

B61

B60

B10

NORTH WEST 1 PANEL

B16A

B16

B8

E 249,000

NOTE : This plan is for information only and should not be used for mining or engineering purposes

Proposed workings

Feb - Mar 2010 workings

Area of 2009 workings

Previous workings

SMP Application Area

Limit of extraction

Proposed subsidence line

Previous subsidence line

B60 Borehole

Subsidence protection zone

Geological feature (fault, dyke)

March 2010

0 100 200 300 400 500m

N

FIGURE 4

Berrima Colliery - Air Photo

4. Infrastructure and Property Management

This section describes the proposed Property Management strategies for future mining area. These are in addition to general property issues covered in other management plans.

4.1 Identification of Surface and Sub-Surface Features

Given the very small production at Berrima Colliery, the mine has been operating in essentially the same area for several years and will only progress at about one panel every two years. The area consists of private agricultural land which is predominantly cleared and used for grazing. Key features of the current and future mining area include:

- A single storey brick house, in-ground water supply tank, machinery shed and weatherboard clad cottage above SW1 Panel;
- Five earth embankment dams for the watering of livestock similar to the one in the photo to the right on the Renehan Property;



- Two larger dams located above 59 Panel, estimated at 5 ML and 15 ML capacity. Each dam has an earthen wall of 5.5 m and 6.1 m high respectively;
- Unsealed gravel access roads and tracks similar to the one shown in the photo to the right which is also located on the Renahan Property;



- Property boundary-line fences;
- Suspended domestic power supply lines (Integral Energy);
- Suspended domestic telecommunications lines (Telstra);
- A full masonry brick structure, in-ground water supply tank, on-site effluent disposal system and two machinery sheds above the NW corner of 404 Panel;
- Two ground water bores to the Wongawilli Seam;





- A weatherboard clad house with sub-surface basement, in-ground water supply tank, on-site effluent disposal system and two machinery sheds above the previously extracted 404 Panel;

- A large full masonry brick house and garage that is approximately 280 m to the north of the NW corner of the proposed 406 Panel.

These features are more fully detailed in the SMP Application and attached plans.

4.2 Characterisation of Surface and Sub-Surface Features

4.2.1 Structural Descriptions

In addition to five earth embankment dams for the watering of livestock, unsealed gravel access roads and tracks, property boundary-line fences, suspended domestic power supply lines (Integral Energy), suspended domestic telecommunications lines (Telstra), there are four residences located either above, or in close proximity to the mining area covered by this SMP. The structures on these properties are described below.

Belbin Residence
The residence is located above the NW corner of 404 Panel and south of South West 1 Panel. Although this residence is not expected to be impacted by any additional mining, it has sustained damage during the mining of 404 Panel and is therefore included in all future monitoring work.

The house is a single storey, full masonry wall structure supported by slab-on-ground footings with thickened edge beams. The house site was cut and benched into the side of the slope with 1.2 m to 1.5 m high mortared stone retaining walls about 10 m from the front of the house and a 0.5 m high wall behind the house. It is suspected that the footings are founded in reactive clay fill or natural clays, which would be thickest beneath the eastern side of the building. A large reinforced water tank exists to the south of the house with metal clad shed upslope of the house.

This property also has a ground water bore to a depth of 130 m (or 10 m above the Wongawilli Seam) located approximately 50 m to the north east of the Belbin Property.

Alcorn Residence
The house is a two storey timber frame/clad structure supported by pier and bearers/joist. The house site is on a relatively flat site with filled 1.2 m high concrete block retaining walls about 10 to 15 m from the house. The house also has a concrete block wall basement/cellar. As with the Belbin Residence, the Alcorn Residence is outside the influence of the current future mining panels however, monitoring and reporting will continue to report on this property in order to verify that no additional impacts occur.

Renahan Residence
This property supports a single storey brick house, in-ground water supply tank, machinery shed and fibro clad cottage above SW1 Panel, with a groundwater bore to a depth of 165 m. This residence falls within the influence of SW1 Panel and 406 Panel and has been given both a SPZ and RMZ.

De Rosa Residence
The De Rosa residence includes a large full masonry brick house and garage that is approximately 280 m to the north of the NW corner of the proposed 406 Panel. It is anticipated that this residence will be unaffected by mining under this current SMP Approval. Monitoring targets have been placed on the structures as well as land slip monitoring.

Eagle Rock Property
This property is an amalgamation of several titles and currently comprises 309.6 ha and has been subject to mining (both pillar development and full extraction) over several years. The property consists of grazing land with shade trees and is held under one ownership but contains several separate buildings, workers cottage and shedding. The property will be affected by 59 Panel and SPZs and RMZs have been incorporated for the main residence and two large dams.

4.2.2 Major Surface Infrastructure

Other than Mandemar Lane and local power and telecommunications, there is no public infrastructure located within the proposed mining area. The remaining infrastructure consists of private dwellings, shedding and land improvements.

4.3 Infrastructure and Property Management Plan

For residences and major dams within the SMP Approved Area, the following management and control initiatives will be implemented:

- Incorporation of a Subsidence Protection Zone (SPZ) defined by a 26.5° angle of draw to provide a conservative setback distance from pillar extraction.
- Incorporation of an additional Risk Management Zone (RMZ) defined by a 35° distance from the feature.

The above features fall under the subsidence monitoring regime consisting of:

- Initial visual inspection and photographic record.

- Monthly surveys of subsidence lines.
- Monthly inspections of targets placed on key structures.
- Monthly visual inspections.
- Fortnightly surveys when mining within a RMZ.
- Weekly surveys if movement greater than 5 mm is found to occur at the targeted structure when extracting with a RMZ.

All identified infrastructure such as fence lines, gates, power poles and access roads have been identified on mining plans and will be monitored and managed in the following manner:

- Liaison with Integral Energy during the course of mining, particularly 406 Panel where an 11 kV transmission line crosses the Renahan Property.
- Prior to extracting coal in 406 Panel, all power poles will be surveyed and conductor clearance confirmed.
- Monthly survey of power poles will be undertaken once extraction approaches the 35º degree angle of draw from these structures.
- Monthly visual inspections of all access tracks and fence lines within the mining area during extraction.

In the event that movement is detected at power line poles, Integral Energy will be contacted and further inspections undertaken in consultation with the Mine Subsidence Board. Berrima Colliery will assist the MSB as required with any remedial work necessary.

As is current practice, Berrima Colliery will continue to liaise with property owners in regard to the condition of existing access tracks. Although no subsidence damage has occurred to tracks and fencing, Berrima has undertaken some remedial and maintenance work as compensation for property access to undertake subsidence monitoring.

5. Public Safety Management Plan

This section describes the measures to be implemented to maintain public safety in the mining area.

5.1 Identification of Public Safety Issues

The main issue regarding public safety is the identification and protection of dwellings. There are other items that have been identified and protected such as large farm dams. The dam structures even without protection zones were considered unlikely to fail and thereby cause a public hazard, but may be weakened or potentially leak. Other items such as sheds again, would be unlikely to fail without subsidence protection but were considered prudent to include in the protection zones afforded to the main residences.

The maximum subsidence predictions for a range of cover depths and proposed pillar geometry are presented in **Table 5.1**.

Table 5.1 - Predicted Maximum Subsidence above Proposed Subsidence Protection Zones

Distance from Goaf Edge (Angle of Draw)	Cover Depth (m)	Pillar Area w x l (h = 2.3 m) (m)	Pre-Mining vertical Stress (MPa)	FTA Stress (MPa)	Service Load Stress (MPa)	Pillar Stress Increase * (MPa)	Predicted Subsidence (m)	
							S_{max} (average)	$2*S_{max}$ (goaf edge)
Alcorn Property SPZ								
0 m (0^o)	137	19.5 x 28	3.43	5.25	9.68	6.26	0.056	0.112
50 m (20^o)	137	19.5 x 28	3.43	5.25	7.46	4.04	0.038	N/A
Belbin Property SPZ								
0 m (0^o)	140	19.5 x 24.6	3.50	4.8	8.15	4.65	0.043	0.087
50 m (20^o)	145	solid	3.50	5.69	6.70	1.01	0.009	N/A
Renahan Property SPZ								
0 m (0^o)	180	19.5 x 32	4.50	6.76	13.69	9.19	0.086	0.172
65 m (20^o)	175	19.5 x 32	4.38	6.57	8.67	4.30	0.040	N/A
90 m (26.5^o)	175	19.5 x 32	4.38	6.57	6.57	2.20	0.021	N/A
125 m (35^o)	175	19.5 x 32	4.38	6.57	6.57	2.20	0.021	N/A
Eagle Rock Dams 1 and 2 SPZ								
0 m (0^o)	130	19.5 x 25	3.12	5.02	9.2	5.95	0.054	0.107
47 m (20^o)	130	19.5 x 25	3.12	5.02	5.12	2.00	0.017	N/A
65 m (26.5^o)	130	19.5 x 25	3.12	5.02	5.02	1.90	0.016	N/A
91 m (35^o)	130	19.5 x 25	3.12	5.02	5.02	1.90	0.016	N/A

Notes:
* - Subsidence based on difference between pillar service stress and pre-mining stress.

The results indicate that for an angle of draw of 26.5°, the vertical stress acting on the pillars are unlikely to exceed FTA (i.e. there will be no abutment loads acting on them). Subsidence over these pillars will be due to stress increases from first workings development only.

It should also be noted that the subsidence at the goaf edge has been determined by multiplying the average stress by 2 to allow for the parabolic stress distribution acting on these pillars.

5.2 Design of Subsidence Protection Zones

The design of reliable Subsidence Protection Zone (SPZ) has taken into account the following key issues:

- The minimum set-back distance from high extraction areas to limit subsidence deformation to below tolerable design limits for the structure and / or steep slope;

- The long-term stability of the pillars in the SPZ under abutment loading conditions from adjacent high extraction areas; and

- Whether the performance of similar SPZs left in previous panels has been adequate.

The design of the previous SPZs was based on consultation with the MSB, Subsidence data for earlier Berrima panels and reference to Shepherd Mining Geomechanics, 2004. The pillars within the SPZ were designed to have a minimum factor of safety of 2.11 under single abutment loading conditions and strain hardening characteristics if overloaded.

The advice given from the MSB was to ensure that any damage to the structures due to mining was “safe, serviceable and repairable” and that the tilt of the structures was not to exceed 5 mm/m (so that the buildings were unlikely to require re-levelling).

A review of the Factor of Safety against pillar crush at the goaf edge of the SPZ was 2.65 and 3.05 under single abutment loading conditions and greater than the minimum design criterion of 2.11.

The current design criteria for the SPZ provides significant confidence that the safety of residents has been satisfactorily resolved and indeed, little if any damage is expected at the residence and associated structures.

5.3 Public Safety Management Provisions

Since public safety issues have been incorporated into the mine design from the outset and therefore it is not considered necessary for any specific additional public safety notices and actions. It is not proposed to erect signage on any public or private property around the mining area. Berrima will however keep the landowners

informed of the progress of mining and give notice prior to access being required for monitoring activities.

It will not necessary to impose any property access restrictions during or after mining. However, in the event that repair work is necessary for private property, the appropriate safety systems covering earthmoving activities will be employed.

Surface cracking is unlikely and is not considered to represent a safety hazard even if it does occur. In the unlikely event that surface cracking is identified, the cracks will be immediately filled and rehabilitated.

Repairs of cracks in access roads may require grading and filling with gravel, but again, are unlikely to be a safety concern.

6. Stakeholder Engagement Plan

Berrima Colliery has been an active member of the local community for over 80 years. The mine is located adjacent to the village of Medway which was originally constructed to house mine workers. The mine still provides raw mine water to the village for non-potable purposes and encourages residents to communicate any issues of concern to mine management. Our good community record is demonstrated by the extremely low level of complaints.

6.1 Objectives

The objectives of stakeholder engagement is to:

- Identify key stakeholders with an interest in the mine and its operation;
- Set a process for engagement with identified stakeholders;
- Communicate effectively with identified stakeholders regarding the mine and its ongoing operation;
- Facilitate informed decision making by providing sufficient information to each stakeholder about the mine and its operation as well as be an active member of the local community.

6.2 Stakeholder Identification

There are three levels of stakeholder relevant to Berrima Colliery:

- Directly impacted residents, these include residents and landowners within our current mining area as well as residents of Medway Village;
- Government agencies involved in the management and regulation of the mine;
- Other community members who have an interest in coal mining activities or the region in general.

6.2.1 Directly Impacted Residents

Berrima Colliery has actively engaged the community who live above our mining area. At any one time, this involves only 2 to 3 landowners, however we also keep surrounding residents informed of our activities.

The protocol for visitation, be it for subsidence monitoring or property inspections, is as follows:

- Contact with each landowner is to be made prior to any property access;
- No access is to be undertaken if requested by landowner;
- Access is to be restricted during wet weather to reduce impacts of vehicles on both existing access roads and paddocks.

Landowners are to be kept informed of our mining progress and are shown on the surface where we are underground. Copies of our existing mine plans and proposed mining areas are provided and explained on a regular basis.

6.3 Government Agencies

Key Government stakeholders include:

- Department of Industry and Investment (Mineral Resources)
- Wingecarribee Shire Council
- Department of Environment, Climate Change and Water
- Sydney Catchment Authority
- Office of Water
- Department of Planning
- Mine Subsidence Board

The above agencies will be kept informed of the project through existing communication and reporting requirements. These include the preparation and distribution of the Annual Environmental Management Report, Annual Agency Inspection, annual reporting under the Environmental Protection Licence and reporting requirements of the SMP Approval.

Appendix A – Trigger Action Response Plan

A.1 Trigger Action Response Plans

Berrima Colliery has developed a series of Trigger Action Response Plans (TARPs) for the goals listed below. These are issues that have been identified through a risk assessment process as having the potential to result in negative impacts, and therefore require proactive management.

Environmental goals to be managed by TARPs:

1. Groundwater discharged from the mine meets EPA Licence conditions (water quality and quantity);
2. Private bores above the mining area are not significantly affected, in terms of water levels within the bore;
3. Groundwater discharged from the mine does not cause adverse impacts on the receiving surface waters (Wingecarribee River); and
4. Land surfaces above the mining area are not made unstable or have increased erosion as a result of subsidence.

The purpose of the Trigger Action Response Plans (TARPs) are to allow early detection of events and actions that may result in material harm to either the environment, the mining operation or people. The level of likely impact that may result from the trigger being activated is assessed as Nil, Low, Moderate or High, which will influence the type of Response Action proposed. The TARPs then go a step further to set out clear guidelines and directions on what actions are to be taken to rectify the situation so that the risk or harm is not allowed to escalate. The key personnel responsible for ensuring that such actions are taken also identified.

Generally three event levels have been assessed. The first event level relates to the normally anticipated or predicted range of impacts which lie within assessment goals or standards. The second event relates to exceedences or measured impacts up to 20% of assessment goals. The third level would be generally regarded as well in excess of the anticipated impacts where environmental damage or harm may reasonably be expected. Proposed monitoring regime is summarised below while the variations or additional investigations are described in Table A1:

- Volume discharge from the V Notch Weir is to be undertaken daily.
- Water quality analysis of the discharge from the V Notch Weir is to be undertaken weekly. Water quality parameters to include pH, conductivity, BOD, Oil and Grease, Iron, Manganese, Zinc and Nickel. Other parameters maybe included from time to time.
- Water quality analysis of the Wingecarribee River to be undertaken monthly.
- Subsidence monitoring to be undertaken monthly outside Subsidence Management Zones and fortnightly within management zones or as triggered by the relevant TARPs.
- Monitoring of water supply bores undertaken monthly.

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter	Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
Groundwater – Aim is to maintain groundwater discharge from the mine within EPA Licence Limits (Goal 1)					
Discharge Volume	Daily monitoring of discharge through the V-notch weir	Daily discharge < 4 ML/day	Nil	**No Action Required** Discharge meets licence conditions and no actions required. Continue daily monitoring of discharge volume.	Undermanager in Charge organises daily recording of discharge volumes.
	Daily monitoring of discharge through the V-notch weir	Daily discharge between 4 ML/day and 6 ML/day	Low	**Action Required** Environmental Officer to determine if increase in water volume is a "once off" event, that is, additional planned dewatering or whether there is a trend of increasing water volume underground. If discharge is planned or expected, no further investigations or actions are required. Mine Manager to investigate sources of water if event is unplanned or unexpected. Environmental Officer to notify DII and EPA of results of investigation.	Environmental Officer to report to DII and EPA results of any investigations.

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter	Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
	Daily monitoring of discharge through the V-notch weir	Daily discharge between 6 ML/day and 10 ML/day	Low	**Action Required** Environmental Officer to determine if increase in water volume is a "once off" event, that is, additional planned dewatering or whether there is a trend of increasing water volume underground. If discharge is planned or expected, no further investigations or actions are required. Mine Manager to investigate sources of water if event is unplanned or unexpected. Environmental Officer to notify DII and EPA of results of investigation. Reporting to DII and EPA should include results of trend analysis, data from underground pumping and additional flow monitoring within the mine in order to identify sources of water. Report to include advice from a Hydrogeologist.	Environmental Officer to report to DII and EPA results of any investigations.

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter	Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
	Daily monitoring of discharge through the V-notch weir	Daily discharge > 10 ML/day but less than 12 ML	Low	**Action Required** Environmental Officer to investigate cause and notify EPA and DII of licence non-compliance. Should discharge be anticipated to exceed 10 ML/day on a regular basis, licence variation to be sought. Undertake actions for previous triggers and report on measures previously incorporated. Environmental Officer to notify DII and EPA of results of investigation. Reporting to DII and EPA should include results of trend analysis, data from underground pumping and additional flow monitoring within the mine in order to identify sources of water. Report to include advice from a Hydrogeologist.	Undermanager in Charge organises daily recording of discharge volumes. Notify Mine Manger and Environmental Officer of Trigger activated.

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter		Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
		Daily monitoring of discharge through the V-notch weir	Daily discharge > 12 ML	Moderate	**Action Required** Environmental Officer to Notify DECCW, Office of Water and DII. Determine source of additional water in the underground workings. Where possible, isolate or redirect water from the main discharge point. Undertake weekly water quality testing of the discharge point and downstream sampling site to determine effects on receiving water quality. Should water quality downstream not meet ANZECC Guidelines for Irrigation (see criteria in metals TARPs), advise downstream water users to cease irrigation activities. Mining within the intersected aquifer or water source to cease until investigations are complete and approval to recommence mining in the affected area obtained by DII.	Environmental Manager to notify DECCW, DII and landowners Mine Manager to determine and implement water redirection within the underground workings and maintain safe working environment.
Discharge Quality	pH	Weekly samples monitored of water flowing through the V-notch weir Weekly samples	6.5 – 8.5	Nil	**No Action Required** Discharge meets licence conditions and no actions required. Continue weekly monitoring of discharge.	Environmental Officer to ensure weekly monitoring carried out.

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter		Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
		monitored of water flowing through the V-notch weir	pH between 5 and 6.5	Moderate	**Action Required** Environmental Officer to report the exceedence of the licence condition to the EPA and DII. Investigate cause of low pH. Continue to undertake weekly water quality testing of the discharge point and downstream sampling site to determine effects on receiving water quality. Should water quality downstream not meet ANZECC Guidelines for Irrigation (see metals TARPs for concentration limits), advise downstream water users to cease irrigation activities. Develop strategy to maintain the pH within acceptable limits. Strategy will include ceasing mining in any identified area which is causing the low pH.	Environmental Officer to ensure weekly monitoring carried out. Mine Manager and Environmental Officer to undertake investigations as required.
		Weekly samples monitored of water flowing through the V-notch weir	pH <5	High	Environmental Officer to report the exceedence of the licence condition to the EPA and DII. Downstream water users to be notified Develop treatment measures to maintain the pH within acceptable limits. Strategy will include ceasing mining in any identified area which is causing the low pH.	Environmental Manager to notify DECCW, DII and landowners Mine Manager to determine and implement water redirection within the underground workings and maintain safe working environment.

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter		Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
		Weekly samples monitored of water flowing through the V-notch weir	pH between 8.5 and 9	Moderate	**Action Required** Environmental Officer to report the exceedence of the licence condition to the EPA and DII. Downstream water users to be notified Develop treatment measures to maintain the pH within acceptable limits. Strategy will include ceasing mining in any identified area which is causing the high pH.	Environmental Officer to ensure weekly monitoring carried out. Mine Manager and Environmental Officer to undertake investigations as required. Maintain close liaison with regulatory authorities.
		Weekly samples monitored of water flowing through the V-notch weir	pH >9		Environmental Officer to report the exceedence of the licence condition to the EPA and DII. Downstream water users to be notified Cease mining until pH control strategies are implemented and approval obtained from DECCW and DII to resume mining	Environmental Officer to ensure weekly monitoring carried out. Mine Manager and Environmental Officer to undertake investigations as required. Maintain close liaison with regulatory authorities.
	TSS	Weekly samples monitored of water flowing through the V-notch weir	<50 mg/L	Nil	**No Action Required** Discharge meets licence conditions and no actions required. Continue weekly monitoring of discharge. Should any trends of increasing solids loading be detected in the discharge water, prepare and implement strategy to increase water storage and retention capacity.	Environmental Officer to ensure weekly monitoring carried out.

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter		Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
		Weekly samples monitored of water flowing through the V-notch weir	Between 50 and 80 mg/L	Low	**Action Required** Environmental Officer to investigate cause and notify EPA and DII of licence non-compliance. Daily inspections of the discharge quality and weekly monitoring to be carried out to determine trends. Monitoring to include downstream sampling site. Develop strategies to enable greater water retention time underground to allow greater settlement of solids before discharge.	Environmental Officer to ensure monitoring and notifications are undertaken carried out. Mine Manager and Environmental Officer to undertake investigations as required.
		Weekly samples monitored of water flowing through the V-notch weir	>80 mg/L	Moderate	Environmental Officer to investigate cause and notify EPA and DII of licence non-compliance. Should additional retention time or operational changes not be successful, the operation should cease until allowed to recommence by DECCW and DII	Environmental Officer to ensure monitoring and notifications are undertaken carried out. Mine Manager and Environmental Officer to undertake investigations as required.
	Oil and Grease	Weekly samples monitored of water flowing through the V-notch weir	<10 mg/L	Nil	**No Action Required** Discharge meets licence conditions and no actions required. Continue weekly monitoring of discharge.	Environmental Officer to ensure weekly monitoring carried out.

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter		Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
		Weekly samples monitored of water flowing through the V-notch weir	Between 10 and 12 mg/L	Moderate	**Action Required** Environmental Officer to investigate cause and notify EPA and DII of licence non-compliance. Determine source of contamination and isolate. Remove source of contamination and remediate Develop strategy to reduce risk of any future oil and grease contamination of the underground water.	Environmental Officer to ensure monitoring and notifications are undertaken carried out. Mine Manager and Environmental Officer to undertake investigations as required.

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter		Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
		Weekly samples monitored of water flowing through the V-notch weir	<12 mg/L	High	Environmental Officer to investigate cause and notify EPA and DII of licence non-compliance. Determine source of contamination and isolate. Remove source of contamination and remediate Develop strategy to reduce risk of any future oil and grease contamination of the underground water. Cease all activities which may have caused or suspected of causing the elevated oil and grease levels. Conduct daily visual inspections and weekly monitoring of discharge point and downstream monitoring points. Advise downstream water users if ANZECC guidelines for irrigation are not met. See metals TARPs for concentration triggers.	Environmental Officer to ensure monitoring and notifications are undertaken carried out. Mine Manager and Environmental Officer to undertake investigations as required.

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter		Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
	Manganese	Weekly Monitoring of V Notch Weir	Equal to or less than historical average (2.5 to 3.5 mg/L)	Low	Monitor manganese concentration at v notch weir and upstream and downstream sites Characterise water quality within the underground workings to determine source of manganese Continue to liaise with water users and government agencies	Environmental Officer to ensure monitoring is undertaken Environmental Officer and Mine Manager to continue to investigate source of manganese within the underground workings
		Weekly Monitoring of V Notch Weir	Trend above historical average where concentration is above 3.5 mg/L for 3 consecutive months or when one sample shows greater than 5 mg/L	Moderate	Environmental Officer to investigate cause and notify EPA and DII. Daily inspections of the discharge quality and weekly monitoring to be carried out to determine trends. Monitoring to include downstream sampling site. Implement strategies to isolate high manganese waters within the underground workings	Environmental Officer to ensure monitoring is undertaken Environmental Officer and Mine Manager to continue to investigate source of manganese within the underground workings and liaison with government agencies

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter		Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
		Weekly Monitoring of V Notch Weir	Concentration is above 5 mg/L for 3 consecutive months or when one sample shows greater than 10 mg/L	Moderate	Cease mine dewatering within areas of high manganese concentration. Environmental Officer to investigate cause and notify EPA and DII. Undertake weekly water quality testing of the discharge point and downstream sampling site to determine effects on receiving water quality. Should water quality downstream not meet ANZECC Guidelines for Irrigation (10 mg/L), advise downstream water users to cease irrigation activities.	Environmental Officer to ensure monitoring is undertaken Environmental Officer and Mine Manager to continue to investigate source of manganese within the underground workings and liaison with government agencies and downstream water users.
	Iron	Monitoring of V Notch Weir	Equal to or less than historical average (0.5 to 1.5 mg/L)	Low	Monitor iron concentration at v notch weir and upstream and downstream sites. Characterise water quality within the underground workings to determine source of iron. Continue to liaise with water users and government agencies	Environmental Officer to ensure monitoring is undertaken Environmental Officer and Mine Manager to continue to investigate source of iron within the underground workings

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter		Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
		Weekly Monitoring of V Notch Weir	Trend above historical average where concentration is above 1.5 mg/L for 3 consecutive months or when one sample shows greater than 5 mg/L	Moderate	Environmental Officer to investigate cause and notify EPA and DII. Daily inspections of the discharge quality and weekly monitoring to be carried out to determine trends. Monitoring to include downstream sampling site. Implement strategies to isolate high iron waters within the underground workings	Environmental Officer to ensure monitoring is undertaken Environmental Officer and Mine Manager to continue to investigate source of iron within the underground workings and liaison with government agencies
		Weekly Monitoring of V Notch Weir	Concentration is above 5 mg/L for 3 consecutive months or when one sample shows greater than 8 mg/L	Moderate	Cease mine dewatering within areas of high iron concentration. Environmental Officer to investigate cause and notify EPA and DII. Undertake weekly water quality testing of the discharge point and downstream sampling site to determine effects on receiving water quality. Should water quality downstream not meet ANZECC Guidelines for Irrigation (10 mg/L), advise downstream water users to cease irrigation activities.	Environmental Officer to ensure monitoring is undertaken Environmental Officer and Mine Manager to continue to investigate source of iron within the underground workings and liaison with government agencies and downstream water users.

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter		Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
	Other metals, including but not limited to Nickel, Aluminium Zinc, Copper	Monitoring of V Notch Weir	Equal to or less than ANZECC Irrigation Long term Trigger Value - Aluminium 5 mg/L - Nickel 0.2 mg/L - Zinc 2 mg/L - Copper 0.2 mg/L	Low	Monitor metals concentration at v notch weir and upstream and downstream sites Characterise water quality within the underground workings to determine source of metals Continue to liaise with water users and government agencies	Environmental Officer to ensure monitoring is undertaken Environmental Officer and Mine Manager to continue to investigate source of metals within the underground workings
		Weekly Monitoring of V Notch Weir	Trend above historical average or where concentration is equal or above ANZECC Livestock Drinking Water trigger - Aluminium 5 mg/L - Nickel 1.0 mg/L - Zinc 20 mg/L - Copper 0.5 mg/L	Moderate	Environmental Officer to investigate cause and notify EPA and DII. Daily inspections of the discharge quality and weekly monitoring to be carried out to determine trends. Monitoring to include downstream sampling site. Implement strategies to isolate elevated metal concentrations within the underground workings Should water quality downstream not meet ANZECC Guidelines for Irrigation, advise downstream water users to cease irrigation activities.	Environmental Officer to ensure monitoring is undertaken Environmental Officer and Mine Manager to continue to investigate source of metals within the underground workings and liaison with government agencies

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter		Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
Groundwater – Aim is to maintain private groundwater bore water levels and quality within natural variability levels (Goal 2)						
Water level		Piezometers monitored every 15 mins, downloaded monthly	No significant change in groundwater level (groundwater level change <2 m) or measured variation is within the normal range and shows normal response to climatic conditions.	Nil	**No Action Required** Continue current monitoring regime and keep landowners informed of the results	Groundwater consultant to advise of changes in standing water levels.
		Piezometers monitored every 15 mins, downloaded monthly	Groundwater level change >2 m over a 6 month period, or is not in line with the normal range or expected response to climatic conditions.	Medium	**Action Required** Discussions with effected landowner. Environmental Officer to investigate cause and notify DII. Monitoring to be increased to fortnightly and investigation of potential interaction between mine extraction and the bore.	Groundwater consultant to inform Mine Manager and Environmental Officer. Environmental Officer to liaise with affected landowner and undertake investigations as required.
		Piezometers monitored every 15 mins, downloaded monthly	Groundwater level change >10 m over a 6 month period, or falls below the depth of the pump, or is not in line with the normal range or expected response to climatic conditions.	High	**Action Required** Discussions with affected landowner. Environmental Officer to investigate cause and notify DII Provisions of alternative water source or drilling of new bore.	Groundwater consultant to inform Mine Manager and Environmental Officer. Environmental Officer to liaise with affected landowner and arrange alternate water sources as required.
Surface Water - Groundwater discharged from the mine does not cause adverse impacts on the receiving surface waters of the Wingecarribee River (Goal 3)						
Discharge Quality	pH	Samples from upstream and downstream of the discharge point on the	6.5 – 8.5	Nil	**No Action Required** Discharge within acceptable limits.	Environmental Officer to ensure water monitoring carried out.

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter		Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
		Wingecarribee River	Downstream pH more than 1 unit above or below the upstream sample	Low	**Action Required** Environmental Officer to confirm mine water discharge meets licence criteria. Investigate the cause of pH variation and determine the influence of the mine discharge on the receiving water.	Environmental officer to ensure monitoring carried out. Seek specialist advice if mine water is considered to be the cause of the pH variation.
	TSS	Samples from upstream and downstream of the discharge point on the Wingecarribee River	<50 mg/L	Nil	**No Action Required** Discharge within acceptable limits.	Environmental Officer to ensure water monitoring carried out.
		Samples from upstream and downstream of the discharge point on the Wingecarribee River	>50 mg/L	Low	**Action Required** Environmental Officer to investigate cause of high solids loading in the Wingecarribee River. If the mine is found to be the cause, the EPA will be notified.	Environmental Officer to ensure water monitoring carried out. Environmental Officer to undertake investigation into the cause.
	Oil and Grease	Samples from upstream and downstream of the discharge point on the Wingecarribee River	<10 mg/L	Nil	**No Action Required** Discharge within acceptable limits.	Environmental Officer to ensure water monitoring carried out.
		Samples from upstream and downstream of the discharge point on the Wingecarribee River	>10 mg/L	Low	**Action Required** Environmental Officer to investigate cause of high oil and grease in the Wingecarribee River. If the mine is found to be the cause, the EPA will be notified.	Environmental Officer to ensure water monitoring carried out. Environmental Officer to undertake investigation into the cause.
Land and Surface Stability – Aim is to prevent land surfaces become unstable, land slides and erosion (Goal 4)						
Slope stability		Monthly subsidence monitoring	Strain and tilt levels within predictions	Low	**No Action** Impact within SMP approval limits, continue monitoring	Mine Manager Environmental Officer

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter	Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
	Monthly subsidence monitoring	Strain and tilt levels more than 10% but less than 20% of predictions	Low	**Action Required** Review subsidence model and determine reasons for greater subsidence movement. Determine whether surface impacts magnified by geological conditions	Mine Manager
	Monthly subsidence monitoring	Strain and tilt levels greater than 20% of predictions	Moderate	Determine level of surface impact including damage to land improvements or cracking of the soil. Advise Mine Subsidence Board and DII. Undertake any land remediation works not covered by MSB responsibilities and in consultation with the landowner	Environmental Officer and Mine Manager
	Monthly subsidence monitoring	Land slip causing soil exposure	Moderate	**Action Required** Determine if impacts mine related and notify DII if impacts are mine related. Develop and implement in consultation with landowners and DII any necessary erosion controls and site rehabilitation to correct cracks or surface expressions. Develop a Property Management Plan in consultation with the landowner to reduce the risk of erosion and slumping to occur.	Mine Manager Environmental Officer

Table A.1 – Berrima Colliery Trigger Action Response Plan

Parameter	Alert System	Trigger	Degree of Impact	Response Action	Responsible Personnel
	Monthly visual Inspections	No change observed	Nil	**No Action Required**	Environmental Officer to carry out inspections.
	Monthly visual Inspections	Cracks or surface expression of subsidence observed	Low - Moderate	**Action Required** Determine if impacts mine related and notify DII if found to be mine related. Develop and implement in consultation with landowners and DII any necessary erosion controls and site rehabilitation to correct cracks or surface expressions. Develop a Property Management Plan in consultation with the landowner to reduce the risk of erosion and slumping to occur.	Environmental Officer to carry out inspections, liaison and implementation of required corrective measures.
	Annual photographic record	No change detected	Nil	**No Action Required** Continue monitoring and inspection program	Environmental Officer to carry out annual monitoring.
	Annual photographic record	Change in vegetation cover and health detected	Low - Moderate	**Action Required** Determine if impacts mine related and notify DII if mine related. Develop and implement in consultation with landowners and DII any necessary site rehabilitation. Develop a Property Management Plan in consultation with the landowner to reduce the risk of further vegetation change.	Environmental Officer to carry out inspections, liaison and implementation of required corrective measures.

Appendix C

Subsidence Impact Assessment

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DgS
Ditton Geotechnical Services

Boral Cement

Berrima Colliery

Subsidence Predictions and General Impact Assessment of the Proposed SW 1, 406 and 59 Pillar Extraction Panels, Berrima Colliery

DGS Report No. BER-003/1

DRAFT#2

Date: 20 September 2010

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Appendix A - Extract from SDPS User Manual

Appendix B - Pillar Stability Analysis Calculations

1.0 Introduction

This report presents mine subsidence predictions and general impact assessment for the proposed SW1, 406 and 59 Pillar Extraction Panels in the Wongawilli Seam at Berrima Colliery, Berrima.

The report has been prepared for inclusion in an Environmental Assessment (EA) for continued operations at Berrima Colliery. This report is consistent with a subsidence assessment report to Industry and Investment NSW in November 2008 (refer to **DgS, 2008a**).

The purpose of this report was to make:

(i) Subsidence impact parameter predictions for the proposed pillar extraction panels (with extraction ratios of ~85%).

(ii) A general impact assessment of natural and man-made surface and sub-surface features within the area of potential subsidence effects.

(iii) Provide Subsidence Protection Zone (SPZ) design advice for the long-term protection of the three structures present on T.J. and D. Renahan's property above 406 and SW1 Panels and two water supply dams located above the proposed 59 Panel.

(iv) Review the performance of previous SPZ's left beneath two residential dwellings above 404 Panel (K. and P. Belbin and R. and D. Alcorn properties), and assess the potential for further impact from the proposed mining layouts.

(v) Provide recommendations for subsidence monitoring plans, including defined Subsidence Risk Management Zones associated with the above properties.

Reference has been made to relevant information provided in subsidence impact reports on previous pillar extraction panels at Berrima Colliery by Ditton Geotechnical Services Pty Ltd (DgS) and the Mine Subsidence Board (MSB - Picton Office).

The recently published report by the NSW Department of Planning (DoP) on the management of subsidence impacts in the Southern Coalfield (refer to **DoP, 2008**) has also been referred to.

This study has been based on mine planning information and subsidence data provided by Berrima Colliery and an influence function-based mine subsidence contour prediction model (refer to **SDPS, 2005**). Reference has also been made to the empirical subsidence models presented in **Holla and Barclay, 2000** for the Southern NSW Coalfield.

2.0 Mining Geometry and Subsidence Protection Zones

Berrima Colliery is proposing to conduct further secondary extraction in SW1 and 406 Panels using pillar-lifting techniques to left and right of regularly spaced 'run-outs'. Panel 59 will be a first workings panel only, and will provide access and ventilation to the newer areas of the mine.

The following mine workings geometry has been assumed in this assessment:

(i) The proposed pillar extraction panels are located at a depth of approximately 130 to 180 m below the surface. The cover depth generally increases from the east to west over the SMP area.

(ii) The panels will have an average face extraction height of 2.6 m in the Wongawilli Seam.

(iii) SW1 Panel will be formed first on a SW / NE orientation, with three central access headings driven at 25 m centres to create 19.35 m wide x 24.5 m long pillars. A 64 m wide barrier will be left between the completed 404 Panel to the southeast.

(iv) For the SW1 panel, 148 m long run outs will be driven to the west at 30 m centres. The run out pillars so-formed will then be lifted to the left and right on retreat back to within 22.5 m distance of the central access headings. The effective panel width after second workings will be 132 m. The run outs will not be lifted within the SPZ beneath the Renahan Property.

(v) Run outs of 93.5 m length will then be formed along the east side of SW 1 Panel at 30 m spacing and also lifted left and right to within 22.5 m of the central headings. The effective panel width after second workings will be 71 m.

(vi) The 406 Panel will be formed on a NW / SE orientation with five access headings driven along the southern side of the panel at 25 m centres to create 19.5 m wide x 24.5 m long pillars. A 70 m wide barrier will be left between the completed 404 Panel to the southwest.

(vii) For the 406 Panel, 72 m long run outs will then be driven to the north at 30 m centres. The run out pillars so-formed will then be lifted to the left and right on retreat back to within 22.5 m distance of the access headings. The effective panel width after second workings will be 49.5 m. The run outs will not be lifted within the SPZ beneath the Renahan Property.

(viii) First workings pillars in each of the production panels will be 19.5 m wide by 24.5 m long (solid) with 5.5 m wide nominal roadway widths.

(ix) The 59 Panel first workings pillars, which have already been formed, will not be extracted. The panel is 150 m to 180 m at a cover depth of 130 m. It has been formed on a NW/SE orientation and between two previous high extraction panels (NW1 and NW2 Panels). A solid barrier width of 40 to 70 m will be left between the panels. It is understood that the previously extracted panels are not flooded.

The panel W/H ratio for the proposed production panels will range from 0.37 to 0.83 for SW1 and from 0.26 to 0.37 for 406 Panel. The above mining geometries indicate sub-critical subsidence behaviour (assumed to occur when W/H < 0.9 at Berrima).

A plan of the previously mined and proposed pillar panels with cover depth contours, surface features and borehole locations are presented in **Figure 1**.

The proposed SPZ below the Renahan's property has been designed based on acceptable damage criterion requested by the MSB and the performance of the previous SPZs below the Alcorn and Belbin residences. Details of the performance of the previous SPZ's are presented in **Section 9.2** and **DgS, 2008a**.

It has also been requested by the MSB that no further damage should occur at the previous two properties above 404 Panel due to the proposed mining layout.

The two dams above 59 Panel are significant water supply dams with 15 ML and 5 ML capacity. The mine requires that these dams are protected from significant impacts such as water storage loss and cracking of the 6.1 m and 5.5 m high earth fill embankments.

Five smaller dams with 0.1 to 0.7 ML storage capacity exist above the proposed 406 and SW1 Panels. It is not proposed to provide SPZs beneath these dams at this stage.

3.0 Method

The work program for the study has included the following activities:

(i) A surface inspection of the proposed mining area to characterise existing surface features and inspect previous mine subsidence affected houses above 404 Panel.

(ii) Development of a geotechnical model for the SMP area.

(iii) A review of maximum subsidence parameters measured above earlier panels and the development of prediction models using local mine subsidence / geological data.

(iv) A review of the Southern Coalfield-based subsidence prediction model presented in **Holla and Barclay, 2000**.

(v) Calibration of an influence function-based subsidence contour prediction model (**SDPS®**) to measured Berrima Colliery's mine subsidence profiles.

(vi) A review of the performance of previous SPZs left beneath residences above 404 Panel and provide appropriate set back distances from existing residences above 406 Panel and the water supply dams above 59 Panel to secondary workings or pillar extraction panel limits.

(vii) A review of the factor of safety of first workings pillars left in earlier SPZ's and proposed SPZ's in 406 Panel.

(viii) Generate subsidence, tilt, curvature and horizontal strain contours for the proposed mining layout, with and without SPZs included in each of the proposed panels.

(ix) Estimate sub-surface fracturing heights above the panels for the assessment of the potential of hydraulic connection occurring to surface creeks / alluvium and sub-surface aquifers.

(x) Assess the impact of the subsidence predictions on the existing or proposed surface features. A discussion of the level of uncertainty in the predictions will also be included to allow effective risk management assessments to be completed.

(xi) Provide recommendations for subsidence management plans to monitor and mitigate against potential mine subsidence impacts.

4.0 Available Information

The following information was provided by Berrima Colliery to prepare this report:

- The previously mined and proposed pillar panel layouts.
- Cover depth contours to the Wongawilli Seam.
- Representative surface to seam borehole logs (BC02, BC03, BC10 and BH24) in the lower eastern area of the lease. There has been no drilling exploration undertaken in the elevated areas to the west of the lease at this stage.
- Geological structure (fault / dyke) locations in the SMP area.
- Surface topographic levels and existing drainage regime locations.

Pre-mining dilapidation and subsidence impact reports on the Alcorn and Belbin Properties by MSB (Picton) were obtained by DgS and have been referred to.

It is unknown whether the embankment dams above the proposed 59 Panel were constructed using engineered fill (i.e. placed in layers and compacted to the requirements of AS3798 - Guidelines on Earthworks for Commercial and Residential Developments). The dams are considered a 'low' to 'moderate' hazard risk to life and property in the event of a breach.

No laboratory testing information on the bore cores is available at this stage, so indicative UCS values have been assumed based on:

- general description of the underground workings conditions by mine site representatives,
- the performance of the subsidence protection zones beneath existing houses to-date, and
- the author's general knowledge of the coal measure rocks in NSW Coalfields.

5.0 Surface Features

The SMP area comprises private land holdings that are Zoned RU2 Rural Landscape by Wingecarribee Shire Council. The land within the SMP area is primarily used for grazing livestock and has been substantially cleared of trees.

The terrain is generally flat in the east with a NE / SW trending, broad crested ridge with moderate to steep slopes along the western side of the SMP area. Several ephemeral creeks and tributaries / gullies drain the site towards the east. Topographic relief ranges from 660 m AHD to 750 m AHD.

There are no near-surface rock exposures present, although the hill slopes are strewn with igneous, cobble-sized rocks (0.1 m to 0.2 m in diameter).

Ground slopes on the ridge in the vicinity of the houses range from 2^o to 5^o along the toe of the ridge and increase to a range of 10^o to 23^o on the mid-slopes and decrease to 4^o on the crest. There are no cliff lines present along the ridges.

Surface levels and ground slopes are presented in **Figure 2**.

Several landslips have occurred on slopes that are above and to the north of the proposed mine workings limits (see **Photos 1** and **2** and **Figure 2**) and are likely to be associated with the Basalt cap and Wianamatta Shale Group rocks (see **Section 6** for geological setting details).

The exposed scarps have exposed orange brown sandy clays / clayey sands and substantial debris flows have developed down slope of the scarps. Some of these areas have been fenced off by the landowners and are considered to be driven by concentrated ground water seepages beneath the relatively impervious basaltic cap and/or weathered shales (which overly the ridge slopes).

Existing developments within the SMP area consist of the following:

- A single storey brick house, in-ground water supply tank, machinery shed and fibro clad cottage above SW1 Panel (T.J. and D. Renahan) - see **Photos 3** to **6**.
- Five small to medium sized earth embankment dams (0.1 to 0.7 ML) above 406 and SW1 Panels for the watering of livestock - see **Photo 7**.
- Two large earth embankment dams (5 and 16 ML) above 59 Panel.
- Unsealed gravel access roads and tracks.
- Property boundary-line fences - see **Photo 8**.
- Suspended domestic power supply lines (Integral Energy) - see **Photo 8.**

- Suspended domestic telecommunications lines (Telstra).

- A full masonry brick structure, in-ground water supply tank, on-site effluent disposal system and two machinery sheds above the NW corner of 404 Panel (K. and P. Belbin) - see **Photo 9**.

- A ground water bore to a depth of 130 m (or 10 m above the Wongawilli Seam) is located approximately 50 m to the north east of the Belbin Property - see **Photo 5**.

  Groundwater makes from the Belbin well ceased after 404 Panel was completed. The base of the well is located 10 m above the mine roof in the Hawkesbury Sandstone and 50 m outside the limits of mining. A second bore has since been established by the mine, and is understood to be making water.

- A groundwater bore to depth of 165 m is located 15 m to the north of the Renahan Property - see **Photo 10** and **Figure 1**. It is understood that the well is still supplying water.

- A weatherboard clad house with sub-surface basement, in-ground water supply tank, on-site effluent disposal system and two machinery sheds above 404 Panel (R. and D. Alcorn) - see **Photo 11**.

- A large full masonry brick house and garage that is approximately 280 m to the north of the NW corner of the proposed 406 Panel (T. De Rosa) - see **Photo 12**.

- One Aboriginal heritage site has been identified within the SMP area and is located above the south eastern corner of 59 Panel. The site is described by OzArk Environmental and Heritage Management Pty Ltd as an open artefact scatter.

The locations of the above features are shown in **Figures 1** and **2**.

6.0 Sub-Surface Conditions

6.1 Geological Setting

Based on reference to the NSW DPI 1:100,000 Geological Sheet for the Southern Coalfield, the proposed SMP area is situated in the Triassic Wianamatta Shale, Hawkesbury Sandstone and Narrabeen Groups and Permian Illawarra Coal Measures. Some near-surface Tertiary Basalt also exists.

Several minor normal faults with throws between 0.1 and 0.2 m strike NW- SE across the previous 404 Panel (see **Figure 1**). The faulted areas intersect the seam beneath the previous SPZs and will probably continue through both of the proposed panels.

6.2 Mine Overburden and Floor Lithology

The overburden above the SMP area typically comprises:

- Tertiary Basalt flows and Wianamatta Group shales and siltstone / sandstone laminites to depths of 20 to 60 m, overlying
- Hawkesbury Sandstone, which consists of thickly bedded sandstone with some minor shale to depths of 120 m and 130 m; overlying
- Narrabeen Group, which consists of 4 to 5 m of medium bedded, sandstone and siltstone; overlying
- Illawarra Coal Measure rocks, which consists of 3.5 to 5.5 m of thinly bedded mudstone, siltstone and coal.

The Wongawilli Seam is 2.3 to 2.6 m thick in the area of the proposed panels.

The floor of the workings will consist of 1.0 to 1.7 m of thinly bedded carbonaceous mudstone and coal above interbedded shale and siltstone.

The coal seam and rock mass in the immediate roof and floor has low to moderate strength (UCS of 10 to 20 MPa) with low moisture sensitivity. The Hawkesbury Sandstone has moderate to high strength (30 to 50 MPa).

Based on the borehole logs, a typical profile of the stratigraphy and inferred UCS range for each of the above units across the SMP area is shown in **Figure 3**.

7.0 Description of Subsidence Development Mechanism

Mining of the proposed panels will commence with first workings or the formation of pillars with a continuous miner and installation of rock bolts into the roof. Very low levels of subsidence (i.e. < 20 mm) usually occur during this stage of panel development.

After the commencement of secondary extraction or lifting of the pillars, the mine roof is initially supported by Mobile Breaker Line Supports (MBLS) and remnant coal pillars (known as 'stooks') during pillar 'lifting'. The mine roof then collapses into the void left behind and as the MBLS units are withdrawn from a mined out area. After several pillars have been taken, the overlying strata or overburden starts to sag down onto the collapsed roof material, resulting in an elongated subsidence 'trough' developing at the surface.

The maximum subsidence occurs in the middle of the extracted panel and is dependant on the mining height, panel width, cover depth, overburden strata strength and stiffness and bulking characteristics of the collapsed strata. For the majority of cases of high pillar extraction ratio mining the Southern Coalfields, the maximum subsidence does not exceed 60% of the mining height. The maximum subsidence is usually lower than this value due to (i) the stiffness of remnant coal pillars or stooks left in the panels and (ii) the spanning or bridging capability of the strata above the collapsed ground (or the goaf).

The combination of the above factors determines whether a pillar panel will be sub-critical, critical or supercritical in terms of maximum subsidence. In the Australian coalfields, sub-critical or (spanning) behaviour generally occurs when the panel width (W) is <0.7 times the cover depth (H). If relatively thick and strong massive strata exist, then sub-critical spanning behaviour can occur for panel W/H ratios of up to 0.9. The maximum subsidence for spanning behaviour is usually significantly < 60% of the extraction height and could range between 10% and 40% of the extraction height.

Beyond the sub-critical range, the overburden is unable to span as a deep arch and starts to 'bend' or sag down onto the collapsed or caved roof strata immediately above the extracted seam (i.e. the panel is critical). Critical panels usually refer to panels with W/H ratios between 0.7 and 1.4, and where the stiffness of the overburden starts to decrease significantly and maximum possible subsidence may start to develop.

Once the span of the panel is too great for critical beam behaviour, the overburden will collapse completely and the subsidence will be limited by the bulked rubble or goaf at seam level. This is referred to as supercritical panel behaviour of the overburden, and usually occurs for panels with W/H > 1.4. In the case of super-critical panels, maximum panel subsidence does not usually continue to increase significantly with increasing panel width.

The surface subsidence 'trough' that forms at the surface will extend outside the limits of extraction for a certain distance (i.e. the angle of draw) and is usually assumed equal to 0.5 or 0.7 times the depth of cover (or an angle of draw to the vertical of 26.5^{o} and 35^{o}) in the Newcastle and Southern NSW Coalfields.

The subsidence prediction models used in this study consider the abovementioned processes and are further described in **Section 8.0**.

Horizontal displacements that are similar in magnitude to the vertical subsidence also occur within the angle of draw and are related to the bending or sagging of the surface. Outside the angle of draw, the horizontal movements are termed 'far-field displacements' which are further discussed in **Section 11.0**.

Undermining steep slopes can also result in tensile and compressive strain concentrations along the slope crests (potentially resulting in surface cracking) and slope bases (resulting in 'shoving') respectively, due to the rotation and down slope movements that can develop.

It is also possible that small uplift movements in creek beds could occur due to stress concentration effects in near surface rocks subject to subsidence deformations. Uplift movements (usually tens of millimetres) can also develop along and just outside the limits of extraction, due to cantilevering overburden above the extracted areas.

A comprehensive summary of the range of mine subsidence effects on the environment and impact management techniques may be found in **DoP, 2008**.

8.0 Subsidence Impact Parameter Predictions

8.1 Review of Subsidence for Previous Panels

The maximum measured subsidence parameters above pillar extraction panel No.s 403 to 405 and 500 have been reviewed and are summarised in **Table 1**.

Table 1 - Summary of Berrima Colliery Subsidence Data

Parameter	Units	Extracted Panels			
		403	**404**	**405**	**500**
Cover Depth (H)	m	135	135 - 145	125	120 - 125
Panel Width (W)	m	150 - 180	210 - 80	200	180
Panel W/H Ratio	m/m	1.1 - 1.3	1.6 - 0.4	1.6	1.5
Maximum Subsidence (S_{max})	m	0.5 - 0.6	0.54 - 0.07	0.71 - 0.74	0.45 - 0.54
Mining Height (T)	m	2.2	2.3	2.2	2.2
Panel Extraction Ratio (e)	%	85	85	85	85
Effective Mining Height (Te)	m	1.87	1.96	1.87	1.87
S_{max}/Te	m/m	0.27 - 0.32	0.28 - 0.04	0.38 - 0.40	0.24 - 0.29
Maximum Tilt, T_{max}	mm/m	3 - 10	3 - 11	9 - 10	9 - 13
Maximum Convex Curvature, C_{max} (radius)	1/km (km)	0.4 (2.5)	0.1 - 0.45 (10 - 2.2)	0.23 - 0.34 (4.3 - 2.9)	0.27 - 0.40 (3.7 - 2.5)
Maximum Concave Curvature, C_{min} (radius)	1/km (km)	0.3 (3.3)	0.1 - 0.39 (10 - 2.6)	0.19 - 0.32 (5.2 - 3.1)	0.50 - 0.58 (2.0 - 1.7)
Maximum Tensile Strain, E_{max}	mm/m	4.1 - 4.7	0.5 - 1.1	2.0 - 2.9	0.5 - 2.9
Maximum Compressive Strain, E_{min}	mm/m	3.0 - 11.0*	0.5 - 2.4	1.6	0.5 - 1.5

* - strain data questionable due to possible peg disturbance.

Based on the proposed sub-critical second workings geometries for SW1 and 406 Panels, it is assessed that the subsidence impact parameters are likely to < the measured values above critical to super-critical panel geometries presented in **Table 1**.

Predictions of best-case and worst-case subsidence above the proposed panels are presented in the following sub-sections.

8.2 Maximum Subsidence

Upper and lower limits of measured subsidence at Berrima for similar mining geometries are presented in **Table 2** and **Figure 4**, the maximum subsidence above the pillar extraction panels after mining is completed, is predicted to range from 0.25 m to 0.59 m for the proposed mining geometries and an assumed mining height of 2.6 m.

The subsidence predictions in **Table 2** are based on local mine site data and are lower than the values observed for high extraction ratio pillar panels in deeper areas of the Southern Coalfield (refer to **Holla and Barclay, 2000**).

Holla and Barclay, 2000 predicts that the maximum panel subsidence will range between 0.47 m and 1.44 m or 18% to 55% of the mining height (see **Figure 4**). It is considered that the key difference between the Berrima Colliery and regional databases is the lower cover depth range at Berrima (125 m to 190 m), compared to a range of 300 m to 500 m for the regional database. The critical span of the Hawkesbury sandstone also appears to be greater at Berrima, due to the cover depth difference as well.

In the case of super-critical panel geometries at Berrima, the overburden probably does not generate as high a load on the collapsed roof material or goaf than at deeper mines in the region (resulting in lower compression of the unconsolidated material).

The thickness and strength of the basalt cap, which could overly much of the elevated areas in the SMP area, is unknown at this stage. Even if the basalt units are unable to 'bridge' or span the proposed mining widths, the subsidence is considered unlikely to exceed the local database model values due to the presence of Hawkesbury Sandstone beneath it.

8.3 Maximum Tilt, Curvature and Horizontal Strain

The differential subsidence parameters of tilt, curvature and horizontal strain (which are the primary causes of impact to surface features) are estimated from the maximum subsidence and the proposed panel geometries. The general location and relative magnitudes of the differential subsidence profiles is shown in **Figure 5a**.

Worst-case tilt, curvature and horizontal strain parameters have been estimated from the predicted worst-case subsidence presented in **Section 8.2** and reference to **Holla and Barclay, 2000**.

The predicted outcomes for the proposed extraction panels are summarised in **Table 2**.

Table 2 - Maximum Subsidence Impact Parameters for 406 and SW1 Panels

Panel #	Cover Depth, H (m)	Panel Width W (m)	Panel W/H	Subsidence	Tilt	Curvature	Strain	
				S_{max} (Berrima Model Limits) (m)	T_{max} tilt (mm/m)	C_{max} sag - hog (km^{-1})	E_{min} compressive (mm/m)	E_{max} tensile (mm/m)
406	135	49.5	0.37	0.12 - 0.24	3 - 4	0.15 - 0.13	1 - 2	1 - 2
	150	49.5	0.33	0.11 - 0.21	2 - 4	0.13 - 0.11	1 - 2	1 - 2
	190	49.5	0.37	0.09 - 0.17	2 - 3	0.12 - 0.10	1 - 2	0.5 - 1
SW1 (LHS)	160	132	0.83	0.20 - 0.54	4 - 10	0.29 - 0.20	2 - 4	1 - 3
	175	132	0.75	0.15 - 0.49	3 - 8	0.24 - 0.19	2 - 3	1 - 2
	190	132	0.69	0.11 - 0.45	2 - 8	0.21 - 0.18	2 - 3	1 - 2
SW1 (RHS)	150	71	0.47	0.16 - 0.31	3 - 6	0.20 - 0.18	1 - 2	1 - 2
	170	71	0.42	0.14 - 0.27	3 - 5	0.18 - 0.16	1 - 2	1 - 2
	190	71	0.37	0.12 - 0.24	2 - 4	0.17 - 0.15	1 - 2	1 - 2

Note:
LHS - Left hand side of panel, looking in-bye; RHS - Right hand side of panel, looking in-bye.
[ ] - Local maximum values. Actual peak curvatures and strains could be 2 x the predicted 'smooth' profile values shown in table due to discontinuous overburden behaviour (i.e. tensile cracking / shear failures of near surface rock).

The measured curvatures and horizontal strains indicate a worst-case value of 13 may be applied to the measured curvatures to estimate the strain (see **Figure 5b**). Local strain concentrations due to cracking or discontinuous overburden behaviour could increase average strains by two times the predicted values.

8.4 Inflexion Points

The measured inflexion points from the solid rib sides has ranged from 66 to 75 m above the previous Berrima panels, giving a d/H range of 0.48 to 0.54 for critical panels. The inflexion point from the SPZ beneath the Alcorn property was 46 m, giving a d/H of 0.34.

Reference to **ACARP, 2003**, where cover depths and strata bridging behaviour are similar to Berrima, indicate the inflexion point values shown in **Table 3**.

Table 3 - Predicted Inflexion Point Distance for Proposed Panels 406 and SW1

Panel No.	W (m)	H (m)	W/H	d/H	d (m)
406	49.5	135 - 190	0.37 - 0.26	0.07 to -0.02	9 to -3
SW1 (LHS)	132	160 - 190	0.83 - 0.69	0.27 to 0.23	42
SW1 (RHS)	71	150 - 190	0.47 - 0.37	0.13 to 0.07	19 to 13

LHS - Left hand side of panel, mining in-bye; RHS - Right hand side of panel, mining out-bye.

Holla and Barclay, 2000 indicates the inflexion point data for deeper areas of the Southern Coalfield with similar W/H ratios to Berrima have a d/H ranging from -0.2 to 0.15. Based on measured values at Berrima, it is assessed that the **ACARP, 2003** model should be used for the inflexion point predictions for the proposed panels.

A summary of the inflexion point data and the above prediction models are presented in **Figure 6**.

8.5 Angle of Draw

The angle of draw (AoD) to 20 mm of subsidence has ranged from 0^o to 22^o degrees to-date at Berrima; see **Figure 7**.

Reference to **Holla and Barclay, 2000** indicates the AoD data for deeper areas of the Southern Coalfield have 70% of the data base values < 35^o and 30% of the database between 35^o and 56^o.

The measured AoD at Berrima appear to be closer to the normal limit applied in the Newcastle Coalfield (where cover depths are similar to Berrima) of 26.5^o, and is normally adopted as an appropriate limit for controlling subsidence impacts to low or negligible levels.

The SDPS model applies the influence angle and inflexion point to define the AoD to <0.6% of the Maximum Panel Subsidence (or 6 mm for 1 m of subsidence). The model therefore

indicates AoD values indirectly when it is calibrated to a measured subsidence profile at a given cover depth. The predicted AoD will then vary with cover depth and the inflexion point distance.

A worst-case AoD of 26.5^{o} has been assumed for design of SCZs in this study.

8.6 Goaf Edge Subsidence

Goaf edge subsidence measurements at Berrima to-date have ranged from 0.03 m to 0.15 m, representing 0.04 to 0.4 times the maximum panel subsidence of 0.45 to 0.74 m.

The goaf edge subsidence above the SPZs beneath the Alcorn properties was 0.106 m, which had goaf on three sides at this location.

Based on the above and the maximum panel subsidence predictions for 406 and SW1 Panels, goaf edge subsidence is estimated to range between 0.02 to 0.15 m for the proposed mining geometries.

8.7 Location of Subsidence Protection Zones

8.7.1 Renahan, Belbin and Alcorn Properties

The predicted maximum values for the SW1 panel in **Table 2** may be used to estimate the impact to the three structures on the Renahan property without a SPZ being left in the proposed workings.

Reference to **AS2870, 1996, Appleyard, 2001** and **Holla and Barclay, 2000,** the 'minor damage' subsidence parameter limits for the house, cottage and machinery shed is estimated in **Table 4**.

Table 4 - Estimated 'Minor' Damage Limits for Structures on the Renahan Property

Structure	Cover Depth, H (m)	Subsidence	Tilt	Curvature		Strain	
		S_{max} (m)	T_{max} tilt (mm/m)	C_{max} hog (km^{-1})	C_{min} sag (km^{-1})	E_{max} tensile (mm/m)	E_{min} compressive (mm/m)
Full Masonry House on Slab	175	<20	<2	<0.1	<0.1	<1	<1
Fibro Cottage on Slab	180	<150	<5	<0.3	<0.3	<2	<2
Metal Clad Machinery Shed	165	<150	<5	<0.2	<0.2	<2	<2

The predicted subsidence impact parameters provided in **Table 2** exceed the 'Minor' damage values presented in **Table 4**, and are likely to result in 'Moderate' damage outcomes for the structures.

It will therefore be necessary to provide Subsidence Protection Zones (SPZs) or first workings only areas beneath these structures with adequate set-back distances provided from high extraction areas. It will also be necessary to limit subsidence development beneath the steep slope directly below the structures. The design of the SPZ is discussed in **Section 9**.

Consideration of the impact of the proposed mining layout on the Belbin residence will also be required, based on concerns raised by the MSB in regard to the potential risk of further significant damage to this structure.

It is considered that the cost of mitigatory works to other surface features (eg small earth embankment dams of < 1 ML capacity, power poles and roads) in the area of influence of the proposed panels do not justify the need for SPZs to be left beneath them. The predicted impacts on these features and proposed management of them during mining are further discussed in **Section 11**.

8.7.2 Large Earth Embankment Dams

The maximum subsidence of < 20 mm for the first workings in 59 Panel will have negligible impact on the two large earth embankment dams without a SPZ being left in the proposed workings.

The stability of the dam walls and stored water areas are susceptible to cracking and internal erosion from mine subsidence induced tilt and strain.

A brief assessment of costs to replace the lost water and repair the dams is likely to be higher than the value of the extracted coal. It is therefore recommended that SPZ's be left below the dam walls (and some of the storage areas) to minimise the risk of cracking should it be decided to extract the pillars in 59 Panel.

Based on the assumption that > 1 mm wide cracks in the embankments due to tensile (and compressive) strains could result in the eventual deterioration and breaching of the dam walls from internal piping erosion, it is recommended that the SPZs beneath dams should limit tensile strains at the embankments to < 0.5 mm/m and storage areas to < 1 mm/m.

9.0 Design of Subsidence Protection Zones

9.1 General

The design of a reliable SPZ will require consideration of the following key issues:

- The minimum set-back distance from high extraction areas to limit subsidence deformation to below tolerable design limits for the structure/dam and/or steep slope.
- The long-term stability of the pillars in the SPZ under abutment loading conditions from adjacent high extraction areas.
- Whether the performance of similar SPZs left in previous panels has been adequate.

9.2 Performance of Previous Subsidence Protection Zones

The design of the previous SPZ's beneath existing houses were specified in **Strata Engineering, 2006** and based on consultation with the MSB, subsidence data for earlier Berrima panels and reference to **Shepherd Mining Geomechanics, 2004**. The pillars within the SPZ were designed to have a minimum factor of safety of 2.11 under single abutment loading conditions and strain hardening characteristics if overloaded.

The advice given from the MSB was to ensure that any damage to the structures due to mining was 'safe, serviceable and reparable' and that the tilt of the structures was not to exceed 5 mm/m (so that the buildings were unlikely to require re-levelling).

The previous two SPZs were also intended to minimise the impact of mining to the houses and control damage to either 'negligible' or 'slight' (i.e. Category 0 to 2 damage), as defined in **AS2870, 1996**. These damage categories are defined as 'minor' and would be considered normal in regards to footing performance over the life of similar types of buildings with moderately reactive clay (Class M) or controlled fill beneath the footings.

As described in **DgS, 2008b**, the houses were impacted by a 'slight' to 'moderate' (Category 2 to 3) damage in accordance with **AS2870, 1996**. The damage and magnitude of movements was assessed to be marginally higher than the predicted amounts due to a combination of mining and non-mining related factors (i.e. inflexible house design detailing, sensitive topography and moisture changes in foundation materials beneath footings).

Another related factor is that the Berrima Colliery lease is not within a proclaimed mine subsidence district, and as a result, the MSB have been unable to impose any development restrictions on the houses built within the lease. As a result, the two houses above 404 Panel were not built with a level of articulation that would be considered appropriate for a limited amount of mine subsidence movement similar to that for a Class M reactive clay site.

*Note: A Class M site is defined by **AS2870, 1996** as having 20 to 40 mm of vertical surface movement due to natural soil moisture content changes over seasonal cycles of wet and dry conditions.*

The subsidence above the pillars in the SPZ beneath the Alcorn residence has been estimated based on the SDPS model calibrated to the 404 Panel XL data (see **Section 11**). The model indicated subsidence at the goaf edge was 0.112 m and 0.035 m at the house with differential subsidence and horizontal displacement each estimated to be about 10 mm along the length of the structure. Tilts and curvatures were assessed as being < 0.5 mm/m and 0.05 km^{-1} respectively. Tensile strains were estimated to have ranged between 0.5 mm/m and 1 mm/m.

The Belbin residence was assessed to have been effected by Category 3 damage as defined in **AS2870, 1996** with hogging and sagging curvature radii of <10 km and associated tensile and compressive strains of 2 to 3 mm/m. Subsidence surveys along the panel cross line (70 m to the south of the house site) indicate similar curvature magnitudes at the base of the ridge slopes but lower tensile and compressive strains of 0.5 and 1.5 mm/m. The maximum subsidence of the house was assessed to be < 20 mm.

A review of the Factor of Safety against pillar crush at the goaf edge of the SPZ was 2.65 and 3.05 under single abutment loading conditions and greater than the minimum design criterion of 2.11. The under-prediction of subsidence movement at the house sites are therefore probably not attributable to the overloading of the SPZ pillars, however, the assumed Young's Modulus values used for the subsidence predictions appear to be lower than was previously assessed (see **Section 10.4**).

A 20^o angle of draw set back distance of 50 m was also provided from the ground water bore adjacent to the Belbin property. However, the draw-down of the groundwater water level after 404 Panel development (i.e. first workings) was completed, resulted in a loss of supply to the well.

The above issues have been considered to assess the level of uncertainty in the predictions to provide an outcome likely to be consistent with expected performance of the SPZ stated previously.

9.3 Minimum Design Set-Back Distances for SPZs

Minimum set back distances required for SPZs will depend upon the type of structure or feature and the consequences of excessive damage if it occurs. The 20^o AoD zone beneath the Belbin and Alcorn properties resulted in higher than expected levels of damage due to mining and non-mining related affects (refer also to **DgS, 2008b**).

Based on the above, and for the purpose of defining appropriate set-back distances from the houses and large dams within the secondary extraction limits of Berrima Colliery, it is considered appropriate that an angle of draw of 26.5^o should be used instead of 20^o to define a conservative setback distance, pending confirmation from early-warning monitoring data (see **Section 13**).

9.4 Pillar Stability

The long-term stability and serviceability requirements of the pillars within the SPZs beneath houses will require the strength of the pillars to be at least 1.63 to 2.11 times the service load acting upon them after mining is completed.

The total worst-case stress acting on the first and subsequent row of pillars in the SPZ beneath the Renahan property has been estimated using the full tributary area (FTA) and abutment load concepts defined in **ACARP, 1998a**. The concept assumes that for standing pillars that have goaf adjacent to them in the workings, the pillars will be acted upon by the column of rock immediately above each pillar (i.e. the FTA load) and a proportion of an abutment load caused by the partial removal of support to the mined out area adjacent to the pillars (i.e. the goaf). The above loading concepts are presented in **Figures 8a** and **8b**.

The total stress acting on the pillars directly below the Renahan residence after mining was estimated as follows:

σ_{pillar} = pillar load/area = (T+RA)/wl = (6.75+0.76(8.89))/(19.5(32)) = 13.43 MPa

where:

T/wl = Full tributary area load of column of rock above each pillar (see **Figure 8a**);

= (w+ r)(l+r).ρ.g.H;

= (19.5+5.5)(32+5.5)0.025(180)/((19.5)(32))

= 6.75 MPa

RA/wl = Single abutment load due to cantilever action of overburden over goaf (see **Figure 8b**);

= 0.5 u H^2 tan(θ)(l+r)/(wl) (where u = unit weight of overburden 0.025 MPa/m
θ = abutment angle (normally taken as 21^o))

= 0.5 (0.025) 180^2 tan (21^o) 37.5/(32(19.5))

= 6.69 MPa

R = Proportion of abutment load acting on first row of SPZ pillars;

= 1- $[(D-w-r)/D]^3$ (where D = distance that load distribution will extend from goaf edge according to **Peng & Chiang, 1986**: D = 5.13√H = 69 m)

= 0.76

w = pillar width (solid) = 19.5m;

l = pillar length (solid) = 32.0 m;

r = roadway width = 5.5 m;

H = depth of cover = 180 m;

The FoS of the SPZ pillars were based on the strength formula presented in **ACARP, 1998b** (i.e. UNSW Power Rule) for 'squat' pillars with width/height (w/h) ratios > 5 as follows:

$S = 27.63\Theta^{0.51}(0.29((w/5h)^{2.5} - 1) + 1)/(w^{0.22}h^{0.11})$

$= 22.9$ MPa

where:

h = pillar height = 2.6 m;

Θ = a dimensionless 'aspect ratio' factor or w/h ratio in this case = 7.5.

The FoS was calculated by dividing the pillar strength, S, with the pillar stress, σ_{pillar}:

FoS = 22.9/13.4 = 1.70.

The next row of pillars inside the SPZ will be subject to significantly lower stress, with an R = 0.24, to give a σ_{pillar} = (6.76+0.24(8.89)) = 8.90 MPa and FoS = 2.57.

The mean FoS for the first two pillar rows will therefore be 2.13, and is considered adequate for the proposed SPZ with a probability of failure of 1 in 1 million (refer to **ACARP, 1998b**).

For completeness, further internal pillar rows will be subject to FTA loads only, to give an FoS = 26.3/6.76 = 3.89.

Similar calculations for the proposed SPZs below the 59 Panel Dams indicate pillar FoS under single abutment loading conditions ranging from 2.74 to 3.02.

Details of the pillar calculations are provided in **Appendix B**.

The pillar w/h ratio is also a very important factor that indicates the post-yield behaviour of the pillars when they are overloaded. Pillars with w/h ratios < 3 are considered most likely to 'strain-soften' if overloaded and result in rapid failure and pillar runs, whereas w/h ratios > 5 are more likely to 'strain-harden' and yield slowly or 'squeeze'.

These types of post-yield behaviour have been discussed in **ACARP, 2005** and demonstrated in **Figure 8c** for various in-situ observations and laboratory experiments. The proposed pillars in the SPZs will have w/h ratios of 7.5 for the nominal mining height range of 2.6 m. The pillars are therefore likely to remain stable as a group and strain harden if local overloading occurs.

9.5 Roof and Floor Bearing Capacity

Reference to **Pells *et al* , 1998** indicates that the bearing capacity of sedimentary rock under shallow footing type loading conditions is 3 to 5 times its UCS strength. Based on the estimated mean UCS of 15 MPa in the immediate floor and roof strata, the general bearing capacity of the floor strata is estimated to range between 45 and 75 MPa.

A similar outcome was assessed by applying 2-layered bearing capacity theory presented in **Merifield, 1999**. The theory indicates that the overall bearing capacity of a weaker layer over a stronger one will be increased if the stronger unit is within 0.5 times the width of the pillar as follows:

$$q_{ult} = 0.5UCS_1(5.14 + c_a w/2t)$$

where

UCS_1 = strength of weaker layer
w = pillar width
t = thickness of weaker layer
c_a = unit adhesion between layers and assessed by laboratory testing to have a lower bound of 0.7 MPa/m

For pillars with widths of 19.5 m and a 4.5 m and 2 m thick low-strength layer above and below the pillars, a bearing capacity of 31.5 MPa and 42.8 MPa is estimated for an average low strength layer with a UCS of 10 MPa.

Considering the average pillar stress range of 6.7 to 13.7 MPa assessed for the SPZ, an overall average FoS against roof and floor bearing failure ranges between 4.7 and 2.3, which is probably within the elastic behaviour range for these materials. Details of the bearing capacity analysis are provided in **Attachment B**.

As the average moisture sensitivity of the floor materials was indicated by the mine to be relatively low by experience, it is also considered unlikely that long-term degradation or weakening of the floor materials will result in significant subsidence.

10.0 Worst-Case Subsidence Contours

10.1 Method

An empirically based prediction model (**SDPS®**) has been used to generate worst-case subsidence contours above the proposed total extraction panels after mining is complete. **Surfer 8®** software been used to generate tilt, curvature, horizontal strain and displacement contours above the panels.

Reference has also been made to **Holla and Barclay, 2000**, which provided general information of mine subsidence development and regional empirical model subsidence predictions for the Southern Coalfield.

SDPS® is a US developed (Virginia Polytechnical Institute) influence function model for making subsidence predictions above longwalls or pillar extraction panels. The model requires calibration to measured subsidence profiles to reliably predict the subsidence and differential subsidence profiles to assess likely impacts on surface features.

The program was selected for this study because of its ability to include the effects of (i) surface topography or cover depth variation, (ii) irregular mining geometry (iii) measured subsidence data and (iv) overburden geology.

An extract from the **SDPS®** user manual defining the parameters and terms used is presented in **Appendix A**.

The model requires calibration to the following key subsidence prediction parameters, which were derived from local mine site data:

- Maximum panel subsidence/extraction height (S_m/T) v. Panel Width the Extraction Ratio.
- Distance of the inflexion point from rib sides and inter-panel pillars relative to cover depth and panel width (i.e. d/H v. W/H).
- Angle of Influence, which is the angle subtended to the horizontal from seam level beneath the surface inflexion point and out to the angle of draw.
- Angle of Draw, which is the angle subtended to the vertical from seam level at the extraction limits and out to the 20 mm surface subsidence point.

Tilts and curvatures have been assessed from the first and second derivatives of the predicted subsidence contours that were generated from SDPS output files and the empirical models provided in **Holla and Barclay, 2000**.

Predictions of horizontal strain were made based on the horizontal strain coefficient, which is the linear constant used to estimate bending strain from predicted curvature. It is equivalent to the reciprocal of the neutral axis of bending (d_n) discussed in **Holla and Barclay, 2000**.

A value of d_n = 5 to 30 m has been derived for the Southern NSW coalfield data in the above reference and demonstrates the wide range of conditions present. Local mine site data has subsequently been used to predict 'smooth' profile strains from the **SDPS®** model curvatures and is further discussed in **Section 11**.

10.2 Calibration of SDPS Model

The SDPS® model was calibrated to the measured subsidence profile along 404 Panel Crossline, see **Figures 9a** to **9d**. The calibration exercise focussed on matching the measured subsidence over (i) the SPZ zone left beneath the Alcorn's Residence and (ii) the measured angles of draw around the panel extraction limits.

The results of the calibration exercise are summarised in **Table 5**.

Table 5 - SDPS Calibration Results Summary

Panel	W (m)	H (m)	Mining Height (m)	Effective Mining Height (m)	Maximum Subsidence S_{max} (m)	Inflexion Point d (m)	Tangent of Influence Angle tanB	Influence Angle B (degrees)
Measured Panels								
NW1	150	125	2.2	1.87	0.65	44	1.7	60
NW2	223	130	2.2	1.87	0.63	51	1.7	60
401	151	135	2.2	1.87	0.57	46	1.7	60
402	250	140	2.2	1.87	0.68	55	1.7	60
403	190	130	2.2	1.87	0.60	51	1.7	60
405	202	135	2.2	1.87	0.74	53	1.7	60
500	180	130	2.2	1.87	0.54	51	1.7	60
404	207	120	2.3	1.96	0.55	46	1.7	60
Panel Predictions								
SW1 (RHS)	132	160-190	2.6	2.6	0.45 - 0.54	42	1.7	60
SW1 (LHS)	71	150-190	2.6	2.6	0.24 - 0.31	16	1.7	60
406	49.5	135 - 190	2.6	2.6	0.17-0.24	3	1.7	60

LHS - Left hand side of panel, mining in-bye; RHS - Right hand side of panel, mining in-bye.

The influence angle has ranged from 30° to 53° degrees from the panel sides to-date at Berrima. An influence angle of 60° was found to give the best fit to the measured subsidence profile above the SPZ beneath the Alcorn residence.

Based on the above data, a design influence angle of 60° was conservatively adopted for the proposed SW1 and 406 panels.

10.3 Worst-Case Subsidence Impact Parameter Contours

Worst-case subsidence, tilt, curvature, horizontal strain and displacement contours have been estimated for the proposed total extraction panels based on local Berrima data. The contours for previously extracted panels and the proposed SW1 and 406 Panels are presented in **Figures 10** to **14**.

10.4 Subsidence Above the Proposed Subsidence Protection Zones

For the purposes of sensitivity studies, an analytical model was applied to estimate subsidence above the proposed SPZ's due to elastic pillar, roof and floor strata compression derived from elastic solid mechanics theories presented in **Das, 1998**:

$s_{max} = s_{pillar} + s_{roof} + s_{floor}$

where

s_{pillar} = σ_{net} h/E_{coal} = compression of pillar

s_{roof} = σ_{net} w I(1-v^2)/E_{roof} = compression roof strata

s_{floor} = σ_{net} w I(1-v^2)/E_{floor} = compression of floor strata

σ_{net} = net pillar stress (FTA stress - virgin stress)

E_{coal} = Young's Modulus for coal = 2 GPa (rock mass equivalent value)

E_{roof} = Average Young's Modulus for the roof strata within one pillar width of the roof = 300 UCS = 15 GPa (laboratory equivalent value); $E_{roof(rockmass)}$ = 6 GPa.

E_{floor} = Average Young's Modulus for the floor strata with one pillar width of the floor = 300 UCS = 9 GPa (laboratory equivalent value); $E_{floor(rockmass)}$ = 4.5 GPa.

The above laboratory equivalent values for Youngs Modulus and adjusted to rock mass values through back analysis of measured subsidence above the SPZs beneath 404 Panel to give a modulus reduction factor of 0.4. The factor is defined in **Hoek and Deidrichs, 2006** and a value of 0.4 is equivalent to a Geotechnical Strength Index (GSI) of 55%, which is considered reasonable for layered coal measure strata.

v = Poisson's Ratio = 0.25 for roof and floor strata;

I = shape factor for square footing = ~ 1 (for a semi-rigid footing)

w = pillar width.

h = pillar height.

The maximum subsidence predictions for a range of cover depths and proposed pillar geometry are presented in **Table 6**.

Table 6 - Predicted Maximum Subsidence above Proposed Subsidence Protection Zones

Distance from Goaf Edge (Angle of Draw)	Cover Depth (m)	Pillar Area w x l (h = 2.3 m) (m)	Pre-Mining vertical Stress (MPa)	FTA Stress (MPa)	Service Load Stress (MPa)	Pillar Stress Increase* (MPa)	Predicted Subsidence (m)	
							S_{max} (average)	$2*S_{max}$ (goaf edge)
Alcorn Property SPZ Above Panel 404								
0 m (0^o)	137	19.5 x 28	3.43	5.25	9.68	6.26	0.056	0.112
50 m (20^o)	137	19.5 x 28	3.43	5.25	7.46	4.04	0.038	N/A
Belbin Property SPZ Above Panel 404								
0 m (0^o)	140	19.5 x 24.6	3.50	4.8	8.15	4.65	0.043	0.087
50 m (20^o)	145	solid	3.50	5.69	6.70	1.01	0.009	N/A
Renahan Property SPZ Above Panels SW1 and 406								
0 m (0^o)	180	19.5 x 32	4.50	6.76	13.69	9.19	0.086	0.172
65 m (20^o)	175	19.5 x 32	4.38	6.57	8.67	4.30	0.040	N/A
90 m (26.5^o)	**175**	**19.5 x 32**	**4.38**	**6.57**	**6.57**	**2.20**	**0.021**	**N/A**
125 m (35^o)	175	19.5 x 32	4.38	6.57	6.57	2.20	0.021	N/A
Dams 1 and 2 SPZ Above Panel 59								
0 m (0^o)	130	19.5 x 25	3.12	5.02	9.2	5.95	0.054	0.107
47 m (20^o)	130	19.5 x 25	3.12	5.02	5.12	2.00	0.017	N/A
65 m (26.5^o)	**130**	**19.5 x 25**	**3.12**	**5.02**	**5.02**	**1.90**	**0.016**	**N/A**
91 m (35^o)	130	19.5 x 25	3.12	5.02	5.02	1.90	0.016	N/A

Notes:
* - Subsidence based on difference between pillar service stress and pre-mining stress.
Bold - SPZ adopted in this study.

Calculation details and charts of subsidence results presented in **Table 6** are given in **Attachment B**.

The results indicate that for an angle of draw of 26.5^o, the vertical stress acting on the pillars are unlikely to exceed FTA (i.e. there will be no abutment loads acting on them). Subsidence over these pillars will be due to stress increases from first workings development only.

It should also be noted that the subsidence at the goaf edge has been determined by multiplying the average stress by 2 to allow for the parabolic stress distribution acting on these pillars (see **Figure 8b**).

11.0 Far-field Displacements and Strains

The term far-field displacements (FFD) generally refer to the horizontal surface movements that occur outside the vertical subsidence limit or angle of draw to an extracted pillar panel or longwall block. It is currently understood that FFDs are a phenomenon caused by the reduction of horizontal stress when collapse of overburden rock (i.e. goafing) occurs above an extracted area.

The magnitude and direction of far-field displacements around a high extraction ratio pillar or longwall panel is considered to be dependent on:

- the cover depth,
- the magnitude of the 'locked' in horizontal stress in the overburden,
- the distance from the extracted area,
- the stiffness of the rock mass,
- geological structure and
- topography.

Predicting FFDs and horizontal strains is therefore difficult and generally requires local data to develop a simple (but usually effective) empirically based model.

Based on reference to **Reid, 1998**, en-masse movement of up to 25 mm has occurred at a concrete dam wall that was 1.5 km from a longwall. The horizontal stress at seam level was understood to be very high (45 MPa) and the cover depth was about 500 m, which indicates an angle of draw to measurable displacement of 72 ~ 73^{o} or 3 times the cover depth in that case.

The horizontal strain associated with this movement was very low however (< 0.3 mm/m), and did not cause any cracking damage to the wall.

At this stage there are indications that FFDs may have contributed to the damage at the Belbin property, however, it would appear that there are several other factors, such as slope instability, which contributed to its manifestation (see **DgS, 2008b**). At this stage it is not considered necessary to monitor far-field displacements at Berrima Colliery.

12.0 Predicted Subsidence Impacts

12.1 General

The likely impact of the predicted subsidence, tilt and strains associated with the proposed extraction panel layout have been assessed for the existing natural features and developments.

Due to the uncertainties associated with mine subsidence prediction for a given mining geometry and geology etc, a credible range of impact outcomes (based on probabilistic design methodologies) have been provided to assist with the development of effective subsidence management plans for the existing site features.

Discussions of likelihood of impact occurrence in the following sections generally refer to the qualitative measures of likelihood described in **Table 7**, and are based on probabilistic terms used in **AGS, 2007** and **Vick, 2002**.

Table 7 - Qualitative Measures of Likelihood

Likelihood of Occurrence	Event implication	Indicative relative probability of a single event
Almost Certain	The event is expected to occur.	90-99%
Very Likely	The event is expected to occur, although not completely certain.	75-90%
Likely	The event will probably occur under normal conditions.	50-75%
Possible	The event may occur under normal conditions.	10-50%
Unlikely	The event is conceivable, but only if adverse conditions are present.	5-10%
Very Unlikely	The event probably will not occur, even if adverse conditions are present.	1-5%
Not Credible	The event is inconceivable or practically impossible, regardless of the conditions.	<1%

12.2 Surface Cracking

Surface cracking of 5 to 20 mm width in deep soil profiles are generally observed above underground NSW coal mines when tensile and compressive strains > 2 mm/m occur (**Willey et al, 1993** and **Ditton et al, 1993**). The width of the cracks is also dependent on the near surface geology and soil thickness. Deep, alluvial soils tend to distribute strains more uniformly than near surface rock exposures, which tend to concentrate strain at joints or mining induced fractures. Cracks in rock therefore tend to be wider than cracks in deep soil profiles.

The development of surface cracking has not occurred above previous panels at Berrima to-date. It is usually caused by the bending of the overburden strata as it sags down into the newly created void in the coal seam. The sagging strata is supported by previously collapsed

roof material (goaf), which then slowly compresses to a maximum subsidence, which is limited by the bulking characteristics of the goaf.

Based on the predicted range of maximum transverse tensile strains (i.e. 1 to 3 mm/m) for cover depths of 135 m to 190 m, maximum surface cracking widths of between 10 mm and 30 mm may occur within the limits of extraction.

The cracks (if they develop) would be expected to develop in the tensile strain zones that usually occur inside and parallel to the panel extraction limits. Tensile cracks are usually tapered and extend to depths ranging from 5 to 20 m in the Southern Coalfield, and sometimes extend deeper into near surface rock exposures and ridges. Cracks within compressive strain zones are generally low-angle shear cracks caused by failure and shoving of near surface strata. Some tensile type cracks can also be present due to buckling and uplift of near surface rock if it exists (see section on valley closure also).

Temporary, arcuate, tensile cracks may also probably develop up to 20 or 30 m behind the advancing goaf edge of the panels. Most of these types of cracks will be transient and of similar width to the cracks which occur due to full subsidence trough development. Transient cracks generally close in the central areas of extraction panels where permanent compressive strains develop after mining is completed.

Remnant pillars or stooks in the goafed areas may result in tensile cracking near the middle of the extracted panels where uneven subsidence development occurs.

Undermining ridges can also result in surface cracks migrating up-slope and outside the limits of extraction for significant distances due to rigid block rotations. Shoving or uplift development along the toe of the slope may also occur due to down-slope movements. These phenomenon will depend upon the slope angle, vertical jointing and the subsidence at the subsidence profile.

Surface crack repair works (such as pouring gravel, concrete or grout into large, deep cracks) may need to be implemented around the affected areas of the lease, and in particular, any steep slopes, public (or private) access roads or ephemeral watercourses that do not infill naturally with sediment due to natural geomorphic processes. As mentioned previously, there has been no evidence of surface cracking because of coal extraction within the Berrima Colliery's mining lease area.

12.3 Sub-Surface Cracking

The caving and subsidence development processes above a pillar extraction panel usually results in sub-surface fracturing and shearing of sedimentary strata in the overburden. The extent of fracturing and shearing is dependent on mining geometry and overburden geology.

International and Australian research on longwall mining interaction with groundwater systems indicates that subsurface fracturing may be defined as either 'continuous' or

'discontinuous' hydraulic fracturing (**Whittaker and Reddish, 1990** and **ACARP, 2003**) as shown schematically in **Figure 15**.

Continuous sub-surface fracturing refers to cracking above a pillar extraction panel that would provide a direct flow-path or hydraulic connection to the workings if a sub-surface (or surface) aquifer were intersected. The present sub-surface aquifers above the workings and within the continuous fracture zone could therefore result in increased water makes at seam level during pillar extraction.

Discontinuous fracturing refers to the additional extent above a pillar extraction panel which could be a general increase in horizontal and vertical permeability, due to bending or curvature deformation of the rock mass. This type of fracturing does not usually provide a direct flow path or connection to the workings; however, it is possible that they will interact with surface cracks, joints, or faults. This type of fracturing can also result in an adjustment of (i) surface and sub-surface flow paths and (ii) rock mass conductivity and storage magnitudes, but may not result in a significant change to the groundwater or surface water resource in the long-term.

Two heights of fracturing models (**Forster, 1995** and **ACARP, 2003**) have been used in this study to (i) ascertain the sensitivity of the predictions and (ii) demonstrate which model is the most conservative. The **ACARP, 2003** model was developed from piezometric data from Newcastle Coalfield in **Forster, 1995** (see **Figures 15** and **16** for fracture zone definitions) and supplemented with drilling fluid loss records from surface to seam drilling logs in subsided, fractured overburden from the NSW Southern Coalfield and Oaky Creek Mine in the Bowen Basin.

The sub-surface fracture data for the Southern Coalfield is summarised in **DoP, 2008**, but the prediction models are considered too broad for making specific predictions at a given site. The **ACARP, 2003** and **Forster, 1993** have been applied successfully in the Newcastle Coalfield and have similar mining geometry to Berrima.

The predicted mean (average) and Upper 95% Confidence Limit (i.e. worst case) values for the continuous and discontinuous sub-surface cracking heights above the pillar extraction panels are summarised in **Table 8** and presented in **Figures 17** and **18**.

The models indicate that the maximum height of continuous or direct hydraulic fracturing to the workings ranges between 86 m and 110 m above the proposed panels for cover depths of 135 m and 190 m respectively. The models also indicate direct surface to seam fracturing is 'very unlikely' for cover depths greater than 135 m.

In-direct or discontinuous sub-surface fracturing could interact with surface cracks where cover depths are < 190 m and surface rock exposures exist. Watercourse flows could then be re-routed to below-surface pathways and re-surfacing down-stream.

Table 8 - Summary of Predicted Sub-Surface Fracturing Heights above the Proposed 406 and SW1 Panels

Panel #	Cover Depth, H (m)	Panel Width, W (m)	Single Panel S_{max} (mean) (m)	Predicted Fracture Heights (m)					
				Continuous (A Horizon)				Discontinuous (B Horizon)	
				ACARP, 2003 Model (mean - U95%CL)		**Forster, 1995**) 21-33T		**ACARP, 2003** Model (mean - U95%CL)	
406 (RHS)	135	49.5	0.24	37	74	55	86	101	*125*
	140	49.5	0.23	37	75	55	86	104	*128*
	150	49.5	0.21	37	77	55	86	109	135
	170	49.5	0.19	38	83	55	86	121	150
	190	49.5	0.17	37	88	55	86	131	164
SW1 (LHS)	160	132	0.54	54	97	55	86	127	*155*
	170	132	0.50	54	100	55	86	132	*162*
	180	132	0.48	55	103	55	86	139	*170*
	190	132	0.45	56	107	55	86	145	*178*
SW1 (RHS)	150	71	0.31	51	91	55	86	119	*145*
	160	71	0.29	51	94	55	86	125	*153*
	170	71	0.27	52	97	55	86	131	*160*
	180	71	0.26	52	101	55	86	137	*168*
	190	71	0.24	52	103	55	86	142	176

Notes:
LHS - Left hand side of panel, mining in-bye; RHS - Right hand side of panel, mining in-bye.
Bold - Direct hydraulic connection to the surface is considered possible if A-Horizon prediction within 13 m of the surface.
Italics - Discontinuous fracturing may interact with surface cracks if B-Horizon within 10 m of surface, resulting in surface flow re-routing.

The model outcomes also indicate that the continuous fracture heights would extend up into the Hawkesbury Sandstone.

Subsurface aquifers within 74 m to 107 m of the workings for cover depths ranging from 135 m to 190 m respectively (i.e. 55 to 56 % of the cover depth) could be affected by direct hydraulic connection to the workings above the extracted panels, with subsequent long-term increases to vertical permeability or relatively free drainage into the workings.

Discontinuous fracturing would be expected to occur above these limits and increase rock mass storage and horizontal permeability without direct hydraulic connection to the workings. Interaction of discontinuous cracks with surface cracks is also possible for cover depths < 190 m (i.e. all of the proposed panels).

Current groundwater and surface aquifer impact studies are considering the above uncertainties in regards to surface and groundwater impacts. The practical options available for controlling subs-surface fracturing are limited to (in order of increasing impact to mining):

(i) repair surface cracks when they occur,

(ii) decrease mining height to limit continuous fracture heights,

(iii) decrease panel width, or

(iv) leave a barrier pillar beneath sensitive area or limit mining to first workings.

These matters had been taken into account in the Preliminary Hydrogeology Assessment prepared by Larry Cook and Associates as part of the SMP application.

12.4 Slope Stability and Erosion

The likelihood of *en-masse* sliding (i.e. a landslip) of the ridges or hills over basal siltstone beds tilted by subsidence has been assessed based on the landslide risk assessment terminology presented in **AGS, 2000**.

The potential for terrain adjustment due to erosion and deposition of soils after subsidence has also been broadly assessed.

The assessments are considered preliminary at this stage and further detailed studies may be necessary in areas identified as 'high' risk in terms of damage to sensitive surface features.

Based on reference to **Fell et al, 1992,** any siltstone and mudstone units that may be present at the base of the ridges on the site have been assumed to have a lower bound, drained angle of friction (Ø') of 15°. Saturated slopes with water filled joints or mining-induced cracks have been assumed representative of worst-case conditions.

Figures 19 and **20** indicate that the predicted subsidence for 406 and SW1 panels are expected to change (increase or decrease) existing slopes by up to 0.5° (i.e. 1%). This would indicate that any near surface beds might have their dip increased from about 3° to 5° to a range of 3.5° to 5.5° on east facing slopes within the SMP area.

The Factors of Safety against *en-masse* sliding of a natural slope in the SMP area due to the predicted bedding dip increase and surface cracking effects mentioned above are estimated for the worst-case condition by the method presented in **Das, 1998** as follows:

Before mining: FoS = (u_b/u_r) tan(Ø')/tan(theta) = 0.6 tan (15°)/tan(5°) = 1.84.

After mining: FoS = (u_b/u_r) tan(Ø')/tan(theta) = 0.6 tan (15°)/tan(5.5°) = 1.67.

where:

u_b = buoyant unit weight of sandstone above the mudstone = 14 kN/m^3

u_r = dry unit weight of sandstone above the mudstone = 24 kN/m^3

Based on a recommended minimum FoS of 1.2 (**Leventhal and Stone, 1995**) for the lower bound residual strength, it is assessed that it is 'very unlikely' that a large scale instability or landslip will occur in the long-term due to mining effects within the SMP area.

Smaller scale translational slips and rotational slumps in the surface soils similar to the observed slope failures to-date are possible if the slopes are subsided or disturbed by mining activity during or not long after periods of wet weather. Surface cracking from subsidence will also exacerbate the apparent marginal condition of the slopes by increasing water ingress into the slope.

The rate of soil erosion is expected to increase significantly in areas with exposed dispersive/reactive soils and slopes > 10°, and where these slopes are subjected to the estimated tilt increases.

Areas with slopes < 10° are expected to have low erosion rate increases, except for the creek channels, which would be expected to re-adjust to any changes in gradient.

Head-cuts would also be expected to develop above the panels and on the side where gradients increase. Sediment would be expected to accumulate where gradients decrease.

To minimise the likelihood of slope instability due to mine subsidence impacts the management strategy should include:

(i) Surface slope displacement monitoring along 406 Panel centre lines (combined with subsidence monitoring plans);

(ii) Infilling of surface cracking to prevent excessive ingress of runoff into the slopes.

(iii) Areas that are significantly affected by erosion before or after mining may need to be repaired and protected with mitigation works such as re-grading and re-vegetation of exposed areas.

(iv) On-going review and appraisal of any significant changes to surface slopes such as cracking along ridges, increased erosion down slopes, foot slope seepages and drainage path adjustments observed during second workings;

Large-scale slope instability after mining may require significant stabilisation works, such as the installation of deep sub-surface drainage trenches (to reduce pore pressures) and strategic catch drains along slope crests to improve surface run-off. Some sections of damaged or landslip effected areas, may also need re-grading works after mine subsidence to limit on-going, long-term degradation. It is recommended however, that any works should be based on consultation with the landowners, relevant government agencies and rehabilitation works consultants.

At present the primary causes of the slope instability include previous land clearing and current land use practices. It is understood that Berrima Colliery personnel are liaising closely with landowners regarding remedial works for the current situation. An active erosion area has been fenced off to exclude stock and has been planted with trees. The mine has also installed survey control points along the slope in order to determine any pre-mining movement.

12.5 Watercourses and Dams

There are no permanent streams or drainage channels within the proposed mining area. A single first order drainage line lies in a steep gully between the Belbin and Renahan Properties. This drainage line flows into two separate farm dams before flowing over a cleared paddock without a formed channel. A similar watercourse feeds Dams 1 and 2 above the 59 Panel location.

The closest stream of importance is Mandamar Creek which is a third order stream and is located some 600m to the south east from the main development roadways.

Due to the soil cover present along the Berrima watercourses, it is unlikely that flows into Dams 1 and 2 above 59 Panel will be affected by mine subsidence.

Non-engineered farm dams and water storages of up to 0.7 ML above the proposed 406 and SW1 extraction limits will be susceptible to surface cracking and tilting (i.e. storage level changes) due to mine subsidence. The tolerable tilt and strain values for the dams would depend upon the materials used, construction techniques, foundation type and likely repair costs to re-establish the dam's function and pre-mining storage capacity.

The predicted worst-case subsidence deformations (subsidence, tilt, horizontal strain and displacement) at the dam sites in the SMP area are shown in **Figures 10** to **14**.

The expected phases of tensile and compressive strain development may result in breaching of the dam walls or water losses through the floor of the dam storage area. Loss or increase of storage areas may also occur due to the predicted tilting.

It should be noted that dams like the ones in the mining area have been undermined by Berrima Colliery in the past have not sustained any damage or loss of water. The dams will be monitored and if dam integrity has been affected by mining the water will be drained, the dam lining repaired and refilled at no cost to the landowner.

12.6 Valley Uplift and Closure

Uplift and closure movements can be expected in cliffs and in the sides of valleys whenever longwalls or high extraction pillar panels are mined beneath them, based on reference to **ACARP, 2002**.Valley-uplift and closure movements can also occur along broader drainage gullies where shallow surface rock is present.

As discussed in **ACARP, 2002**, when creeks and river valleys are subsided, the observed subsidence in the base of the creek or river is generally less than would normally be expected in flat terrain. This reduced subsidence is due to the floor rocks of a valley buckling upwards when subject to compressive stresses generated by surface deformation. In most cases in the Newcastle and Southern NSW Coalfields, the observed uplift has extended outside steep sided valleys and included the immediate cliff lines and the ground beyond them.

It should also be understood that these movements are strongly dependent on the level of 'locked-in' horizontal stress immediately below the floor of the gullies and more importantly the bedding thickness of the floor strata (i.e. thin to medium bedded sandstone is more likely to buckle than thicker beds). The influence of the aspect ratio (i.e. valley width/depth) is also recognised as an important factor, with deep, narrow valleys having greater upsidence than broad, rounded ones, due to higher stress concentrations.

As the valleys across the mining lease are broad and there is a lack of thick, massive beds of conglomerate and/or sandstone units along the creeks / valleys, the development of upsidence and closure is likely to be negligible.

If 'upsidence' does occur, it may cause some minor, localised deviation of surface flows along ephemeral creek beds into sub-surface routes above the panels. Failure and cracking of the near surface rocks due to tensile bending or compressive/shear strains will also contribute to the re-routing of surface flows. Re-routed surface flows would be expected to re-surface down stream of the damaged area.

The impact of upsidence and valley bending effects may be managed as follows:

(i) Install and monitor survey lines along ephemeral drainage gullies and along gully crests during and after longwall undermining. Combine with visual inspections to locate damage (cracking, uplift).

(ii) Review predictions of upsidence and valley crest movements during mining.

(iii) Assess whether repairs (i.e. cementitious grouting) to cracking, as a result of upsidence or gully slope stabilisation works (i.e. spot bolts and meshing) are required to minimise the likelihood of long-term degradation or risks to personnel and the general public.

It is highly unlikely that the single ephemeral drainage line between the Belbin and Renahan properties will be subject to uplift or cracking.

12.7 Ponding

Surface slopes in the SMP area range between 2° and 20° and are unlikely to be affected by ponding caused by closed form depressions from subsidence trough development. The net fall across the area will be sufficient to allow surface drainage to continue unimpeded after mining is completed, based on the 1 m post-mining surface level contours are shown in **Figure 21**.

Potential ponding of < 0.1m is estimated for the flatter areas of the site and likely to be 'in-channel' or within the confines of the natural watercourses that are present.

An appropriate management strategy would still require the on-going review and an appraisal of any changes to surface drainage paths and surface vegetation after each panel is extracted.

12.8 Residential Dwellings, In-ground Tanks and Machinery Sheds

As previously discussed, all residences and associated machinery sheds, in-ground tanks and pipes within the SMP Area will be protected from significant damage by the SPZs.

The maximum subsidence is estimated to be < 20mm for minimum set back distances of 26.5 degrees for the proposed SPZ beneath the Renahan property.

No further impacts due to mining are expected from the Belbin and Alcorn properties, which are located outside a 35^{o} angle of draw from 406 and SW1 Panels. On-going monitoring and inspection of these properties will still be required during mining however, as a precautionary measure due to the potential for slope movements or instability to occur above the properties.

It is assessed that Mr T.D. Rosa's property is well outside the angle of draw to the proposed second workings limits. The property is located approximately two times the cover depth from the proposed second workings limits 406 Panel, and is very unlikely to be impacted by far field displacements and strains due to the properties location in gently undulating terrain.

An inspection of the above properties should be made by the MSB or qualified building consultants before, during and after mining and any repair works to internal/externals cracking or re-levelling of damaged structures be implemented as soon as mining related movements have ceased.

12.9 Unsealed Gravel Access Roads and Tracks

The unsealed gravel access roads and tracks above the proposed panels could be damaged by cracking and 'shoving' at tensile and compressive strain zones; see **Figure 13**.

The worst-case surface crack widths that could occur due to the predicted strains are estimated to range between 10 mm and 30 mm. The cracks would be expected to develop during and after extraction of the proposed SW1 panel only.

Inspection and maintenance of the roads and access tracks should be undertaken as required when the impacts occur.

12.10 Property Fences and Livestock

The impact of mining on the grazing of livestock would primarily require the management and repair of surface cracking and fences. Ponding is not expected to affect grazing or pasture areas.

12.11 Aboriginal Heritage

Based on the subsidence predictions, it is assessed that no significant impact is expected to occur to the artefact scatter site above 59 Panel. It is therefore considered unnecessary for the mine to establish further protection measures for the site.

13.0 Proposed Monitoring Program

13.1 Surface Impact Monitoring

Based on the surface topography and surface infrastructure present above the proposed panels and SPZs the following subsidence and strain-monitoring peg layouts and survey program is proposed in order to provide adequate information to implement subsidence impact management plans to the satisfaction of the stakeholders.

Survey lines and monitoring station layouts proposed are:

(i) Extension of 404 Centreline to a distance of 70 m past the extraction limits of 406 panel.

(ii) Extension of 403 and 406 Crosslines to a distance of 85 m past the extraction limits of SW1 panel.

(iii) Installation of a centreline down the middle of 406 Panel and SW1 Panel for a minimum distance equal to 0.7 times the cover depth beyond each end of the proposed mining limits.

(iv) Install a minimum of 4 pegs in the ground at the corners of each of the Renahan structures.

(v) Monitoring of utility infrastructure may also be necessary and proposed monitoring of the power poles, conductor clearances and loss of signal/service should be discussed with Integral Energy and Telstra prior to subsiding these features.

The above monitoring layout proposed is intended to allow the comparison between predicted and measured subsidence parameters for the panels and at a sensitive feature.

If far-field movements are a concern for future panels, then a network of monitoring station 'triangles' (with 10 m side lengths) may need to be established outside the limits of panel extraction at distances of 0.5, 1, 2, 3 and 4 times the cover depth in order to monitor 3-D displacements and principal horizontal strains after each panel is extracted. It should be understood however, that FFDs of < 20 mm and strains < 0.3 mm/m are difficult to measure using current GPS and terrestrial surveying technologies, and are also unlikely to cause impact to sensitive surface features.

It is considered that the magnitudes of potentially damaging displacements and strains are more likely to occur within a distance equal to half the cover depth or an AoD of 26.5o from the limits of second workings at Berrima Colliery.

The survey pegs should be driven to refusal in soil or drilled and installed securely into rock at a spacing of 10 m. A minimum of two baseline surveys of subsidence and strain is recommended before mine subsidence effects occur.

Survey lines may be installed in stages provided new pegs are installed and base line surveys completed before the advancing mining 'front' encroaches within a 35^{o} angle of draw from the station.

Based on reference to **DoP, 2008** it will be necessary to determine subsidence Risk Management Zones (RMZs) for sensitive features within the SMP area, which are defined by either an AoD of 35^{o} from the feature.

It is proposed to conduct monthly surveys of the panel crosslines and centreline and the Renahan Property stations after mining commences in a given panel, with fortnightly surveys proposed while second workings encroaches within 35^{o} (125 m) from the features in the RMZs.

Monitoring of the slopes adjacent to the Renahan and Belbin properties will also be required and will occur by default once mining enters the RMZ.

Monitoring of subsidence and the condition of the Belbin and Alcorn properties should continue during extraction of 406 and SW1 Panels as well.

If movements greater than the survey accuracy limits of 5 mm are detected (or the residents advise the MSB) at either of the Alcorn, Belbin or Renahan buildings, then weekly monitoring of these sites will be required and inspection of the houses undertaken by the MSB until the movements cease.

The location of the proposed monitoring lines and RMZs for 406 and SW1 Panels are presented in **Figure 22**.

The monitoring program suggested also assumes visual inspections and mapping of damage to houses, machinery sheds, dams, fences and access roads will be conducted before, during, and after mining is complete.

Subsidence and strains may be determined using total station techniques to determine 3-D coordinates, provided that the survey accuracy is suitable. Survey accuracy using EDM and traverse techniques from a terrestrial base line is normally expected to be +/- 2mm for level and +/- 7 mm for horizontal displacement (i.e. a strain measurement accuracy of +/- 0.7 mm/m over a 10 m bay-length).

Strain measurements using the steel tape method generally improve the accuracy to +/- 2mm (or 0.2 mm/m strain over 10 m) and would be the preferred method for measuring strain.

13.2 Sub-Surface Impact Monitoring

It is understood that sub-surface monitoring of fracture heights above the panels will be determined through groundwater bore water level monitoring and mine water makes in the SMP area.

The installation of shallow and deep borehole piezometers will allow the height of continuous and discontinuous fracturing to be ascertained for future panels.

14.0 Conclusions

The subsidence predictions presented in this study have been based on empirical and calibrated analytical models of overburden and pillar behaviour. The proposed SMP Area will have three pillar extraction panels that will have widths of 71 m and 132 m in SW1 Panel and 49.5 m in 406 Panel. Cover depths range from 135 m to 190 m beneath low lying rural terrain in the east and a broad-crested ridge above the western area of the site.

The key outcomes of the study are presented below:

(i) Final maximum panel subsidence after extracting a 2.6 m high face in the Wongawilli Seam is estimated to range from 0.17 m to 0.54 m (6.5% to 21% of the mining height).

(ii) It is proposed to leave a SPZ around the structures and borewater well on the Renahan's property. The SPZ will be defined by a 26.5^{o} Angle of draw (i.e. 0.5 times the cover depth) from the corners of each building.

Maximum subsidence above the pillars in the proposed SPZs around the Renahan Property is estimated to be < 20 mm.

(iii) It is understood that 59 Panel will remain a first workings panel only and will not be extracted. If second workings in 59 Panel are proposed in the future, it will be necessary to leave a 26.5^{o} AoD SPZ below each of the two large dams.

(iv) No further movements due to mine subsidence are anticipated at the Belbin and Alcorn properties, however, subsidence monitoring and visual inspection of the properties should continue until mining of 406 and SW1 panels have ceased.

The proposed mining limits of 406 and SW1 panels are located outside a 35^{o} AoD from the Belbin and De Rosa residences at this stage, with no further or new impacts expected.

(v) Maximum panel tilts are estimated to range from 4 to 10 mm/m, with concave curvatures ranging from 0.41 to 0.19 km^{-1} (or radii of 2.4 km to 5.2 km) and convex curvatures from 0.16 to 0.10 km^{-1} (or radii of 6.3 km to 10 km).

(vi) The maximum horizontal strains associated with the curvatures over the panels are estimated to range from 0.5 mm/m to 3 mm/m (tensile) and from 1 to 4 mm/m (compressive). Subsidence cracks of 10 to 30 mm width could develop in the tensile strain zones within the mining limits and along the crests and mid-slopes of undermined ridges. Experience at Berrima Colliery to-date suggests that no cracking will develop on the surface after mining is competed.

(vii) Subsidence and associated impact parameter contours of principal tilt, horizontal strain have been prepared for subsequent surface feature impact assessment.

(viii) Increase or decrease of surface gradients above panels of up to 1% (0.5^{o}).

(ix) Potential ponding depths of <0.1m above the panels and creeks in the flatter areas of the site, based on post-mining contour predictions. This is largely a result of these ephemeral streams having no defined channel below the existing farm dams with overflow tending to form sheet flow across the paddocks.

(x) Direct hydraulic connection to the workings of any sub-surface aquifers within 86 to 110 m above the proposed panels, due to fracturing of the overburden. It is considered very unlikely that surface to seam connection will occur where cover depths are > 130 m below ephemeral drainage gullies.

(xi) Discontinuous fracturing would be expected to occur up to 190 m above the workings and result in an increase in rock mass storage and horizontal permeability without direct hydraulic connection to the workings. Rock mass permeability is unlikely to increase significantly outside the limits of extraction, however, draw-down effects are expected to affect ground water bores below the estimated heights of fracturing and within a distance equal to the cover depth (and possibly further) from the mining limits.

(xii) Creek flows could be re-routed to below-surface pathways and re-surfacing down-stream of the mining extraction limits. This phenomenon behaviour usually only occurs where shallow surface rock is present and unlikely to occur where deep soil profiles exist. Remedial works may require repair works where cracks are enable to 'self-heal' through natural sedimentation deposits in the cracks over time. As such rock lined creeks do not occur within the proposed mining area, the potential for subsurface flows is considered remote.

(xiii) En-masse slip of hills or ridges along weakened bedded partings in thinly bedded siltstones due to the predicted tilts is considered unlikely within the SMP Area, however translational or rotational slides in near surface soils are possible due to the presence of several previous slides inside of and to the north of the limits of the SMP area.

(xiv) Small stock watering dams within the SMP Area may be damaged by mine induced cracking and/or shearing resulting in dam wall breach or storage losses through the floor of the dam storage areas. Repairs to the dams and temporary supplies of water may be required by the stakeholders. It is understood that no impact has occurred to similar dams above previous panels to the south.

(xv) The various unsealed roads and tracks around the site are likely to be subject to cracking and shoving caused by mining that may require repair works and maintenance.

(xvi) No impacts are expected to occur to the Aboriginal open artefact scatter site above the first workings only 59 Panel after mining is completed. It is therefore considered unnecessary for the mine to establish further protection measures for the site.

The above items will require further discussion with the stakeholders to enable more site specific property plans to be developed. A suggested program for monitoring subsidence and strain along panel crosslines and centrelines and at features within the Risk Management Zones has been provided for the purpose of implementing and reviewing subsequent SMPs.

Management of the predicted impacts may subsequently require further subsidence control (i.e. mining planning changes) or mitigation techniques to be applied where the predicted outcomes are considered unacceptable by the stakeholder and government agencies.

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Photos 1 - 12

Photo 1 - Landslips to the North of the SMP Area



Photo 2 - Old Landslip in the SMP Area



Photo 3 - Single Story Masonry Veneer House on the Renahan Property



Photo 4 - Single Storey Fibro Clad Cottage and Borewater Pump House on the Renahan Property



Photo 5 - Sheet Metal Clad Machinery Shed on Renahan Property



Photo 6 - In-Ground Water Supply Tank on Renahan Property



Photo 7 - Typical Stock Watering Dams in SMP Area



Photo 8 - Domestic Powerline and Fences in SMP Area



Photo 9 - K. and P. Belbin Residence to South of the Renehans Driveway



Photo 10 - K. and P. Belbin Borewater Well Location

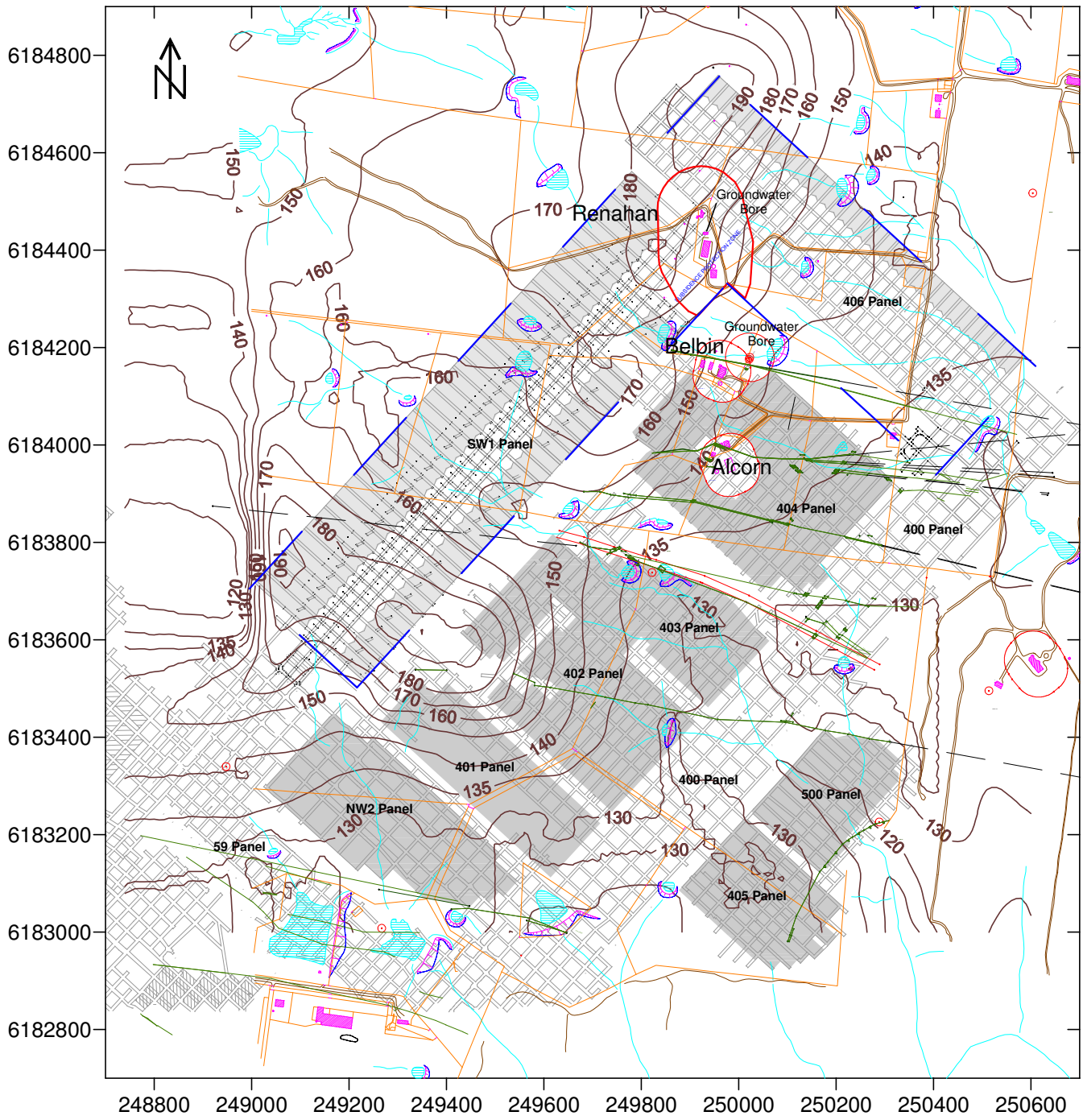


Photo 11 - R. and D. Alcorn Residence



Photo 12 - T. De Rosa Residence to North of SMP Area

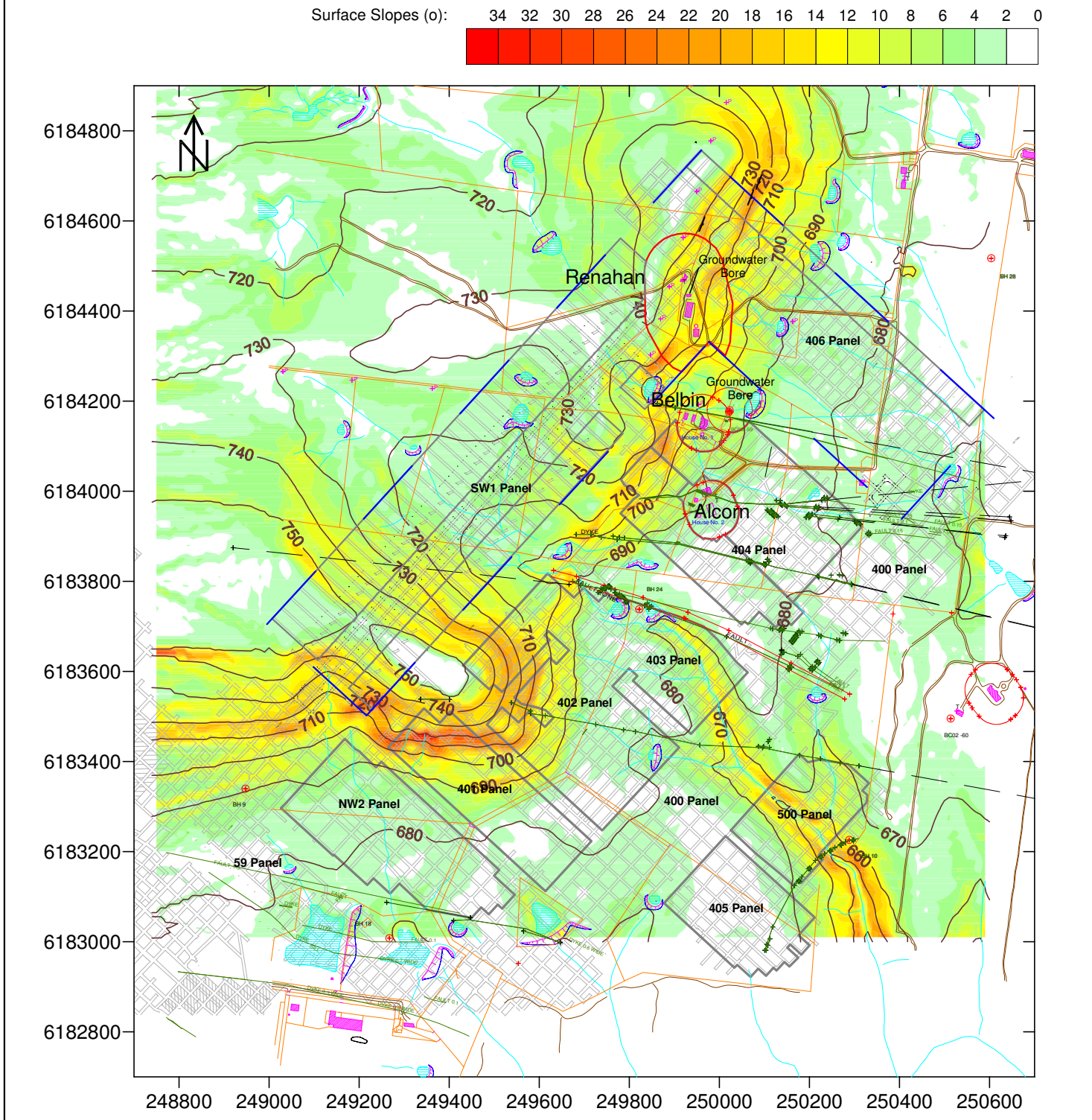




Key:

- Cover Depth (m)
- First Workings
- Old Second Workings
- Proposed Second Workings Area
- Water courses (gullies)
- Farm Dams
- Faults
- SMP Area Limits
- Fences
- Buildings/ Sheds/ Tanks
- P Power Poles
- Unsealed Roads/ Tracks
- Subsidence Protection Zone Limits

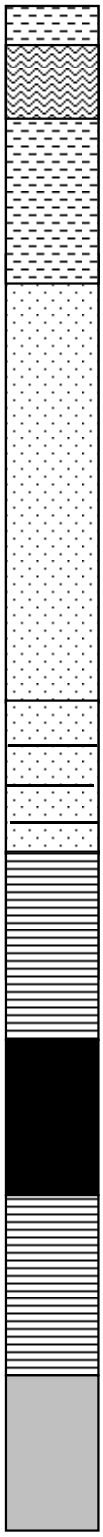
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	Drawn:	S.Ditton			
	Date:	20.09.10	Title:	Proposed SW1, 406 and 59 Panels with Depth of Cover Contours and Surface Features	
	Ditton Geotechnical Services Pty Ltd		Scale:	1:12,500	Figure No: 1



Key:

- Surface Levels (AHD)
- Second Workings Limits
- First Workings
- SMP Area Limits
- Water courses (gullies)
- Farm Dams
- Faults
- Landslip Scarps
- Fences
- Buildings/ Sheds/ Tanks
- Power Poles
- Unsealed Roads/ Tracks
- Subsidence Protection Zone Limits

DgS	Engineer:	S.Ditton	Client:	Berrima Colliery BER-003/1	
	Drawn:	S.Ditton			
	Date:	20.09.10	Title:	Proposed SW1, 406 and 59 Panels with Surface Topography, Ground Slopes and Surface Features	
	Ditton Geotechnical Services Pty Ltd		Scale:	1:12,500	Figure No: 2



Interbedded Shale / Claystone, (Wianamatta Shale), 10 - 60 m thick,
with some Tertiary Basalt (ELEVATED AREAS OF SITE ONLY)
(UCS = 10 - 20 MPa)

Sandstone (Hawkesbury), 110.5 - 123 m thick,
(UCS =30-50 MPa)

Interbedded Siltstone / Sandstone, 3.75 - 5.25 m thick,
(UCS 15 - 30 MPa)

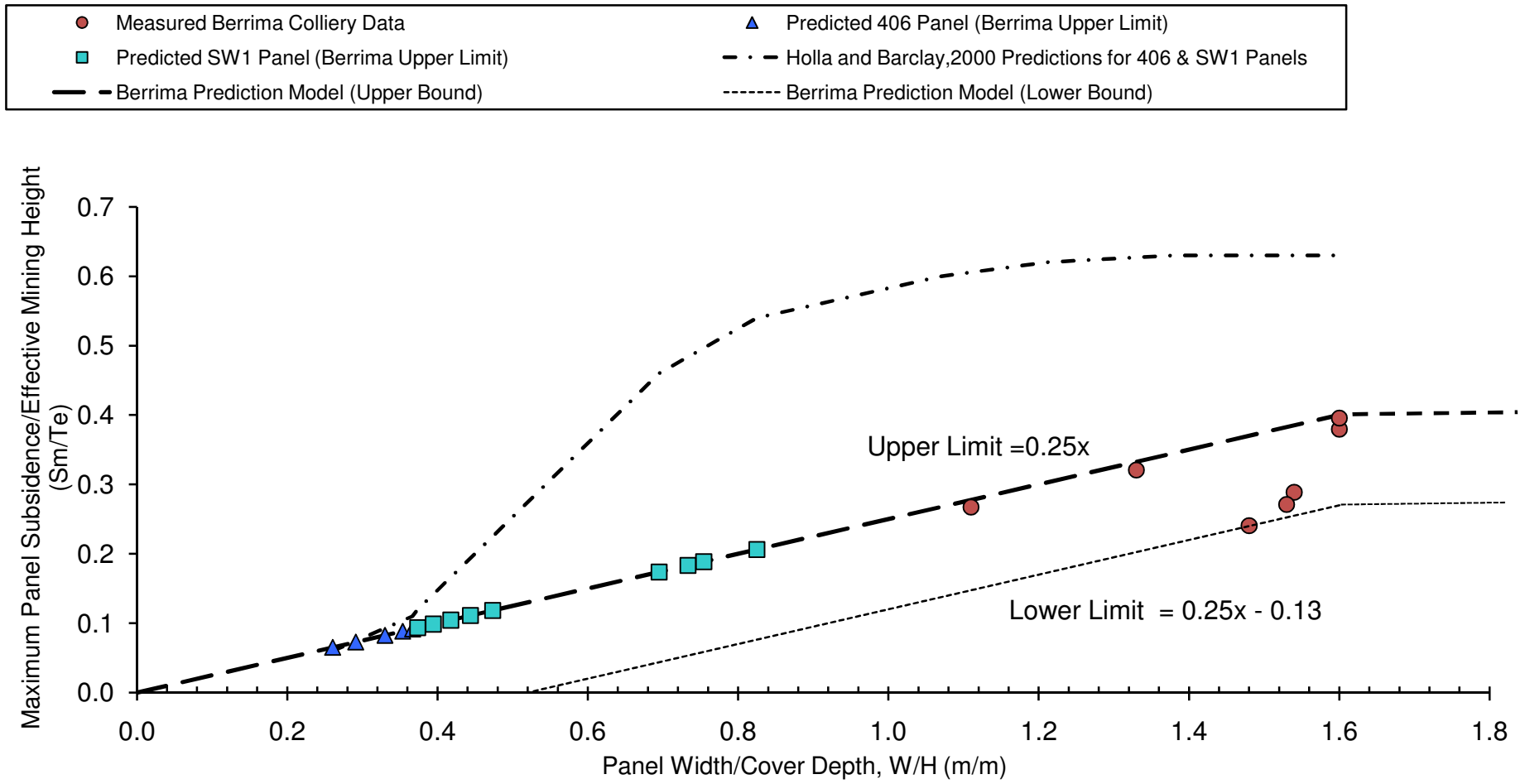
Interbedded Mudstone / Siltstone, 3.5 - 5.5 m thick,
(UCS = 10 - 20 MPa)

Wongawilli Seam, 2.2 - 2.4 m thick,
(UCS = 10 - 15 MPa)

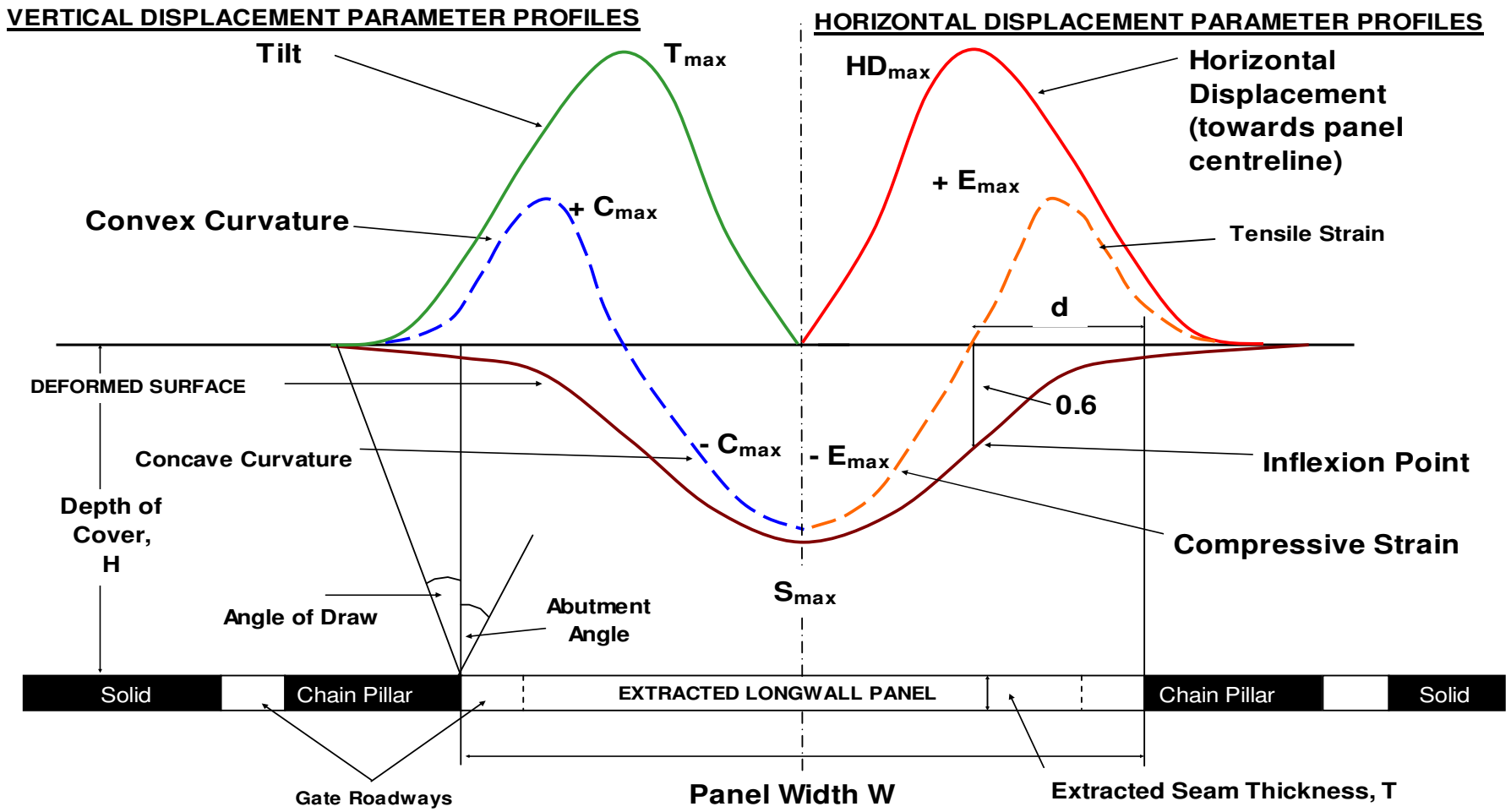
Carbonaceous Mudstone / Coal, 1 .0 - 1.75 m thick,
(UCS = 10 - 20 MPa)

Interbedded Shale / Siltstone > 10m,
(UCS = 15 - 30 MPa)

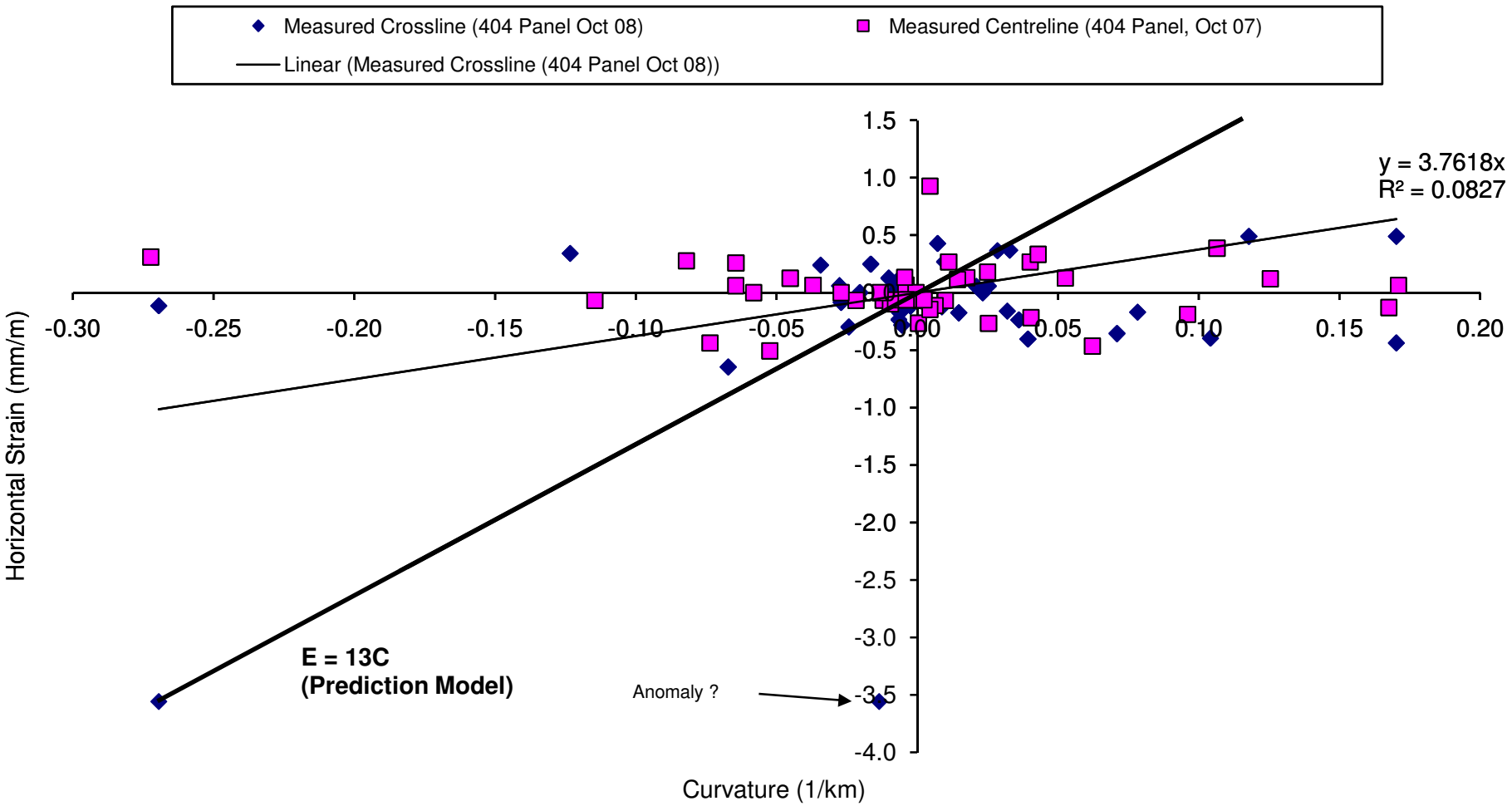
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	Drawn:	S.Ditton		BER-003/1	
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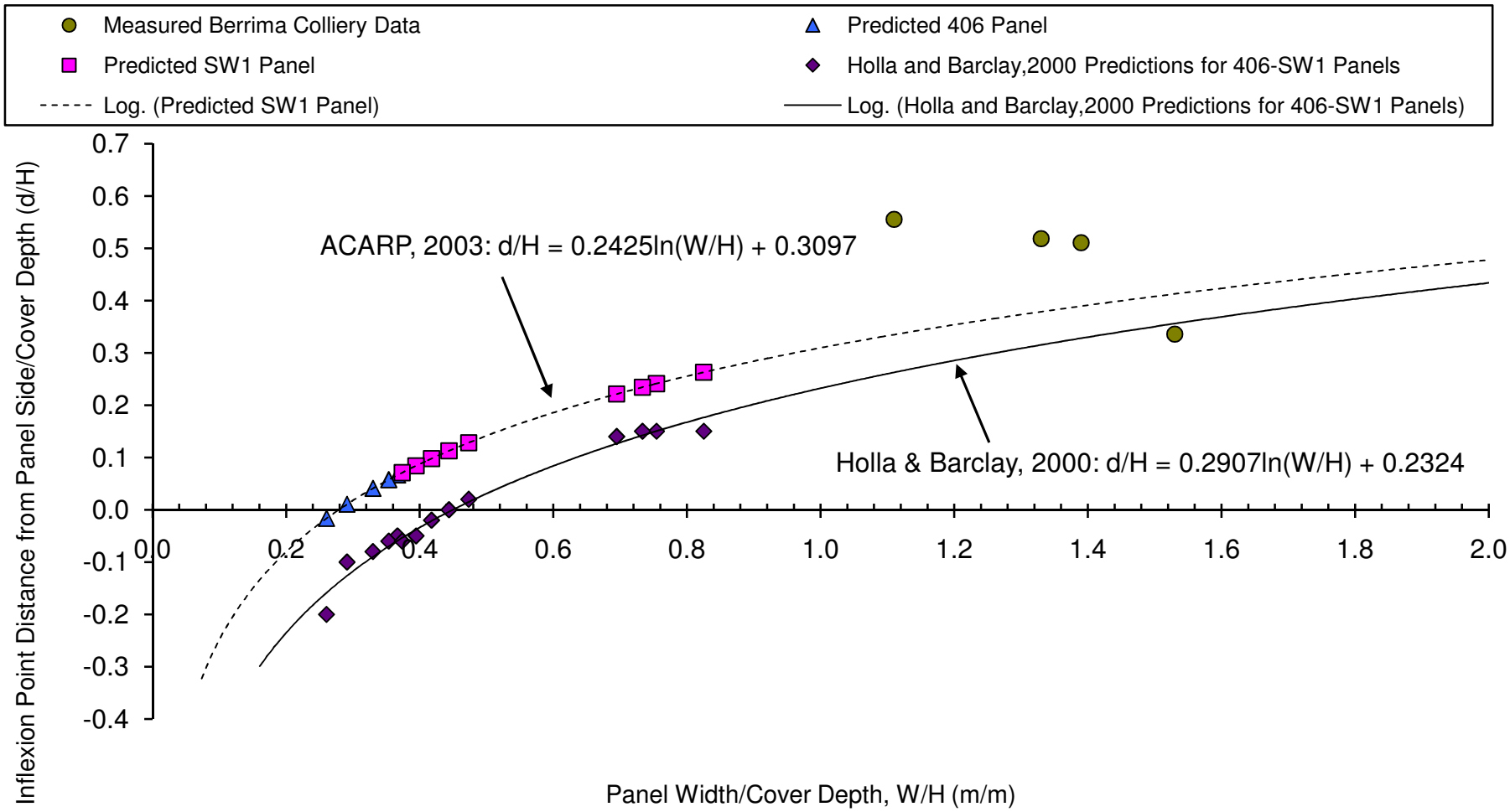
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	Drawn:	S.Ditton			
	Date:	10.09.10	Title:	Measured Maximum Subsidence for 403 to 405 and 500 Total Extraction Panels with Predictions for 406 and SW1 Panels	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 4



DgS	Engineer:	S.Ditton	Client:	Berrima Colliery BER-003/1	
	Drawn:	S.Ditton			
	Date:	20.09.10	Title:	Mine Subsidence Trough Deformation Parameters Above Longwall Panels (adapted from Holla, 1987)	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 5a



DgS	Engineer:	S.Ditton	Client:	Berrima Colliery BER-003/1	
	Drawn:	S.Ditton			
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	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 5b

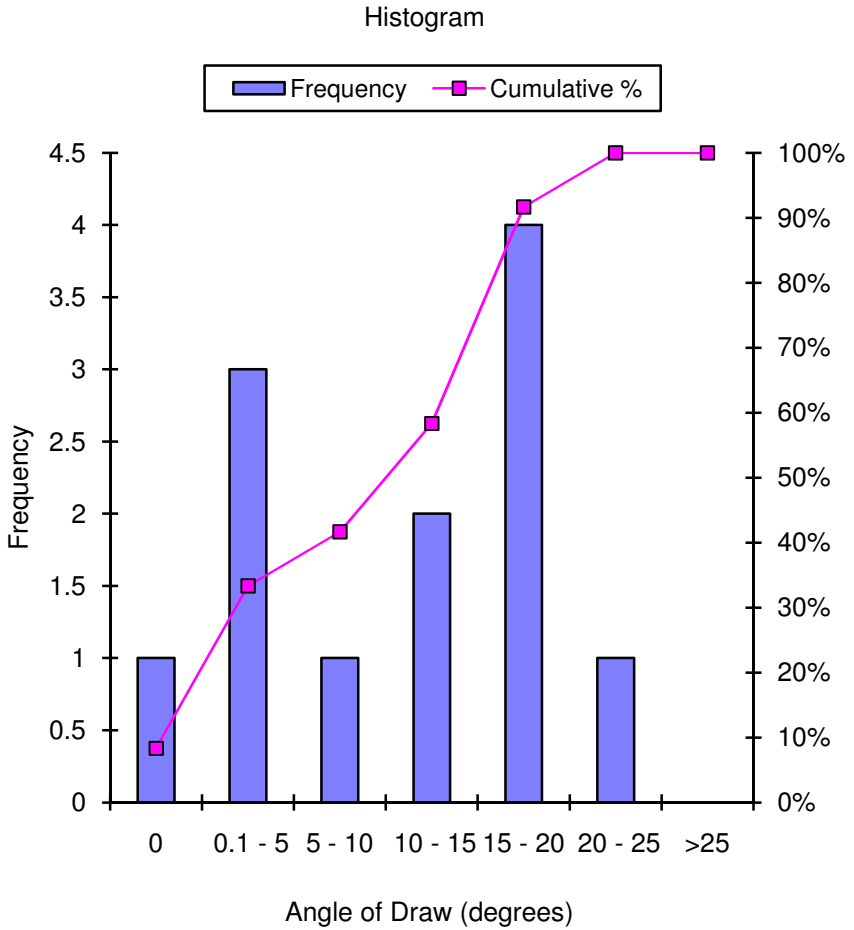


DgS	Engineer:	S.Ditton	Client:	Berrima Colliery BER-003/1	
	Drawn:	S.Ditton			
	Date:	20.09.10	Title:	Measured Inflexion Point Distance/Cover Depth for 403 to 405 and 500 Total Extraction Panels and Predictions for 406 and SW1 Panels	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 6

Statistics	
Mean	10.91
Standard Error	2.26
Median	11.20
Mode	#N/A
Standard Deviation	7.84
Sample Variance	61.41
Kurtosis	-1.52
Skewness	-0.11
Range	22
Minimum	0
Maximum	22
Sum	130.9
Count	12

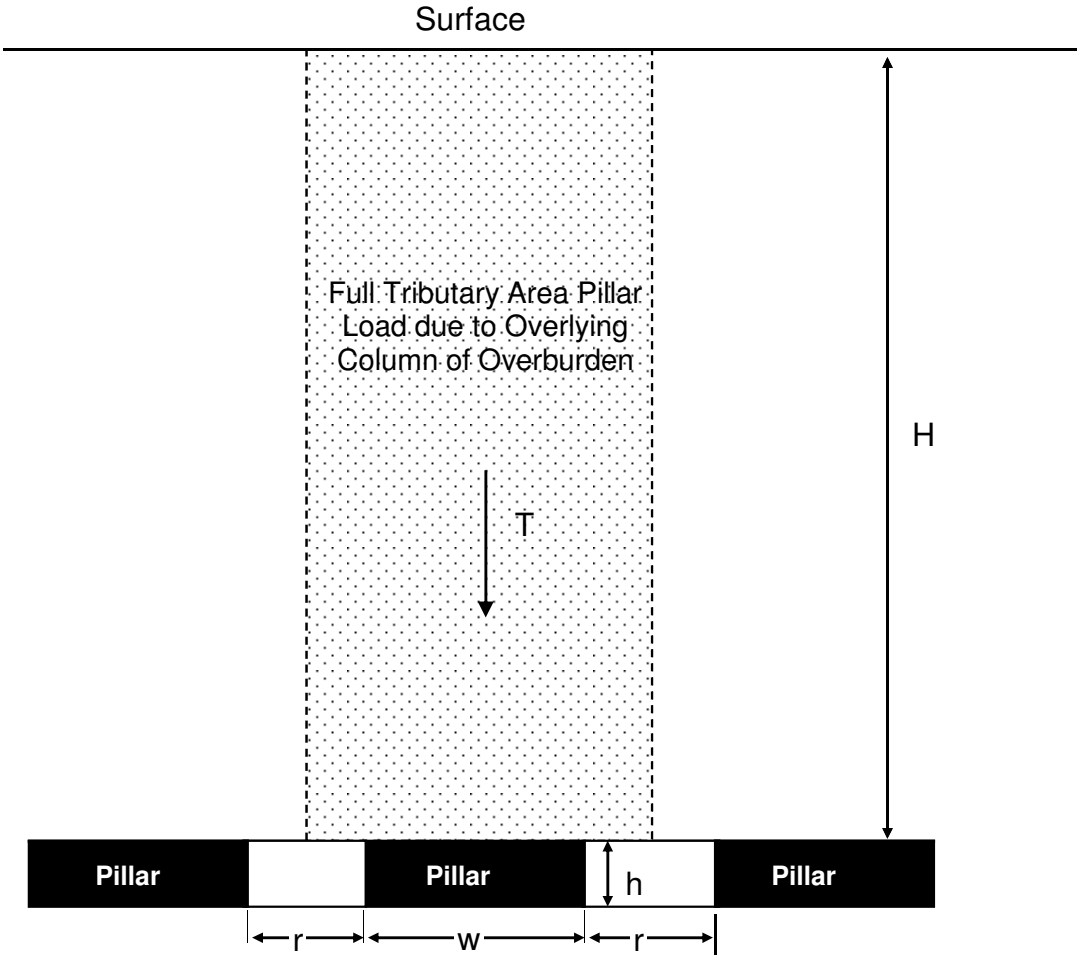
Bin	Frequency	Cumulative %
0	1	8.3%
0.1 - 5	3	33.3%
5 - 10	1	41.7%
10 - 15	2	58.3%
15 - 20	4	91.7%
20 - 25	1	100.0%
>25	0	100.0%

AOD Data:
10.4
19
7.7
0.1
17.4
22
0
19.4
12
3.4
4
15.5



Note: Angle of draw is the angle to the vertical from the limit of workings to 20 mm subsidence point at the surface.

DgS	Engineer: S.Ditton	Client:	Berrima Colliery
	Drawn: S.Ditton		BER-003/1
	Date: 20.09.10	Title:	Measured Angle of Draw for 403 to 405 and 500 Total Extraction Panels
	Ditton Geotechnical Services Pty Ltd	Scale:	NTS — Figure No: 7



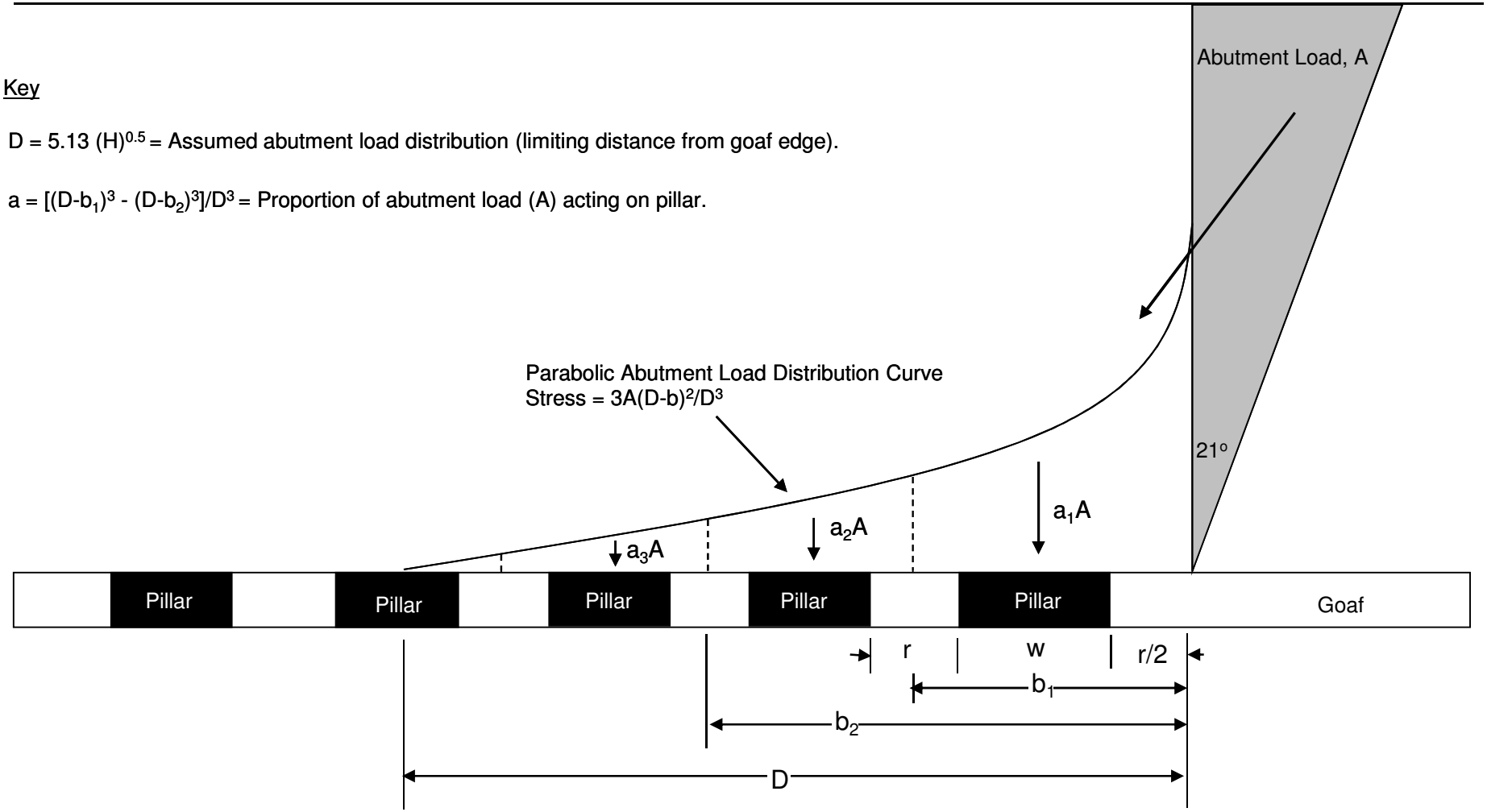
Notes: r = bord width (m)
w = pillar width (m)
h = mining height (m)
H = depth of cover (m)
e = extraction ratio = 1 - [wr/(w+r)(l+r)]
T = Pillar Load = 0.025H/(1-e) (MPa)

DgS	Engineer:	S.Ditton	Client:	Berrima Colliery	
	Drawn:	S.Ditton		BER-003/1	
	Date:	20.09.10	Title:	Analytical Model for Calculating Full Tributary Area Loads on Pillars in the SPZs before 2nd Workings	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 8a

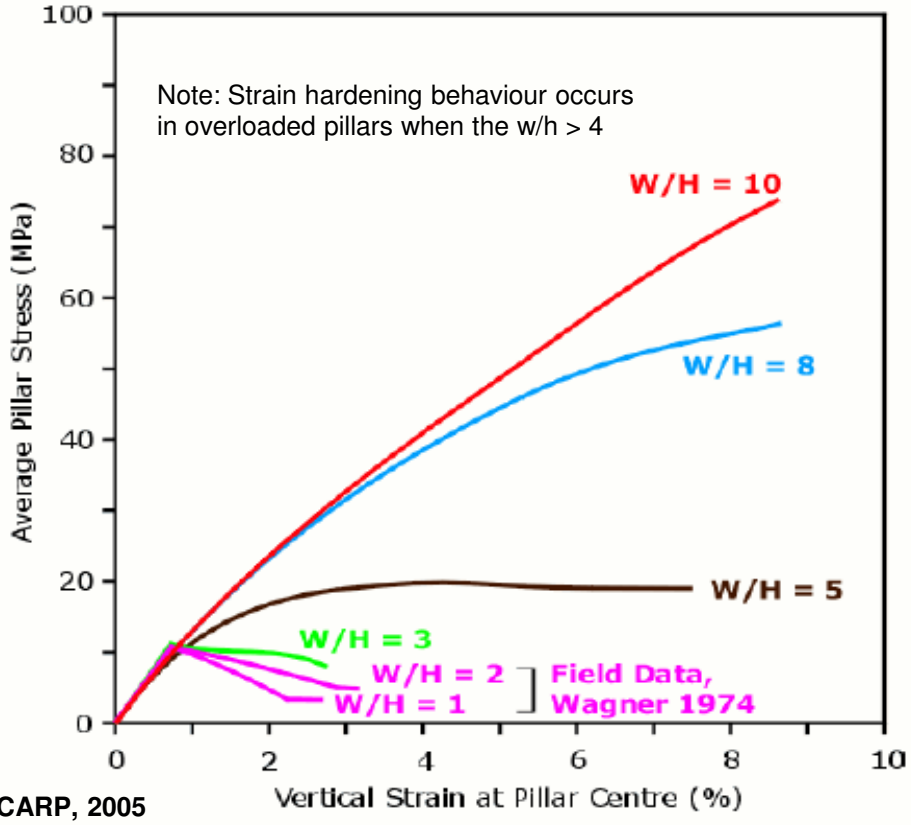
Key

$D = 5.13\ (H)^{0.5}$ = Assumed abutment load distribution (limiting distance from goaf edge).

$a = [(D-b_1)^3 - (D-b_2)^3]/D^3$ = Proportion of abutment load (A) acting on pillar.



DgS	Engineer:	S.Ditton	Client:	Berrima Colliery BER-003/1	
	Drawn:	S.Ditton			
	Date:	20.09.10	Title:	Analytical Model for Calculating Abutment Loads on Pillars in Subsidence Control Zones (based on reference to **Peng and Chiang, 1986** and **ACARP,1998a**)	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 8b



Ref: **ACARP, 2005**

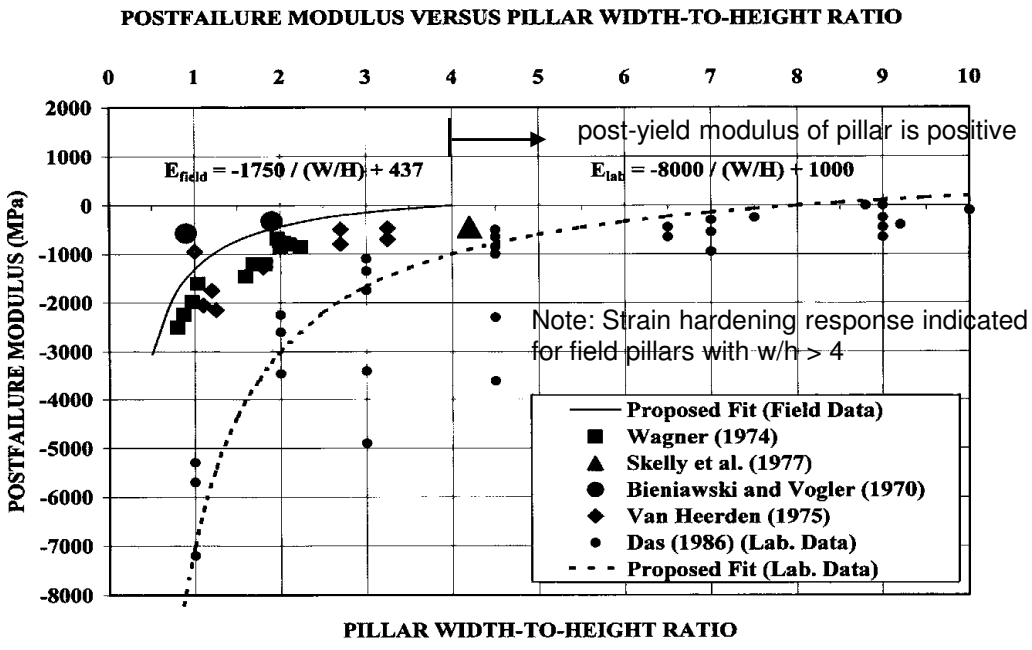
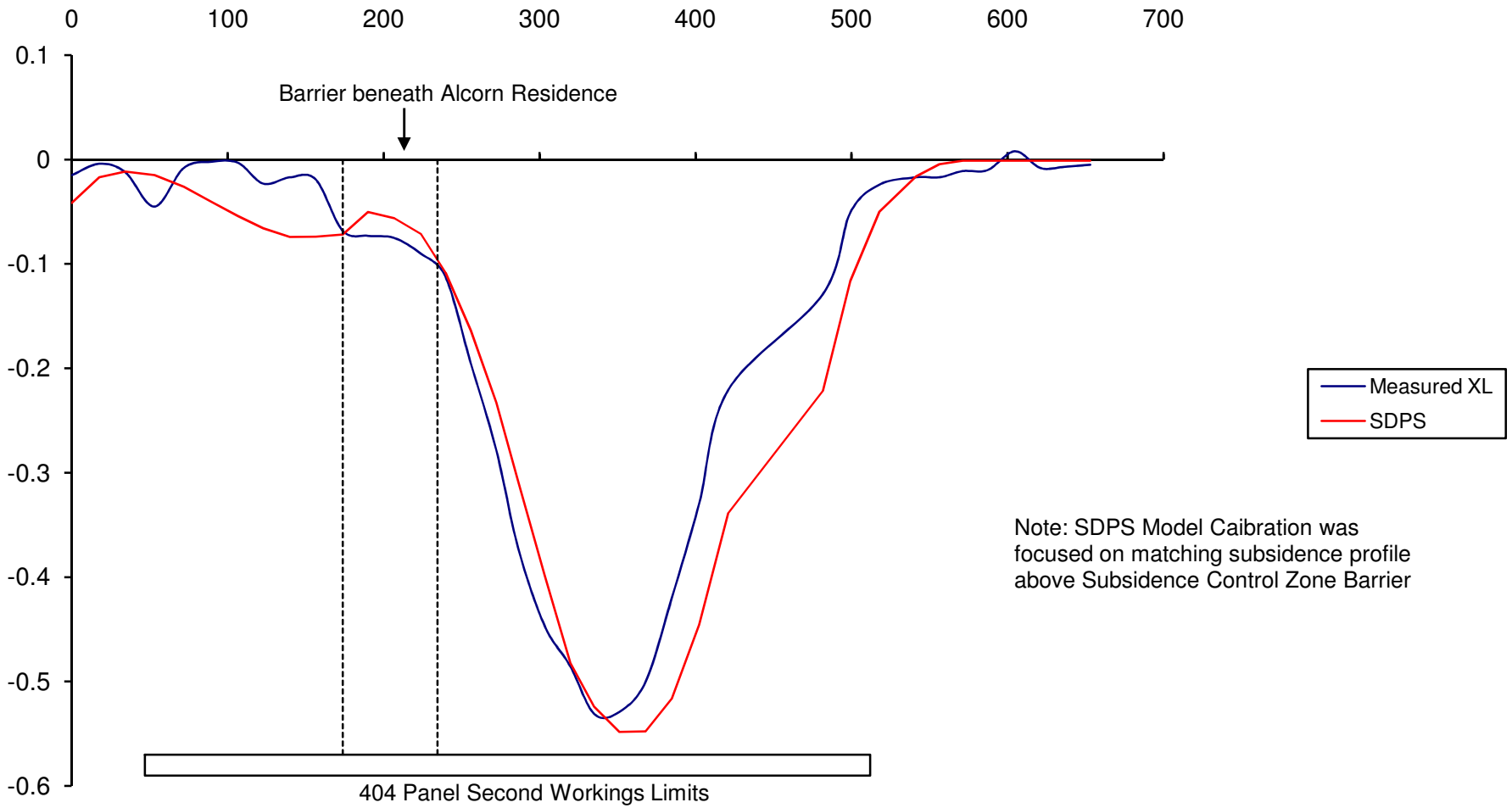


Figure 5.—Summary of postfailure modulus data for full-scale coal pillars and laboratory specimens. Also shown is proposed approximate equation for E_p.

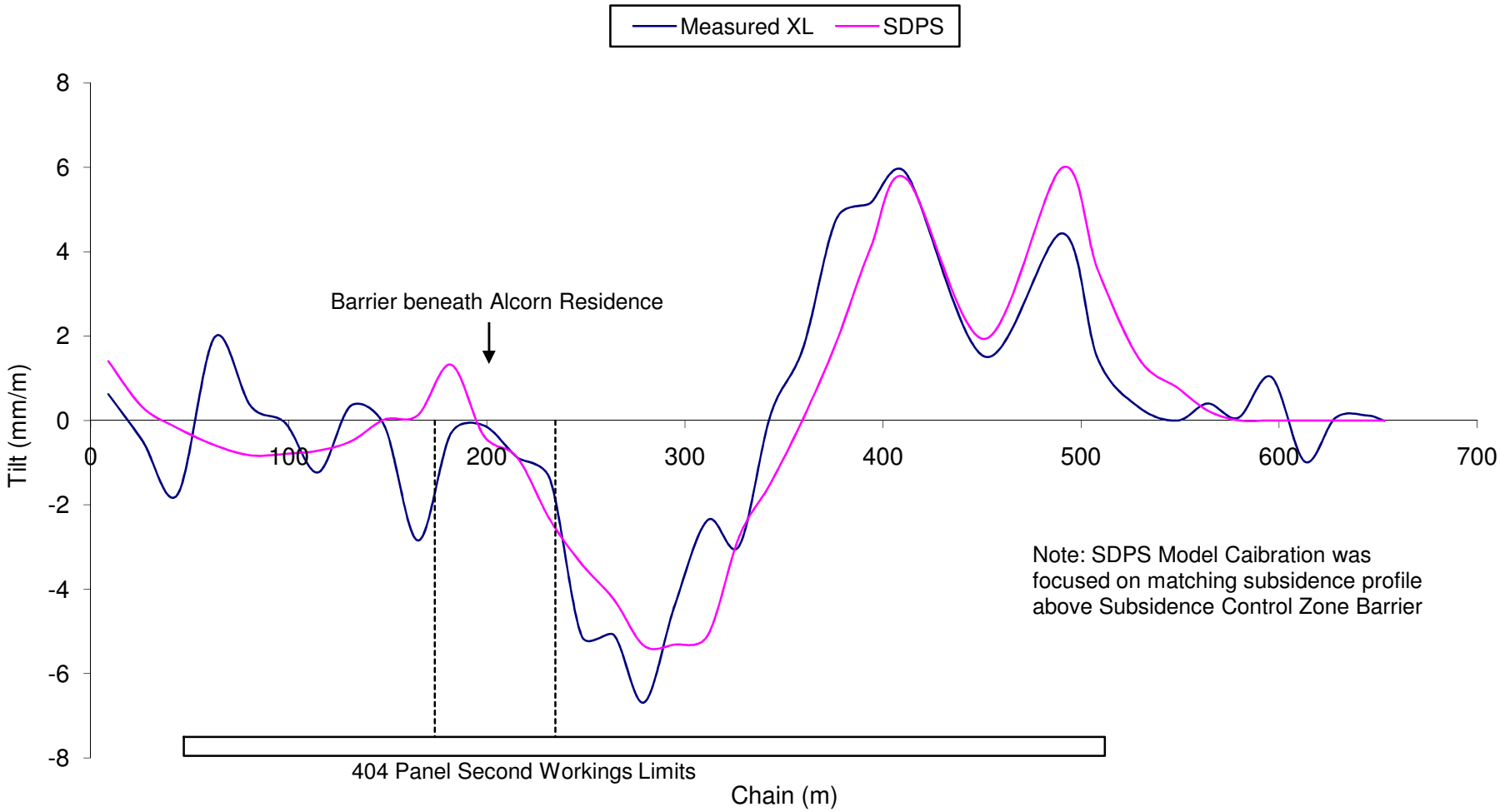
Ref: **Zipf, 1999**

DgS	Engineer:	S.Ditton	Client:	Berrima Colliery	
	Drawn:	S.Ditton		BER-003/1	
	Date:	20.09.10	Title:	In-situ Pillar Stress v. Strain Behaviour for a Range of Pillar Width/Height Ratios	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 8c

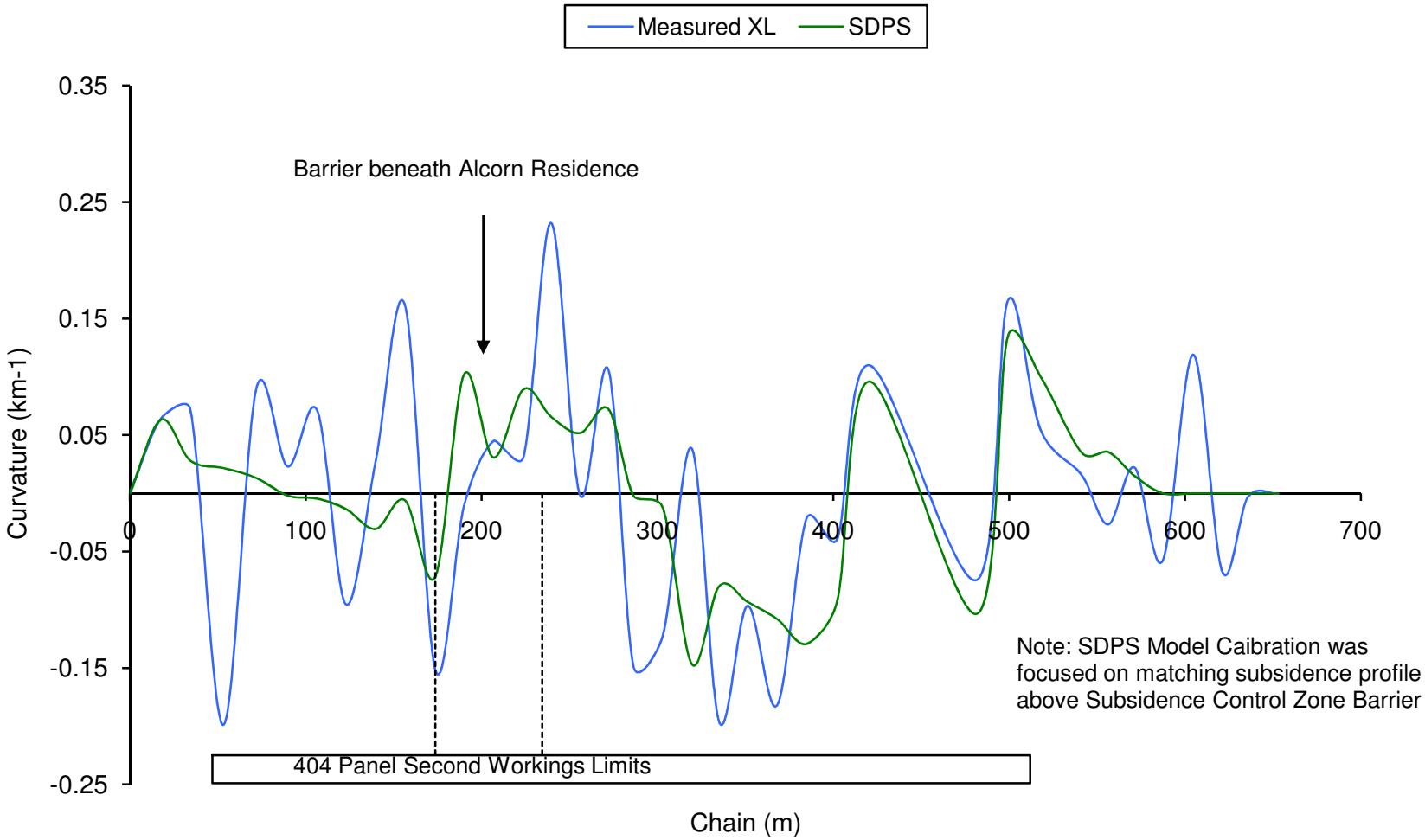


Note: SDPS Model Caibration was focused on matching subsidence profile above Subsidence Control Zone Barrier

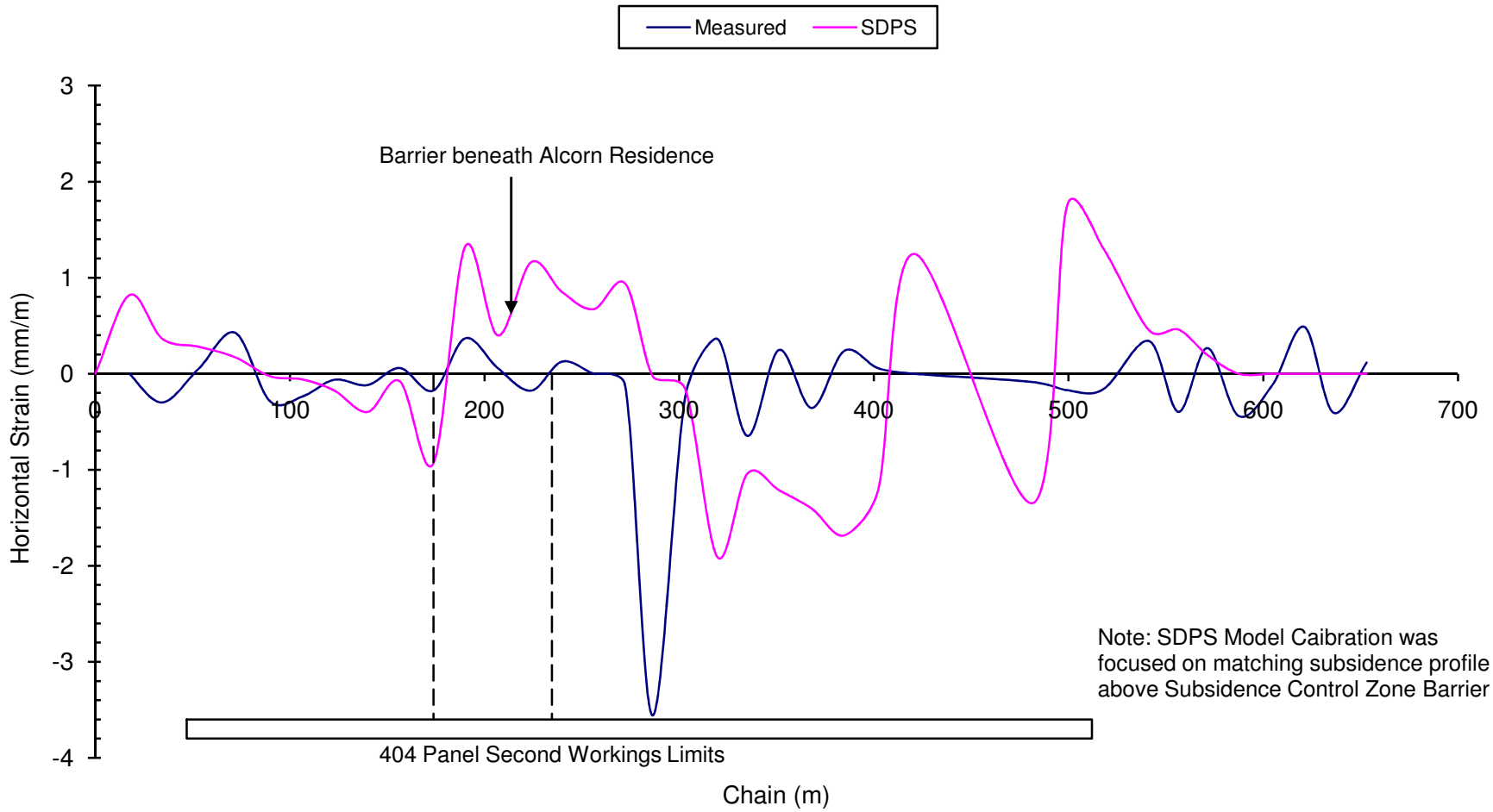
DgS	Engineer:	S.Ditton	Client:	Berrima Colliery BER-003/1	
	Drawn:	S.Ditton			
	Date:	20.09.10	Title:	Calibrated SPDS Model Outcome v. Measured XL Subsidence for 404 Panel Total Extraction Panel	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 9a



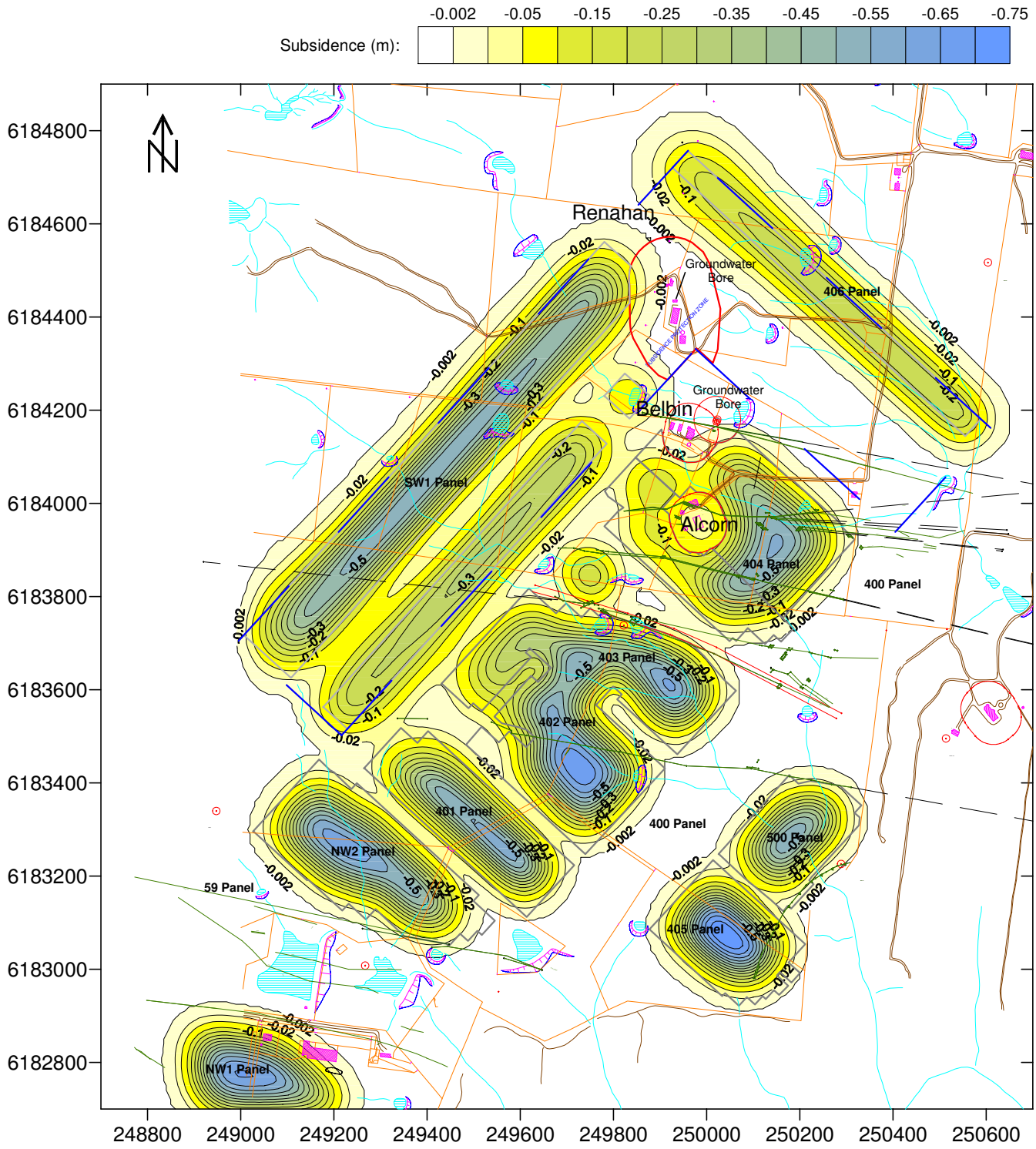
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	Date:	20.09.10	Title:	Calibrated SPDS Model Outcome v. Measured XL Tilt for 404 Panel Total Extraction Panel	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 9b



DgS	Engineer:	S.Ditton	Client:	Berrima Colliery BER-003/1	
	Drawn:	S.Ditton			
	Date:	20.09.10	Title:	Calibrated SPDS Model Outcome v. Measured XL Curvature for 404 Panel Total Extraction Panel	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 9c



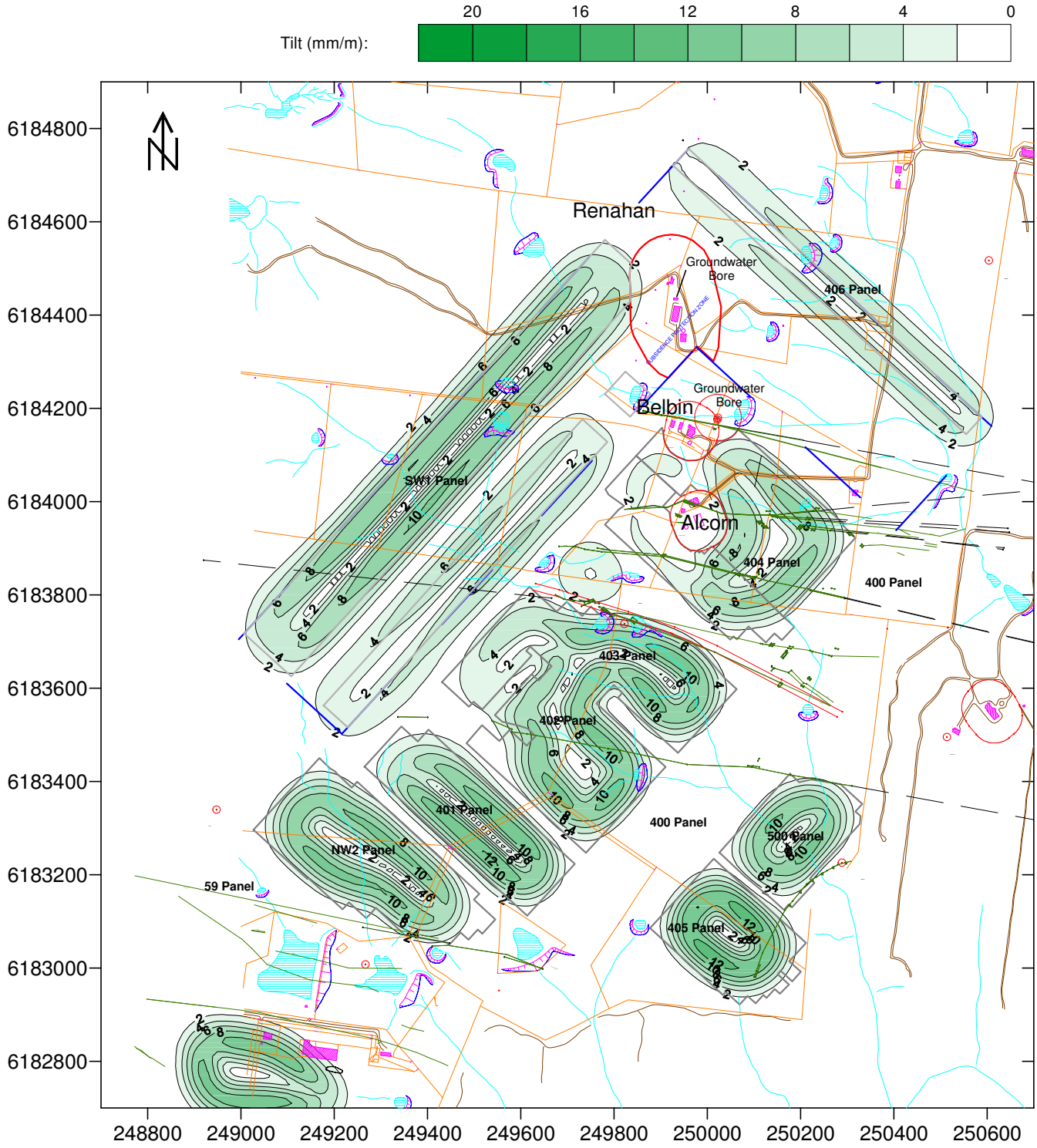
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	Drawn:	S.Ditton		BER-003/1	
	Date:	20.09.10	Title:	Calibrated SPDS Model Outcome v. Measured XL Horoizontal Strain for 404 Panel Total Extraction Panel	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 9d



Key:

- Subsidence (m)
- Old Second Workings
- Proposed Second Workings Area
- Water courses (gullies)
- Farm Dams
- Faults
- Fences
- Buildings/ Sheds/ Tanks
- Power Poles
- Unsealed Roads/ Tracks
- Subsidence Protection Zone Limits

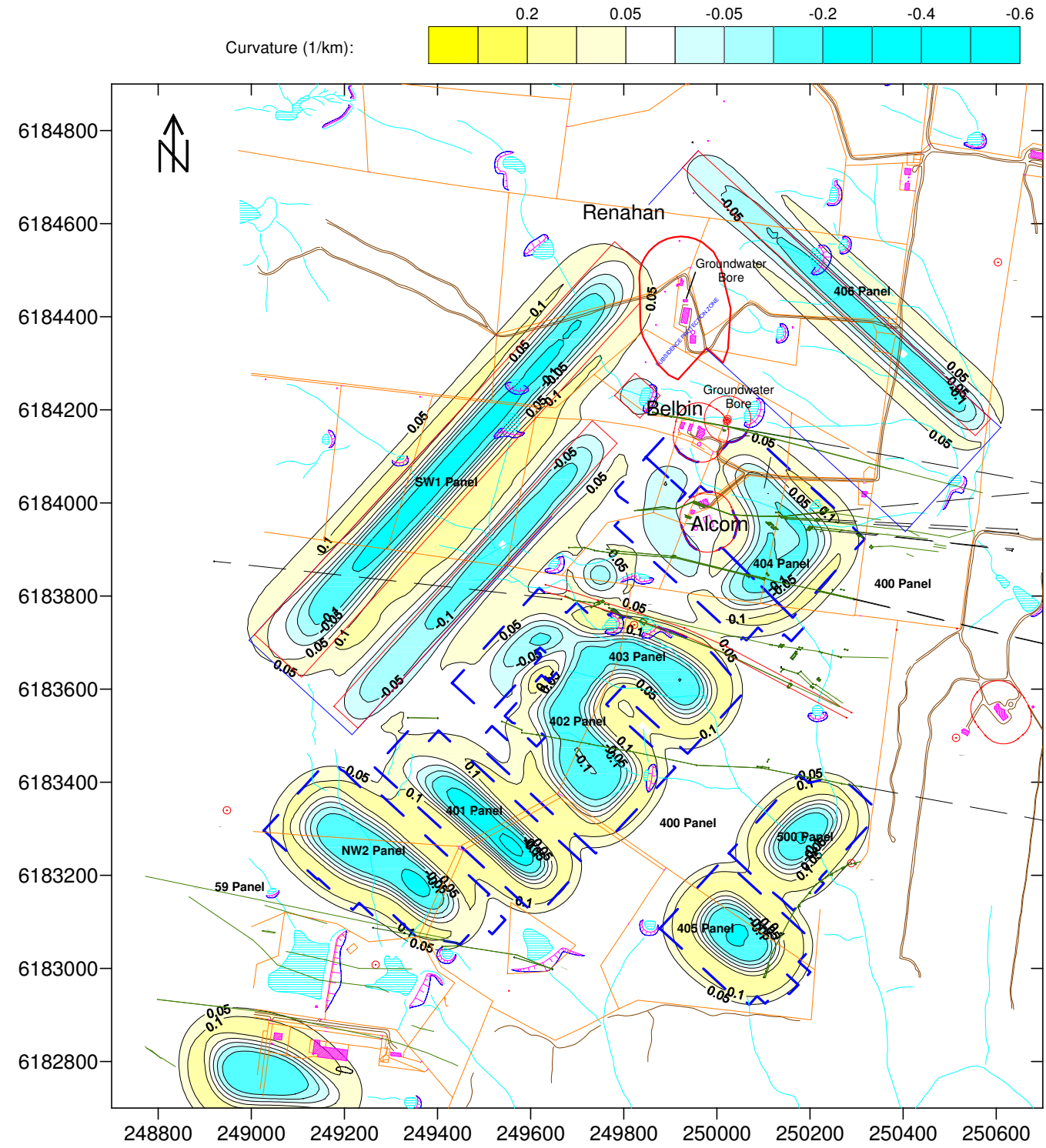
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	Drawn:	S.Ditton			
	Date:	20.09.10	Title:	Predicted Worst-case Subsidence Contours for the Proposed SW1 and 406 Pillar Extraction Panels	
Ditton Geotechnical Services Pty Ltd			Scale:	1:12,500	Figure No: 10



Key:

- Tilt (mm/m)
- Old Second Workings
- Proposed Second Workings Area
- Water courses (gullies)
- Farm Dams
- Faults
- SMP Area Limits
- Fences
- Buildings/ Sheds/ Tanks
- P Power Poles
- Unsealed Roads/ Tracks
- Subsidence Protection Zone Limits

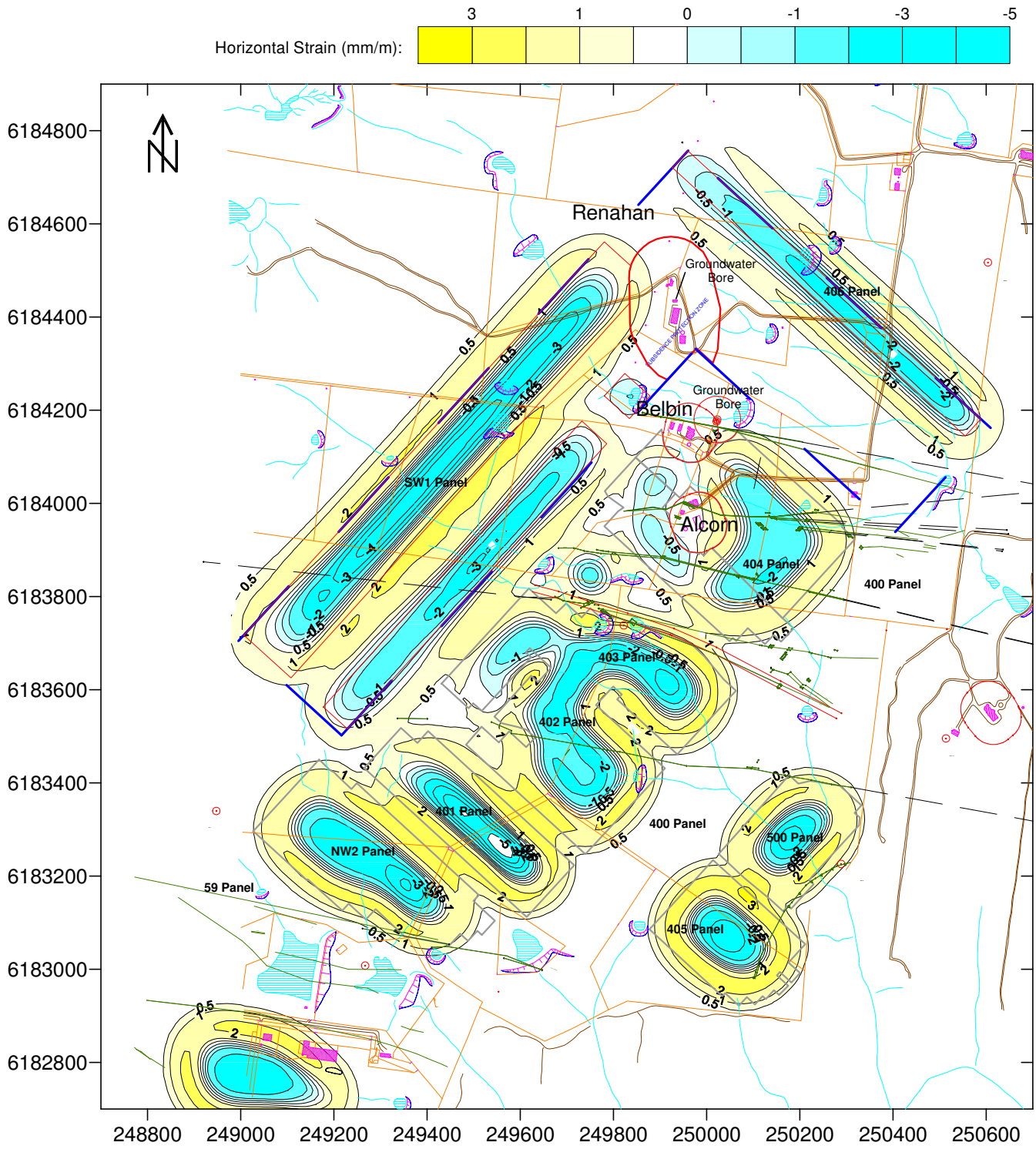
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	Drawn: S.Ditton		
	Date: 20.09.10	Title:	Predicted Worst-case Tilt Contours for the Proposed SW1 and 406 Pillar Extraction Panels
Ditton Geotechnical Services Pty Ltd		Scale:	1:12,500 Figure No: 11



Key:

- Curvature (1/km)
- Old Second Workings
- Proposed Second Workings Area
- Water courses (gullies)
- Farm Dams
- Faults
- SMP Area Limits
- Fences
- Buildings/ Sheds/ Tanks
- P Power Poles
- Unsealed Roads/ Tracks
- Subsidence Protection Zone Limits

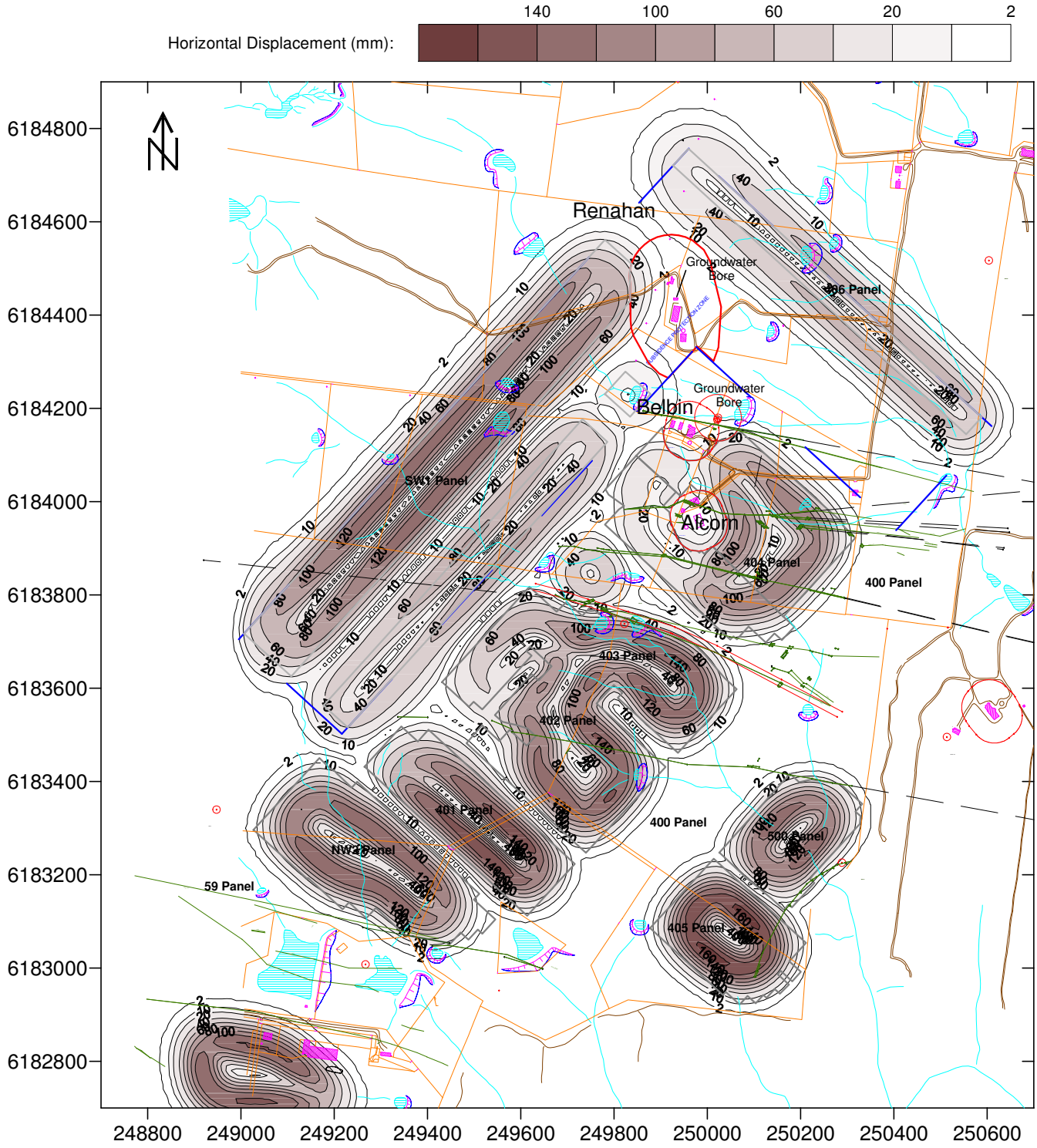
DgS	Engineer:	S.Ditton	Client:	Berrima Colliery BER-003/1	
	Drawn:	S.Ditton			
	Date:	20.09.10	Title:	Predicted Worst-case Curvature Contours for the Proposed SW1 and 406 Pillar Extraction Panels	
Ditton Geotechnical Services Pty Ltd			Scale:	1:12,500	Figure No: 12



Key:

- Strain (mm/m)
- Old Second Workings
- Proposed Second Workings Area
- Water courses (gullies)
- Farm Dams
- Faults
- SMP Area Limits
- Fences
- Buildings/ Sheds/ Tanks
- P Power Poles
- Unsealed Roads/ Tracks
- Subsidence Protection Zone Limits

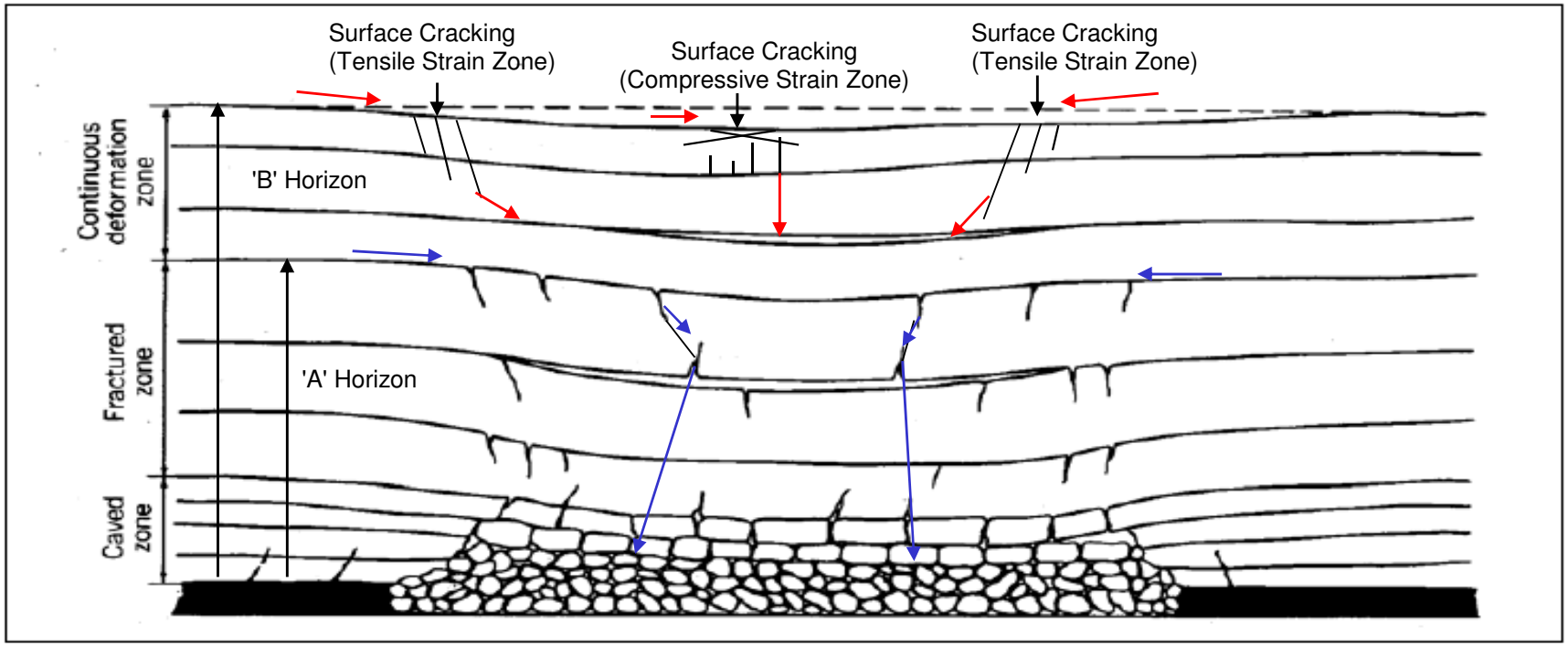
DgS	Engineer:	S.Ditton	Client:	Berrima Colliery BER-003/1	
	Drawn:	S.Ditton			
	Date:	20.09.10	Title:	Predicted Worst-case Horizontal Strain Contours for the Proposed SW1 and 406 Pillar Extraction Panels at Berrima Colliery	
Ditton Geotechnical Services Pty Ltd			Scale:	1:12,500	Figure No: 13



Key:

- Tilt (mm/m)
- Old Second Workings
- Proposed Second Workings Area
- Water courses (gullies)
- Farm Dams
- Faults
- SMP Area Limits
- Fences
- Buildings/ Sheds/ Tanks
- P Power Poles
- Unsealed Roads/ Tracks
- Subsidence Protection Zone Limits

DgS	Engineer:	S.Ditton	Client:	Berrima Colliery BER-003/1	
	Drawn:	S.Ditton			
	Date:	20.09.10	Title:	Predicted Worst-case Horizontal Displacement Contours for the Proposed SW1 and 406 Pillar Extraction Panels	
Ditton Geotechnical Services Pty Ltd			Scale:	1:12,500	Figure No: 14



Zones in the Overburden According to Peng and Chiang (1984)

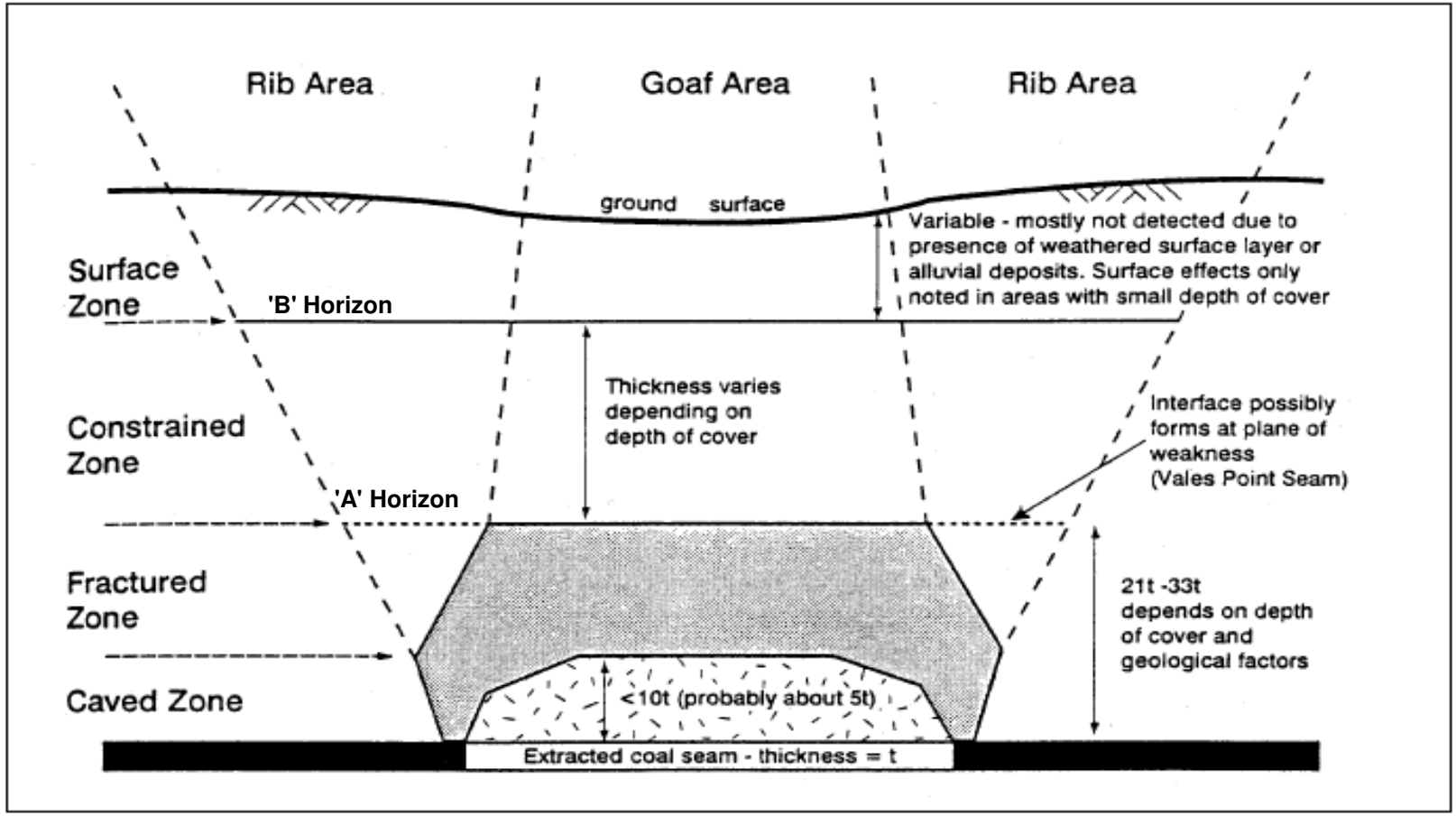
Key

'A' Horizon - Zone of Continuous Crack Connection to Workings (**Whittaker and Reddish,1989**)

'B" Horizon - Zone Of Discontinuous Crack Connection to Workings (**Whittaker and Reddish, 1989**)

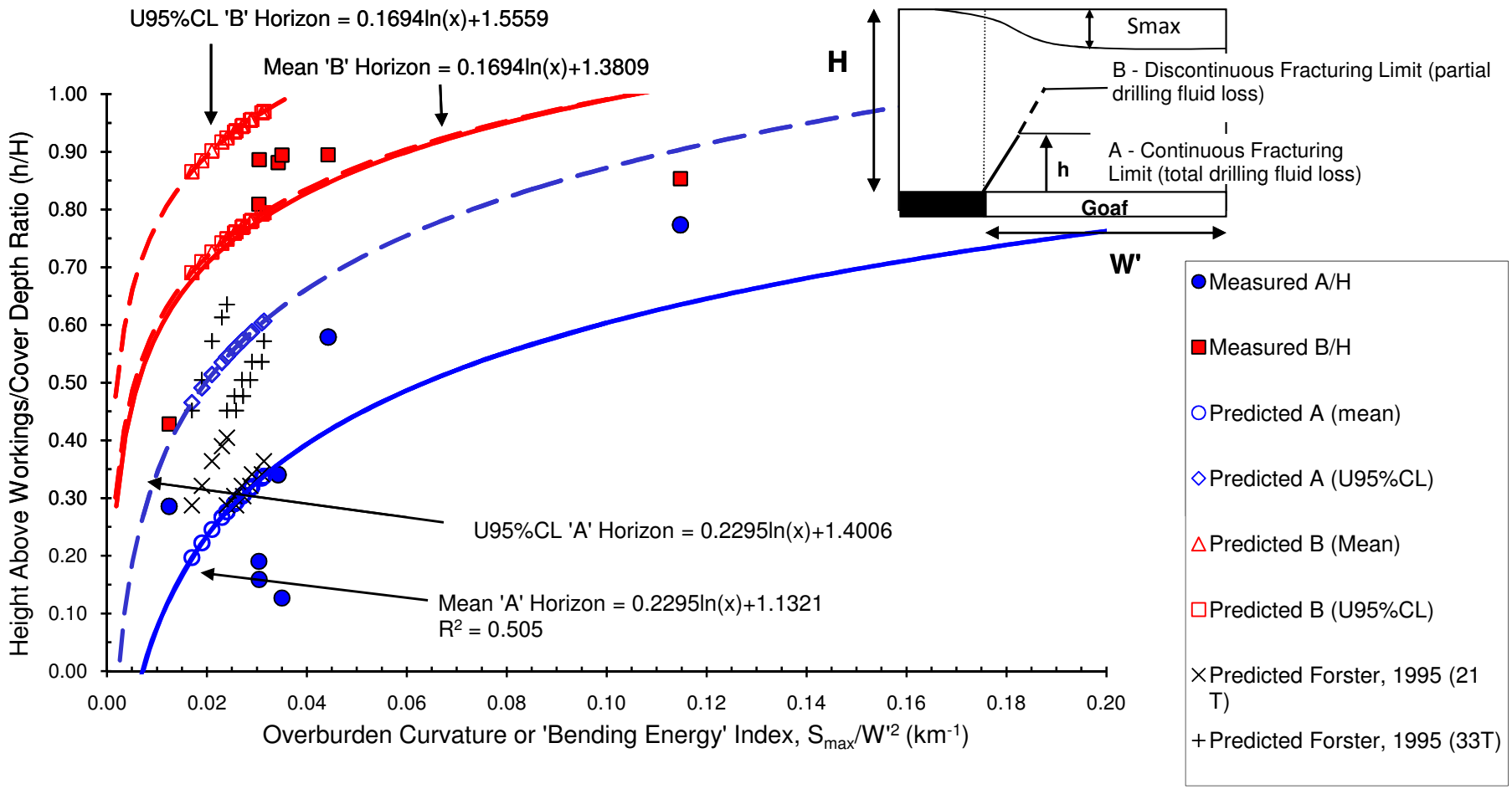
→ Surface water flow path → Sub-surface water flow path

DgS	Engineer:	S.Ditton	Client:	Berrima Colliery BER-003/1	
	Drawn:	S.Ditton			
	Date:	20.09.10	Title:	Schematic Model of Overburden Fracture Zones by Various Researchers	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 15

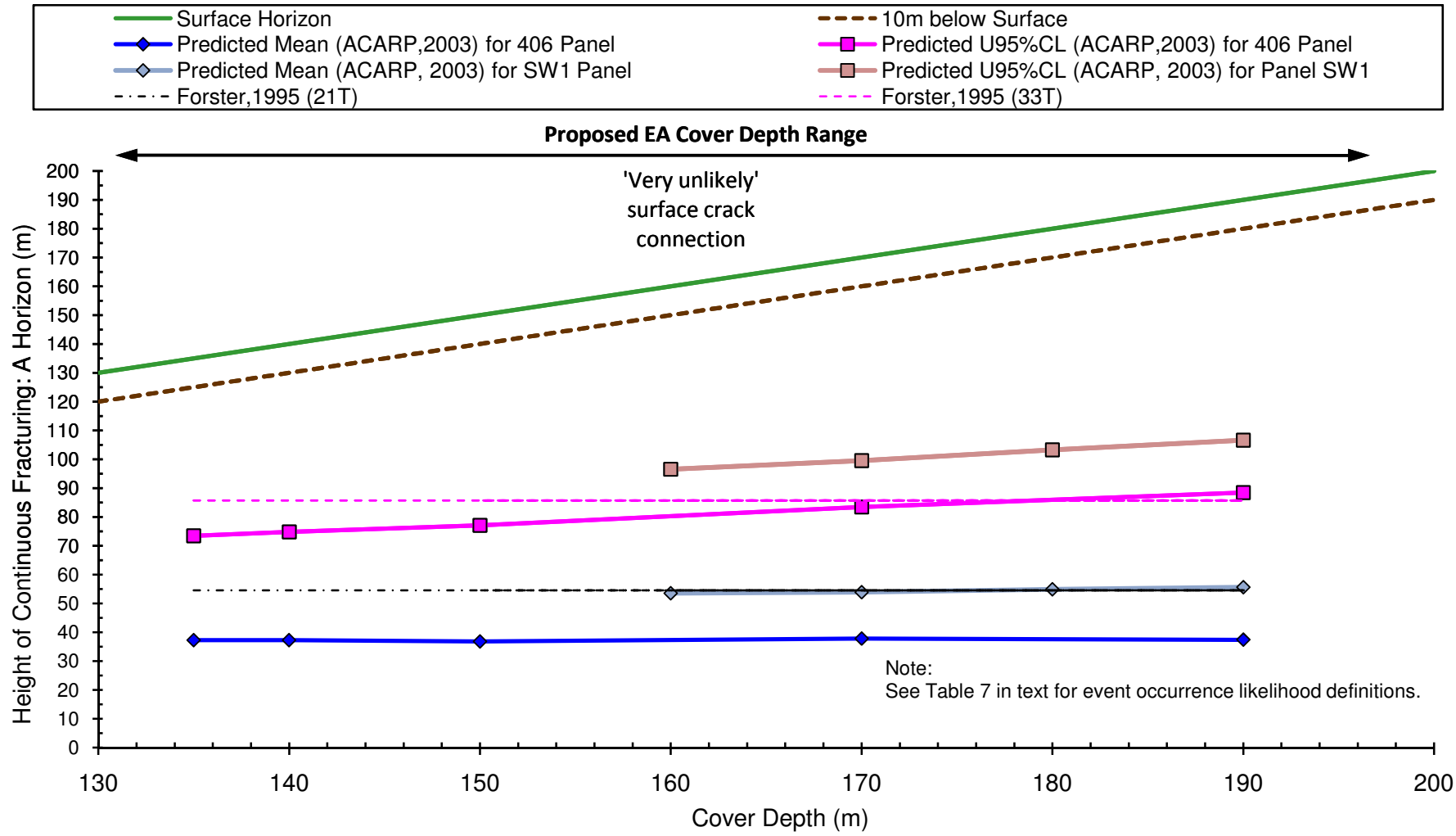


Zones in the Overburden according to Forster (1995)

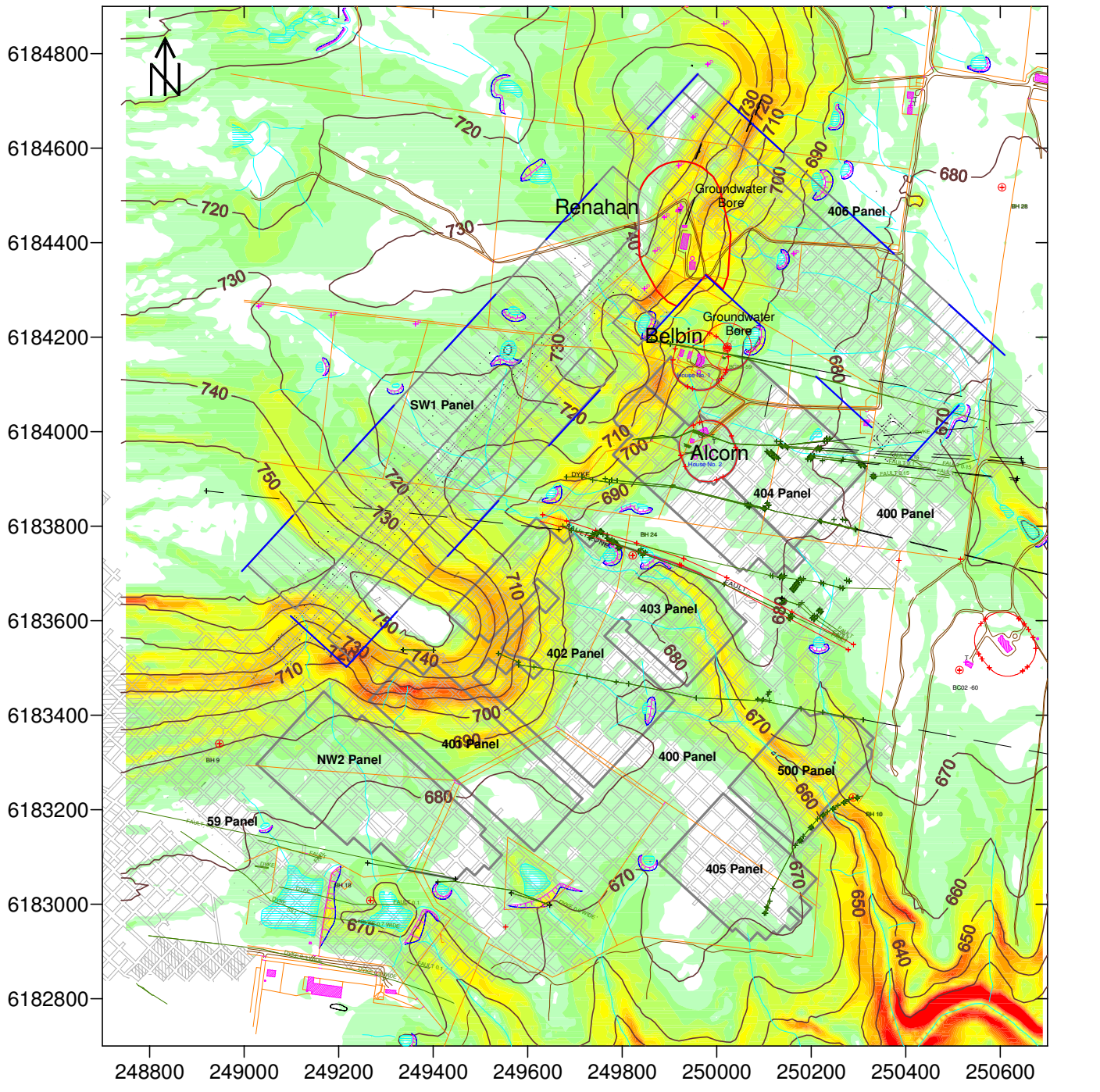
DgS	Engineer:	S.Ditton	Client:	Berrima Colliery BER-003/1	
	Drawn:	S.Ditton			
	Date:	20.09.10	Title:	Schematic Model of Overburden Fracture Zones in **Forster, 1995** Model (based on Piezometric Data Above Total Extraction Panels in the Newcastle Coalfield)	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 16



DgS	Engineer:	S.Ditton	Client:	Berrima Colliery	
	Drawn:	S.Ditton		BER-003/1	
	Date:	20.09.10	Title:	Continuous and Discontinuous Sub-Surface Fracture Heights above the Proposed Pillar Extraction Panels (based on ACARP, 2003 and Forster,1995)	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 17



DgS	Engineer:	S.Ditton	Client:	Berrima Colliery	
	Drawn:	S.Ditton		BER-003/1	
	Date:	20.09.10	Title:	Predicted Sub-surface Fracture Height v. Cover Depth above	
	Ditton Geotechnical Services Pty Ltd			Extraction Panels (based on ACARP, 2003 Model)	
			Scale:	NTS	Figure No: 18

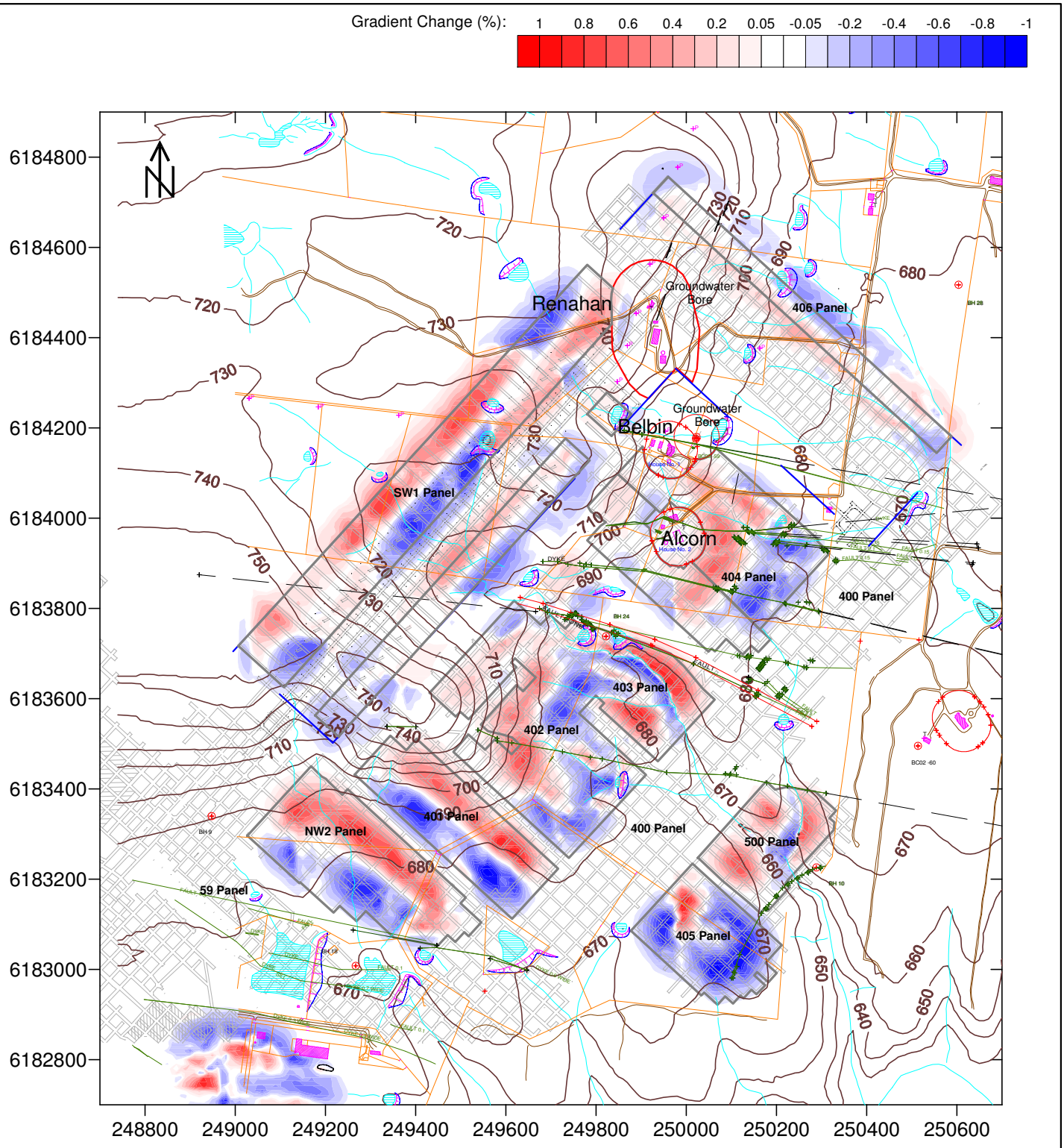


Surface Slopes (o): 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0

Key:

- Surface Levels (AHD)
- Second Workings Limits
- First Workings Limits
- SMP Area Limits
- Water courses (gullies)
- Farm Dams
- Faults
- Landslip Scarps
- Fences
- Buildings/ Sheds/ Tanks
- P Power Poles
- Unsealed Roads/ Tracks
- Subsidence Protection Zone Limits

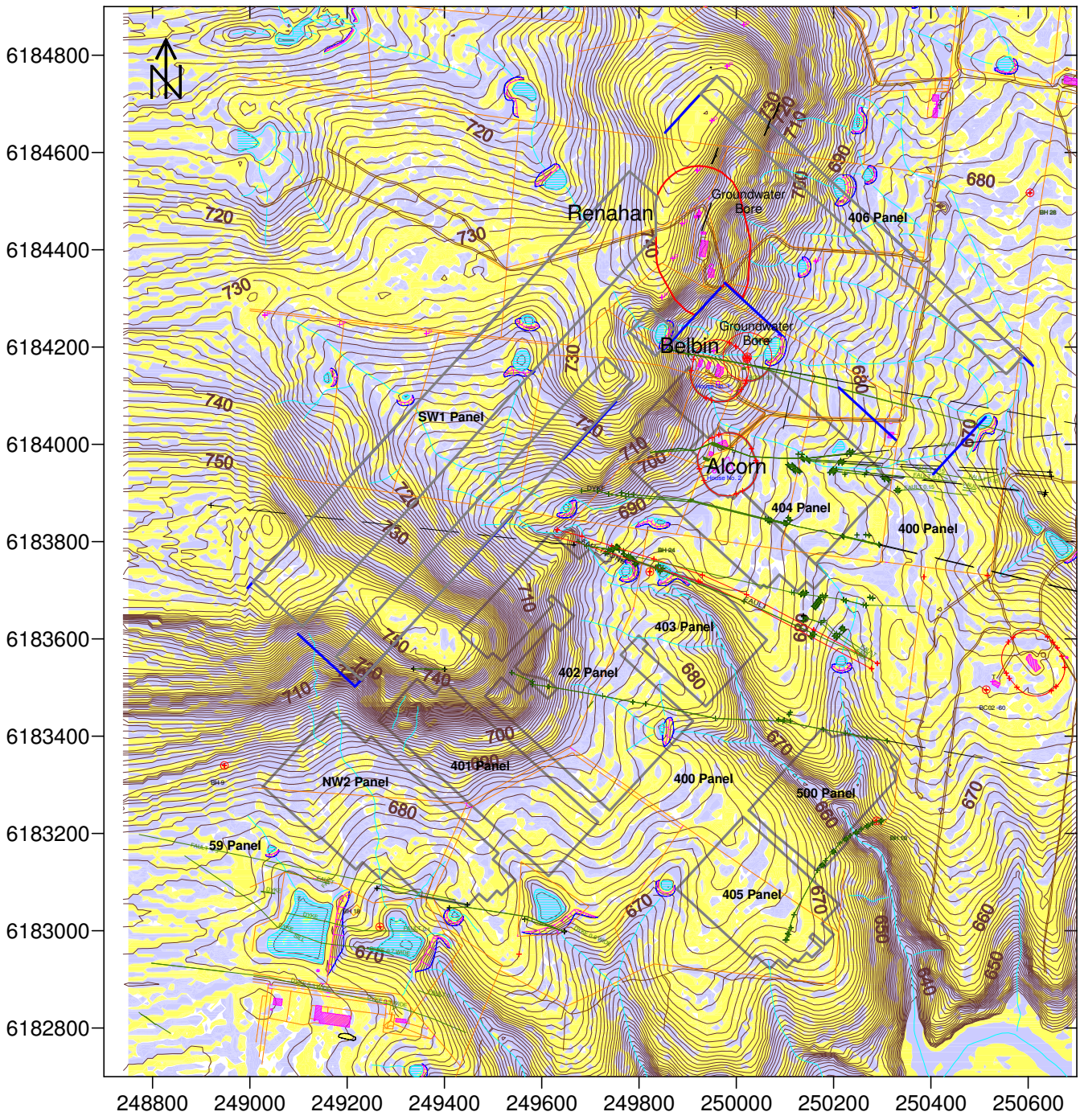
DgS	Engineer: S.Ditton	Client:	Berrima Colliery BER-003/1
	Drawn: S.Ditton		
	Date: 20.09.10	Title:	Proposed SW1, 406 and 59 Panels with Post Mining Surface Topography, Ground Slopes and Surface Features
Ditton Geotechnical Services Pty Ltd		Scale: 1:12,500	Figure No: 19



Key:

- Surface Levels (AHD)
- Second Workings Limits
- First Workings
- SMP Area Limits
- Water courses (gullies)
- Farm Dams
- Faults
- Landslip Scarps
- Fences
- Buildings/ Sheds/ Tanks
- Power Poles
- Unsealed Roads/ Tracks
- Subsidence Protection Zone Limits

DgS	Engineer:	S.Ditton	Client:	Berrima Colliery BER-003/1	
	Drawn:	S.Ditton			
	Date:	20.09.10	Title:	Post Mining Surface Slope Changes and Levels after the Proposed Panels 406 and SW1 are Extracted	
	Ditton Geotechnical Services Pty Ltd		Scale:	1:12,500	Figure No: 20

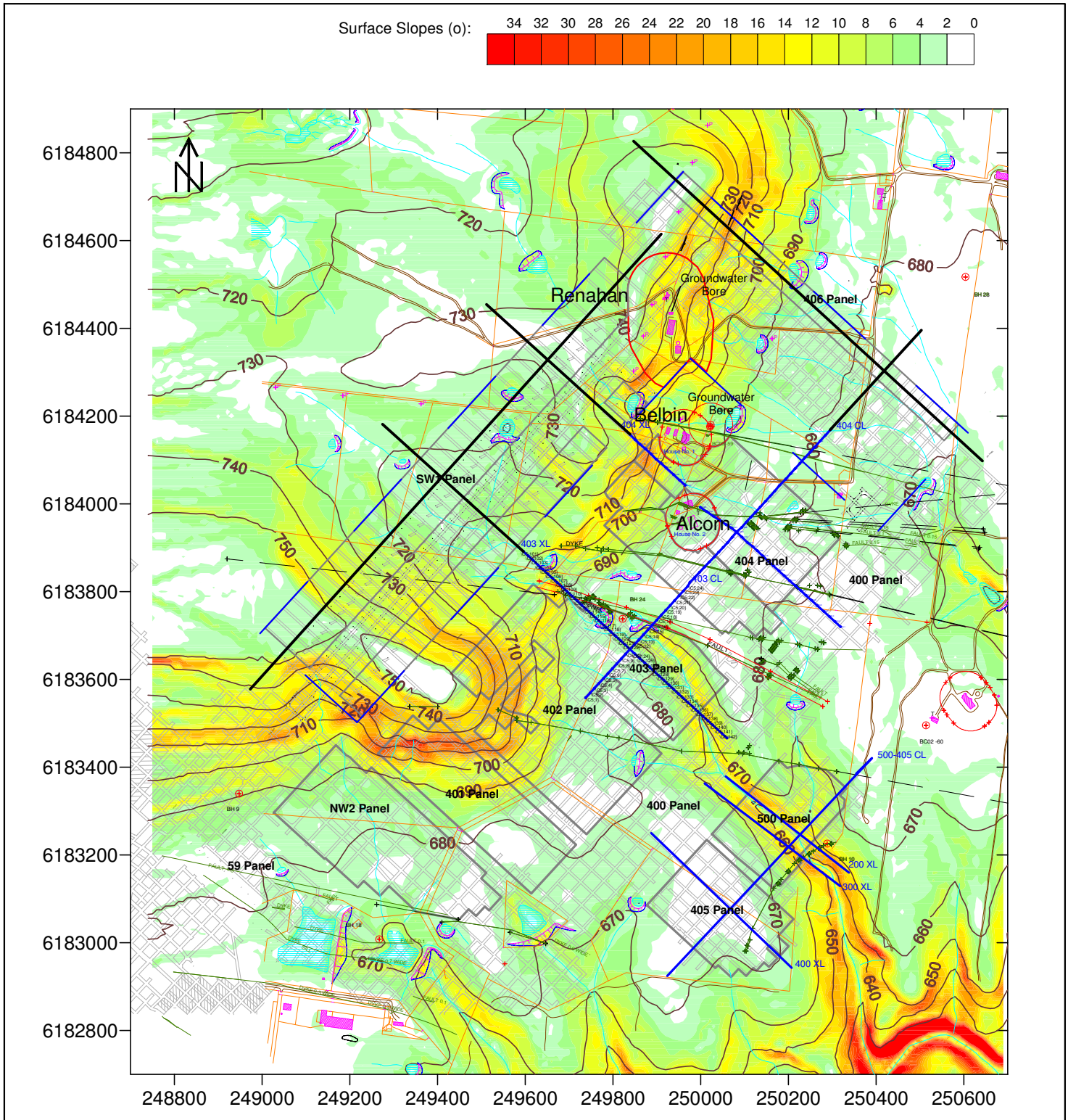


Surface Curvature: Convex (Hog) — Concave (Sag)

Key:

- Surface Levels (AHD)
- Second Workings Limits
- SMP Area Limits
- Water courses (gullies)
- Farm Dams
- Faults
- Landslip Scarps
- Fences
- Buildings/ Sheds/ Tanks
- P Power Poles
- Unsealed Roads/ Tracks
- Subsidence Protection Zone Limits

DgS	Engineer: S.Ditton	Client:	Berrima Colliery BER-003/1
	Drawn: S.Ditton		
	Date: 20.09.10	Title:	Post-mining Topography (1 m contours) due to Proposed SW1, 406 and 59 Panels for Ponding Potential Assessment
Ditton Geotechnical Services Pty Ltd		Scale: 1:12,500	Figure No: 21



Key:

- Surface Levels (AHD)
- Second Workings Limits
- First Workings Limits
- SMP Area Limits
- Existing Survey Lines
- Water courses (gullies)
- Farm Dams
- Faults
- Landslip Scarps
- Proposed Survey Lines
- Fences
- Buildings/ Sheds/ Tanks
- Power Poles
- Unsealed Roads/ Tracks
- Subsidence Protection Zone Limits

DgS	Engineer:	S.Ditton	Client:	Berrima Colliery BER-003/1	
	Drawn:	S.Ditton			
	Date:	20.09.10	Title:	Proposed Subsidence Monitoring Lines Above the Proposed SW1 and 406 Panels	
	Ditton Geotechnical Services Pty Ltd		Scale:	1:12,500	Figure No: 22

APPENDIX A - Extract from SDPS® User Manual

S D P S

Surface Deformation Prediction System
for Windows
version 5.2

Quick Reference Guide and Working Examples

by

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Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061-0239

This software package is the property of the Department of Mining and Minerals Engineering, VPI & SU. It has been licensed and may be distributed only to O.S.M.R.E. and State Regulatory Agencies. The SDPS software can be purchased by individuals and/or companies through Carlson Software.

February 2002

List of Symbols

w	the panel width; the minimum dimension of a panel
h	panel depth; the vertical distance between the mining horizon and the surface; also known as the overburden thickness
m	the seam thickness; the extraction thickness (note that the extraction thickness may be different than the seam thickness)
R	the extraction ratio
R*	the adjusted extraction ratio
d	the distance of the inflection point from the rib (a positive value indicates that the position of the inflectionpoint is inby); also referred to as the “edge effect”
β	the influence angle
r	the influence radius
Smax	the maximum subsidence
a	the maximum subsidence factor
Bs	the strain coefficient
%HR	the percent hardrock in the overburden
Wp	the pillar width
Hp	the pillar height
Wo	the opening width

1.7 Overview of Subsidence Parameters

Maximum Subsidence Factor
The values of maximum subsidence factor, as function of the width-to-depth ratio and the percent hardrock in the overburden, are shown in the supercritical subsidence factor tables for longwall panels and for room-and-pillar panels respectively. When using the profile function method, the subsidence factor is calculated for the actual width-to-depth ratio of the panel. For example, for a panel with W/h = 0.8 (subcritical) and %HR = 50% the subsidence factor is equal to 0.38.

When using the influence function method, the technique requires knowledge of the supercritical subsidence factor, which will subsequently be adjusted through the superposition concept by the program itself. For example, for a panel with W/h = 0.8 (subcritical) and %HR = 50% the subsidence factor is found for W/h = 1.5 (supercritical) and equal to 0.40.

Notes:
A panel is considered supercritical for W/h greater than 1.2. Due to numerical approximations there may be slight variations to the supercritical subsidence factors presented in the supercritical subsidence factor tables.

Inflection Point
The location of the inflection point from the rib, with respect to overburden depth (d/h), can be estimated based on two empirical curves (see the Inflection Point Diagram). Both curves were statistically generated from the available field data. The first is an average curve based on a least squares estimator, while the second is considered an envelope or conservative curve in the sense that it tends to overpredict the surface impact of a given excavation area. In essence, this means that for average data the predicted subsidence profile could be either inside or outside of the measured subsidence line, whereas for conservative (envelope) data, an attempt is made to keep the prediction lines outside the measured ones, i.e. overestimate the influence of the mined area to the surface.

From experience and constant validation of the programs, the authors recommend that, for Appalachian predictions, improved accuracy is obtained by using the following rule:
determine the d/h ratio using the conservative curve for subcritical panels (W/h < 1.2)
determine the d/h ratio using the average curve for supercritical panels (W/h >= 1.2).

Notes:
Always use the actual width-to-depth ratio.

Angle of Influence
The angle of principal influence (β, beta) is one of the basic parameters used in the influence function method since it has a major impact on the distribution of the deformations on the surface. It is measured in degrees from the horizontal and the

average value determined for the Appalachian coalfields is beta=67 deg. The parameter required for these calculations is the tangent of this angle (i.e. tanβ = 2.31). The angle of influence is related to the radius of influence as shown in the equation:

$$\tan\beta = \frac{h}{r}$$

where
h = the overburden depth
r = the radius of influence

This value should be determined for each site by fitting a calculated subsidence profile to a measured subsidence profile. If this is not possible, the influence angle can be approximately set as the complementary angle to the angle of draw.

Supercritical Subsidence Factor Tables
The supercritical subsidence factors used in the calculations are presented in Tables 1.7.1 and 1.7.2.

Table 1.7.1: Calculation of maximum subsidence factors (Smax/m) for longwall panels

	Percent Hardrock in the Overburden							
W/h	10%	20%	30%	40%	50%	60%	70%	80%
0.6	0.64	0.59	0.51	0.42	0.34	0.26	0.21	0.16
0.7	0.69	0.63	0.55	0.46	0.36	0.28	0.22	0.18
0.8	0.71	0.65	0.57	0.47	0.38	0.29	0.23	0.18
0.9	0.72	0.66	0.58	0.48	0.38	0.30	0.23	0.19
1.0	0.73	0.67	0.58	0.49	0.39	0.30	0.24	0.19
1.1	0.74	0.68	0.59	0.49	0.39	0.31	0.24	0.19
1.2	0.74	0.68	0.59	0.49	0.39	0.31	0.24	0.19
1.3	0.74	0.68	0.60	0.49	0.40	0.31	0.24	0.19
1.4	0.75	0.69	0.60	0.50	0.40	0.31	0.24	0.19
1.5	0.75	0.69	0.60	0.50	0.40	0.31	0.24	0.19
1.6	0.75	0.69	0.60	0.50	0.40	0.31	0.24	0.19
1.7	0.75	0.69	0.60	0.50	0.40	0.31	0.24	0.19
1.8	0.75	0.69	0.60	0.50	0.40	0.31	0.24	0.19
1.9	0.76	0.69	0.60	0.50	0.40	0.31	0.24	0.19
2.0	0.76	0.69	0.60	0.50	0.40	0.31	0.24	0.19

Table 1.7.2: Calculation of maximum subsidence factors (Smax/(m R*)) for high extraction room-and-pillar panels

	Percent Hardrock in the Overburden							
W/h	10%	20%	30%	40%	50%	60%	70%	80%
0.6	0.52	0.48	0.42	0.35	0.28	0.22	0.17	0.13
0.7	0.57	0.53	0.46	0.38	0.30	0.24	0.19	0.15
0.8	0.60	0.55	0.48	0.40	0.32	0.25	0.19	0.15
0.9	0.61	0.56	0.49	0.41	0.32	0.25	0.20	0.16
1.0	0.62	0.57	0.49	0.41	0.33	0.26	0.20	0.16
1.1	0.62	0.57	0.50	0.41	0.33	0.26	0.20	0.16
1.2	0.63	0.58	0.50	0.42	0.33	0.26	0.20	0.16
1.3	0.63	0.58	0.51	0.42	0.34	0.26	0.20	0.16
1.4	0.64	0.58	0.51	0.42	0.34	0.26	0.21	0.16
1.5	0.64	0.59	0.51	0.42	0.34	0.26	0.21	0.16
1.6	0.64	0.59	0.51	0.42	0.34	0.26	0.21	0.16
1.7	0.64	0.59	0.51	0.43	0.34	0.27	0.21	0.16
1.8	0.64	0.59	0.51	0.43	0.34	0.27	0.21	0.17
1.9	0.64	0.59	0.51	0.43	0.34	0.27	0.21	0.17
2.0	0.64	0.59	0.52	0.43	0.34	0.27	0.21	0.17

Horizontal Strain Factor

The value of this factor is directly related to the magnitude of the calculated strains and curvatures over an undermined area. It can be empirically estimated by the average ratio of measured strain and curvature over a set of surface points.

The average value determined for the Appalachian coalfields is:

$$Bs = (0.35 \pm 0.05)\ \frac{h}{\tan\beta}$$

where h is the excavation depth and tanβ is the influence angle. The horizontal strain factor is expressed in units of length. The horizontal strain coefficient is unitless and its default value is 0.35.

Note: The higher the value for this coefficient, the larger the predicted strains and displacements.

Chapter 3: The Influence Function Method

3.1 Overview of the Influence Function Method

Influence function methods for subsidence prediction have the ability to consider any mining geometry, to negotiate superposition of the influence from a number of excavated areas having different mining characteristics and, also, to calculate horizontal strains as well as other related deformation indices. The function utilized in SDPS is the bell-shaped Gaussian function. This method assumes that the influence function for the two-dimensional case is given by:

$$g(x,s) = \frac{S_o(x)}{r}\exp\left[-\pi\frac{(x-s)^2}{r^2}\right]$$

where:

r	=	the radius of principal influence = h / tan(beta);
h	=	the overburden depth;
beta	=	the angle of principal influence;
s	=	coordinate of the point P, where subsidence is considered;
x	=	coordinate of the infinitesimal excavated element; and
So(x)	=	convergence of the roof of the infinitesimal excavated element.

Subsidence at any point P(s), therefore, can be expressed by the following equation:

$$S(x,s) = \frac{1}{r}\int_{-\infty}^{+\infty} s_o(x)\exp\left[-\pi\frac{(x-r)^2}{r^2}\right]$$

where:

So(x)	=	m(x) a(x);
m(s)	=	extraction thickness; and
a(x)	=	roof convergence (subsidence) factor.

The influence function formulation can thus be applied to calculate surface deformations (subsidence, strain, slope, curvature, displacements) above longwall and room-and-pillar panels, given the geometry of the excavation, information on the overburden geology, as well as the location of the prediction points on the surface. More specifically, the required data include:

- the geometry of the mine plan and the associated properties (extraction thickness, subsidence factor for supercritical conditions)

- the location (coordinates) of the points on the surface for which prediction of the deformation indices (subsidence, strain, slope, curvature, horizontal displacement) is to be performed
- the empirical parameters that numerically represent the behavior of the overburden

The typical steps required to calculate surface deformations using the influence function method, are shown below. The corresponding flowchart is also shown in Figure 3.1.1. Figure 3.1.2 presents a schematic diagram for creating the input data. Figure 3.1.3 presents typical distributions for the deformation indices that can be calculated by the influence function method. Table 3.1.1 shows all the indices that can be calculated by the influence function method.

✓ Load the Influence Function Program
✓ Input Data
✓ Mine Plan Data
  - Prediction Point Data
  - Empirical Parameters
✓ Select calculation options
  - Subsidence
  - Horizontal Strain
  - Horizontal Displacement
  - Slope
  - Curvature
✓ Save Project File
✓ Calculate Surface Deformations
✓ Load Graphing Program
✓ View Calculated Deformations

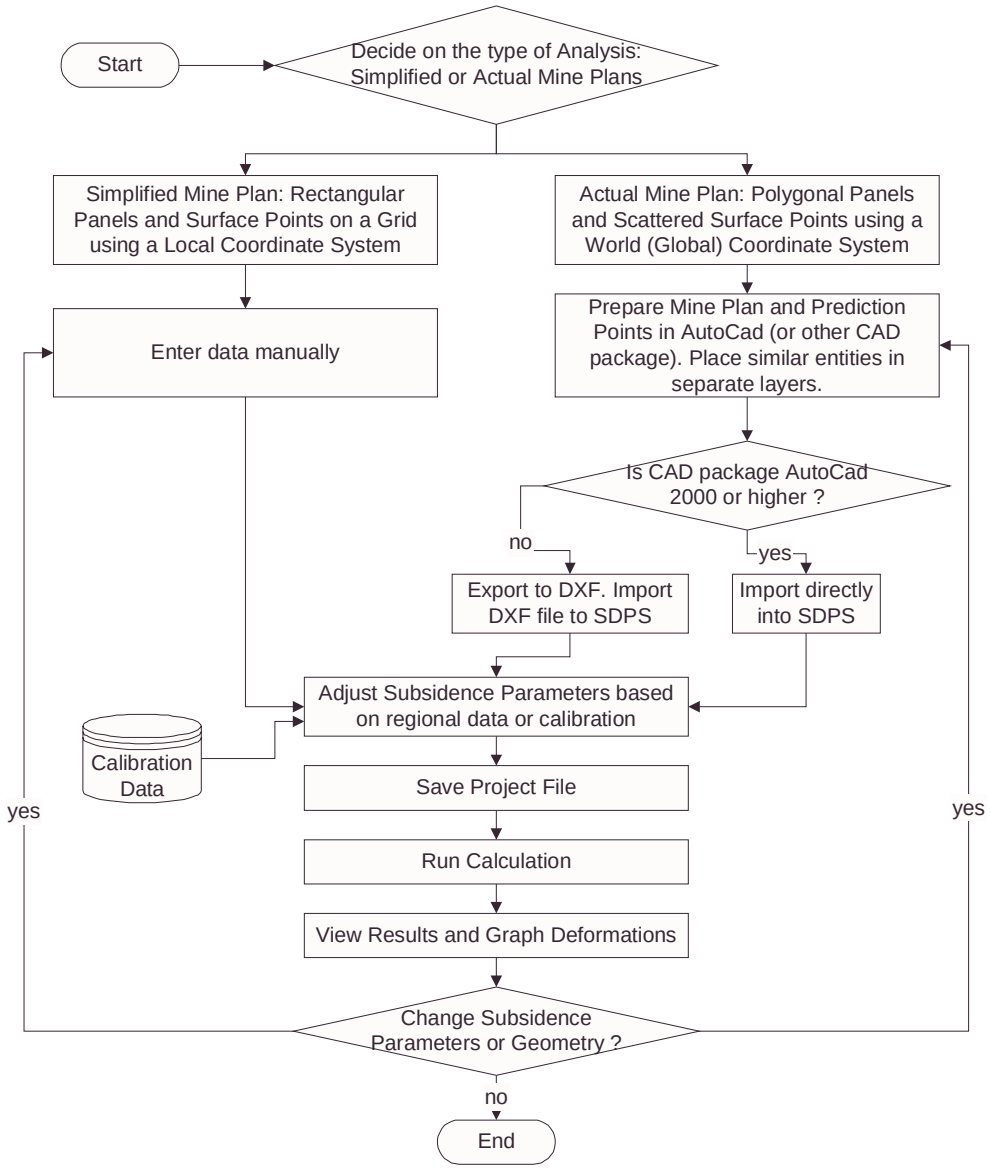
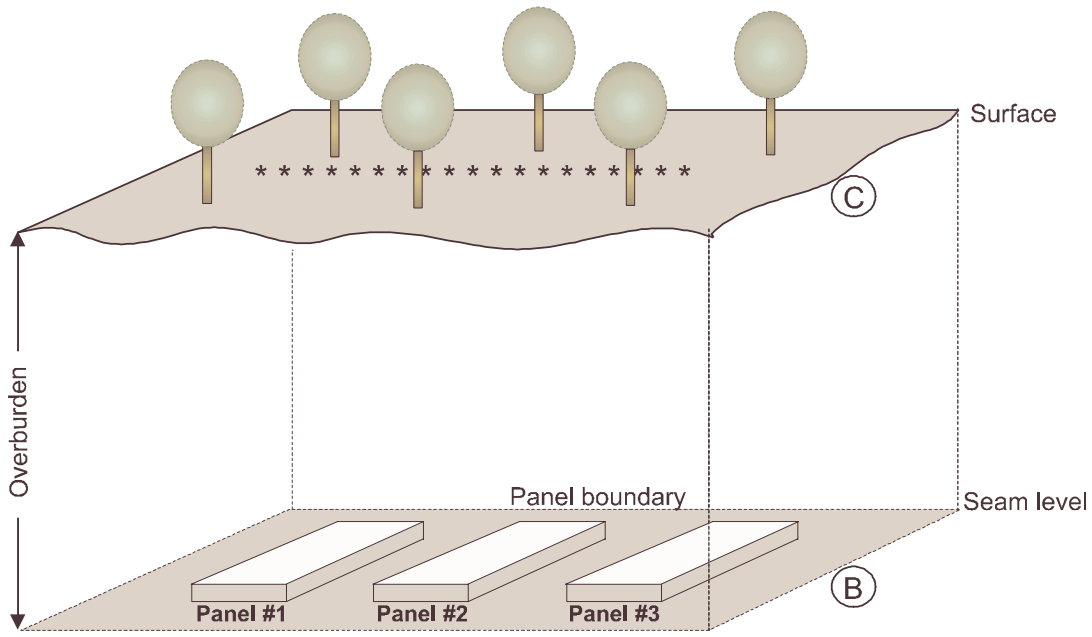


Figure 3.1.1: Flowchart diagram for using the influence function module



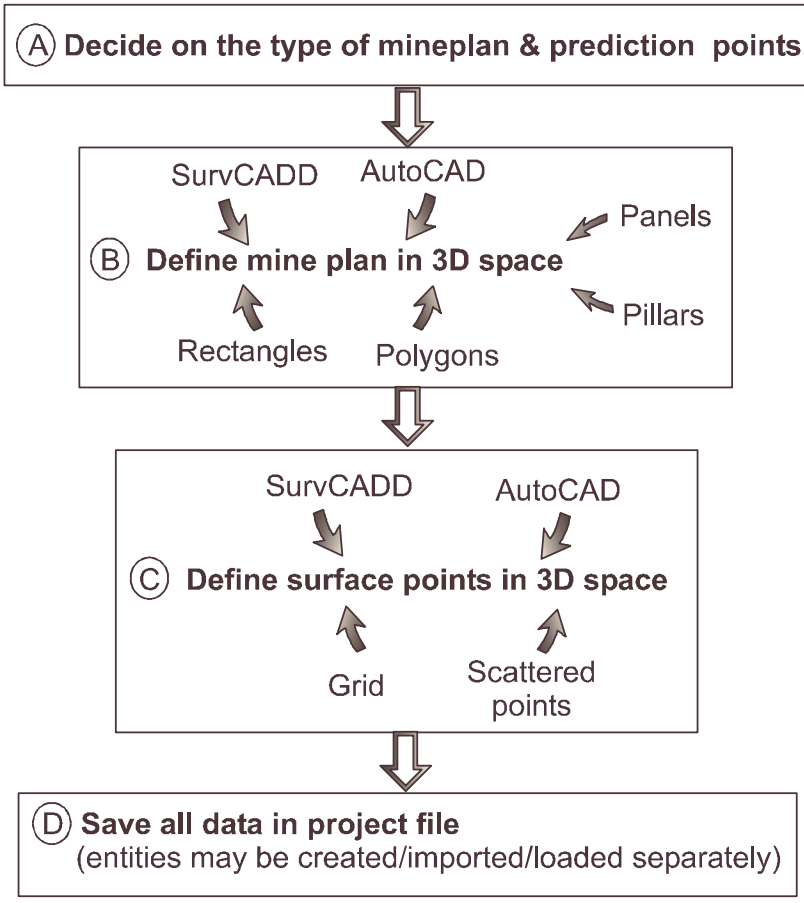
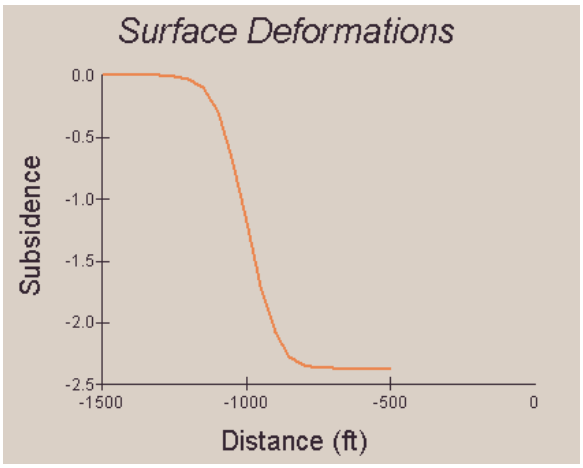
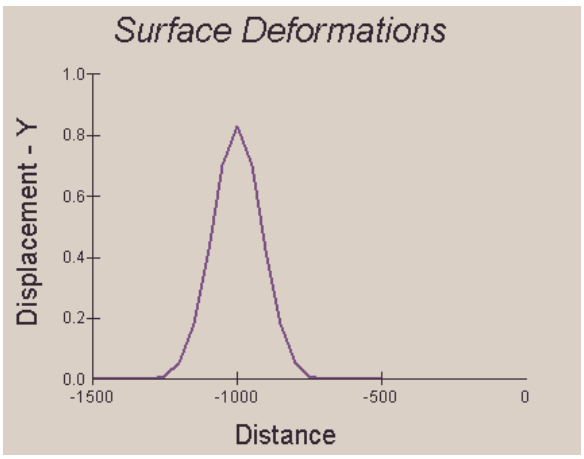
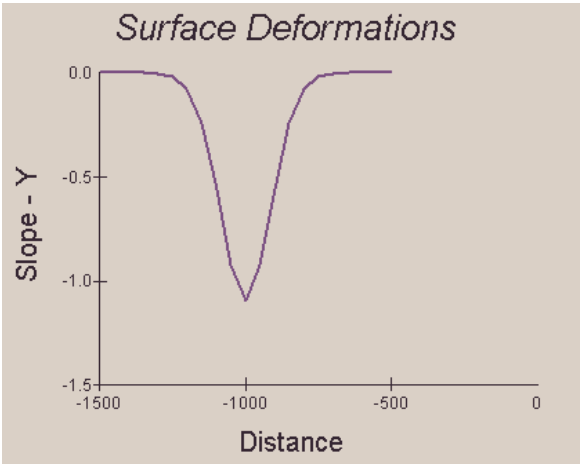


Figure 3.1.2: Steps in defining a project file







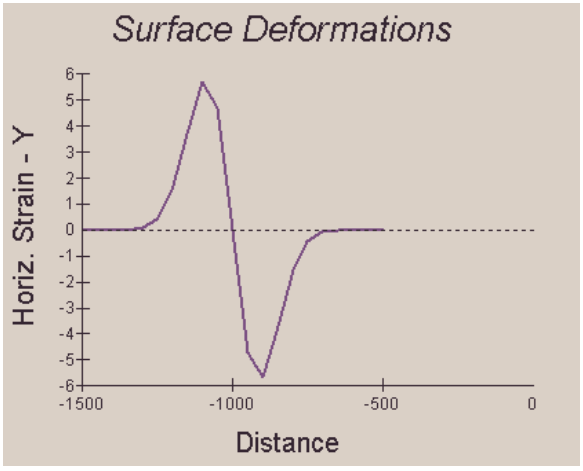


Figure 3.1.3: Typical deformation distributions

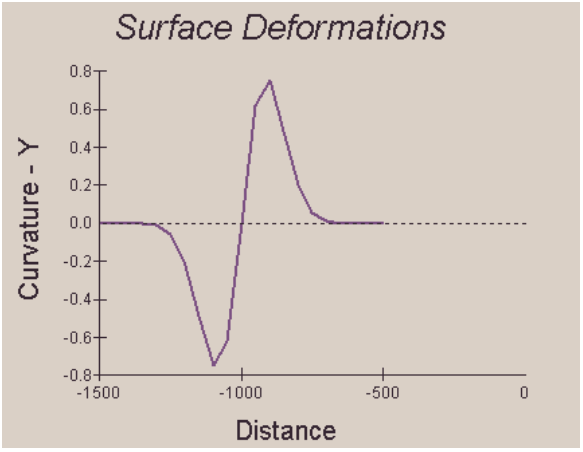


Table 3.1.1: Identification codes for deformation indices

Number	Deformation Index Name	Code	Units
1	Subsidence	SU	ft or m
2	Slope in the X-direction	TX	%
3	Slope in the Y-direction	TY	%
4	Directional Slope	TA	%
5	Maximum (Total) Slope	TM	%
6	Angle[1] of Maximum Slope	TE	deg
7	Horizontal Displacement in the X-direction	VX	ft or m
8	Horizontal Displacement in the Y-direction	VY	ft or m
9	Directional Horizontal Displacement	VA	ft or m
10	Maximum (Total) Horizontal Displacement	VM	ft or m
11	Angle[1] of Maximum Horizontal Displacement	VE	deg
12	Curvature in the X-direction	KX	1/ft or 1/m [2]
13	Curvature in the Y-direction	KY	1/ft or 1/m [2]
14	Directional Curvature	KA	1/ft or 1/m [2]
15	Maximum Principal Curvature	K1	1/ft or 1/m [2]
16	Minimum Principal Curvature	K2	1/ft or 1/m [2]
17	Maximum Curvature	KM	1/ft or 1/m [2]
18	Angle[1] of Maximum Principal Curvature	KE	deg
19	Horizontal Strain in the X-direction	EX	- [3]
20	Horizontal Strain in the Y-direction	EY	- [3]
21	Directional Horizontal Strain	EA	- [3]
22	Maximum Strain	EM	- [3]
23	Maximum Principal Strain	E1	- [3]
24	Minimum Principal Strain	E2	- [3]
25	Angle[1] of Maximum Principal Strain	EE	deg

[1] This angle is calculated in degrees from the positive x-axis in a counter-clockwise direction. It gives the direction of the maximum value of the corresponding index on the x-y plane.

[2] expressed in tenths of ppm (divide by 10.000 to obtain result)

[3] expressed in millistrains (divide by 1000 to obtain result)

3.2 Definition of the Mine Plan in the Influence Function Program

Mine plan data describe the extraction area under consideration using various conventions. An extraction area is always defined in three-dimensional space by specifying the X,Y,Z coordinates of the points defining that area. Mine panels and pillars are referred to as excavation parcels. A parcel can be either active or not active. A parcel, which is not active, is not deleted from the file, but it does not participate in the calculations.

Geometry and Boundary Adjustment:

The geometry of a mine plan is determined by the geometry of the excavation panels adjusted by the edge effect. This parameter represents the distance between the actual rib of the excavation and the position of the inflection point, as determined by panel geometry and site characteristics. The location of the inflection point, which defines the transition between horizontal tensile and compressive strain zones, is very important for the application of the influence function method. The distance of the inflection point from the rib using either an average and a conservative estimate as a function of the width-to-depth ratio of a panel can be estimated using this graph.

Thus, the magnitude of the edge effect can be determined as follows:

- ✓ from the graph estimating the location of the inflection point for the conservative or average estimate (Figure 3.1.1),
- ✓ by clicking on the *Subs.Parm* button in the rectangular mine plan form of the influence function program,
- ✓ by analyzing subsidence curves measured at a specific site or region.

Panel Representation:

- ✓ Simple mine layouts can usually be approximated using sets of rectangular extraction areas. In this case, the input required for every parcel includes the parcel number; the coordinates of the west, east, south, and north borders; the seam elevation; the extraction thickness (mining height); and the average supercritical subsidence factor (in percent) associated with it. These coordinates can be specified in a local or a global coordinate system with axes parallel to the parcel sides. In the Influence function module, this option is implemented as **Rectangular Mine Plans.**

- ✓ Complex mine layouts can usually be approximated by a closed polygon (i.e. a piece-wise linear shape). In this case, the input required for every point within a parcel includes the point reference number; the northing (Y), easting (X), and elevation (Z); the extraction thickness (mining height); and the supercritical subsidence factor (in percent) associated with it. The mine plan editor can

provide access to all points in a parcel, add new points, and add new parcels provided that the current parcel is defined by three or more points. The points should be entered in a counter-clockwise fashion. The location of each point should be adjusted to reflect the edge effect, or the relative position of the inflection point. The maximum number of parcels and points per parcel can be adjusted within the limits of the available memory. In the Influence function module, this option is implemented as Polygonal Mine Plans.

Warning:

Pillars can not exist outside extracted areas. If a pillar is defined outside an extracted area the results are unpredictable. Currently, the parcel definition module of the program can not check for such inconsistencies. Examples of erroneous panel definitions are given in Appendix 3.

Notes:

- ✓ If no adjustments are made to the geometry of the mine plan, the program assumes that the inflection point is over the rib of the excavation.
- ✓ The user must specify whether each parcel represents an extracted panel or a pillar within an extracted panel. A pillar is mathematically represented as a parcel with a negative subsidence factor. Setting the pillar option on a parcel will reset the subsidence factor associated with this parcel. In that sense, an extraction area can be either positive (i.e. longwall panel) or negative (i.e. pillar in the middle of a panel). Thus, a mine plan that consists only of pillars (without an extraction boundary) will produce a mathematically positive! subsidence.
- ✓ It should be emphasized that the subsidence factor used here is the subsidence factor for supercritical conditions.
- ✓ The reason for supporting more than one format for input data is for the user's convenience. For example, certain panels or pillars can be easily represented as rectangles and can be entered as single entities, compared to four or more entries required if these panels are digitized point by point. Additionally, calculations for rectangular parcels are much faster compared to calculations for parcels defined by individual points.

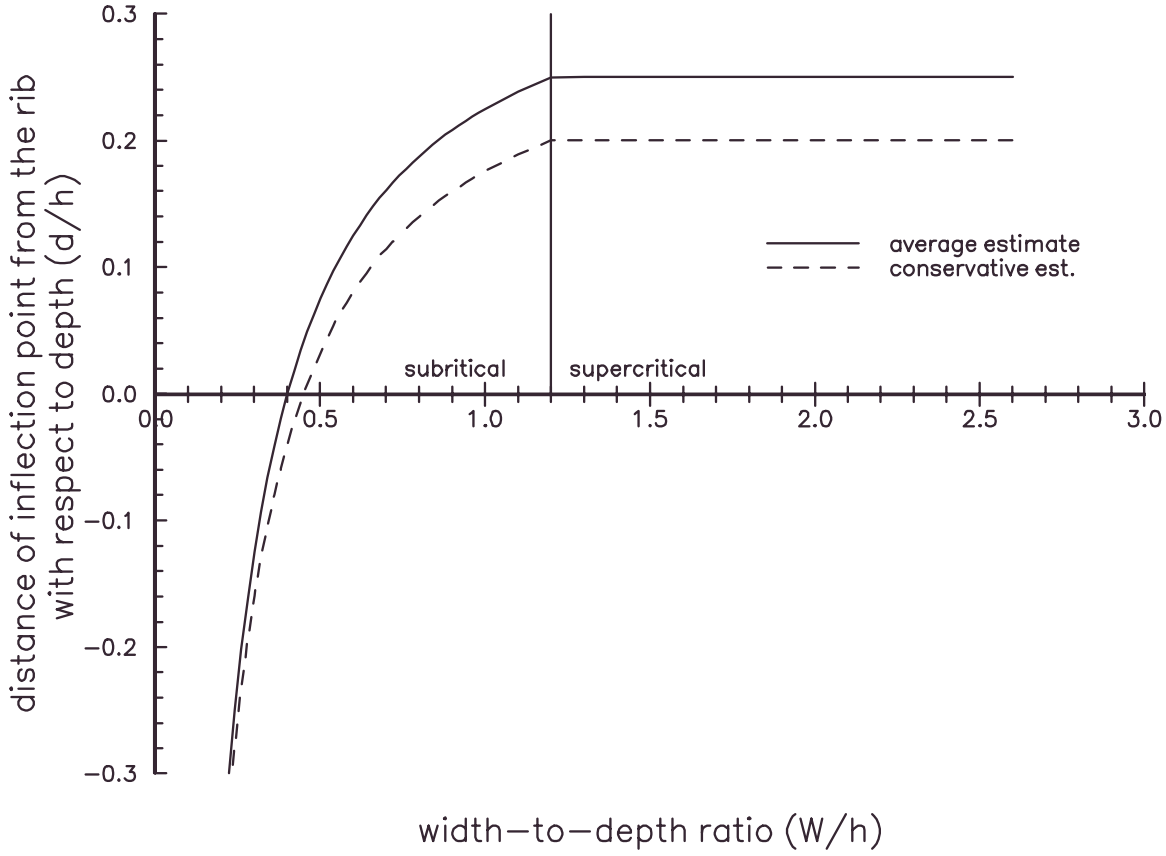


Figure 3.2.1: Determination of the offset of the inflection point.

3.3 Definition of the Prediction Points in the Influence Function Program

Prediction point data describe the surface points where the deformation indices will be calculated. Prediction points are always defined in three-dimensional space, by specifying the X,Y,Z coordinates of these points. A point can be either active or not active. A point which is not active is not deleted from the file but will not be included in the calculations.

Scattered Points

A scattered point set may consist of any number of points that are randomly located on the surface. If such points can be specified as part of a grid, then the Grid Points option should be used. Required parameters for each point include:

- ✓ the point reference code which can be any alphanumeric string,
- ✓ the easting, northing and elevation of each point,
- ✓ the point status, i.e. active or not active (an inactive point will not be displayed in the View option and will not participate in any of the calculations)

Grid Points

A grid point set may consist of any number of points in a window. This window is defined by minima and maxima in the X- and Y- directions as well as the cell size in each direction.

The grid can only be oriented parallel to the current coordinate system. If the grid needs to be oriented at an angle to the current coordinate system, the grid points should be generated by a different tool and imported as scattered points into the Influence Function module.

The user has two options regarding grid elevations.

- ✓ to consider a flat surface and specify a uniform elevation for all points, and
- ✓ to consider each point on an individual basis and specify individual point elevations.

Surface Deformation Characteristics Above Undermined Areas: Experiences from the Eastern United States Coalfields

M. KARMIS, A. JAROSZ, P. SCHILIZZI & Z. AGIOUTANTIS*

SUMMARY Damage resulting from surface movements due to underground mining may range from simple land settlement to severe structural damage. Since subsidence prevention is not feasible, it is important that accurate ground movement prediction techniques are developed, so that damage due to underground mining as well as the amount of coal lost due to the protection of surface structures can be minimized.

To facilitate the mitigation of the deleterious effects of subsidence in the Eastern U.S. region, empirical subsidence prediction techniques for longwall mining were developed from 45 case studies collected within the coalfield. From these subsidence prediction techniques a strain prediction model was also formulated. These subsidence and strain prediction methods can be used to predict ground movements as part of the mining plan and to evaluate the impacts of underground mining on the surface.

1 INTRODUCTION

Surface subsidence is rapidly gaining emphasis as an important environmental consequence of underground coal mining in the United States. Its impact has been witnessed in both rural and urban areas, and can be associated with active as well as abandoned mining operations. The damage associated with this phenomenon may include land settlement and fracturing, structural damage to surface buildings or facilities and disruption or contamination of ground water supplies.

As the need for energy increases, coal production will undoubtedly be accelerated, and since over 99 percent of all subsidence recorded in the United States arises from underground mining, it is evident that the incidence of subsidence will increase. With this increase in production and as underground mining moves into more populous areas, the prediction of surface subsidence, horizontal displacements, strains, and associated damages will surely become a requisite.

To exemplify the significance of this problem, a recent U.S. Bureau of Mines report indicated that over 32,000 km^2 have been undermined in the United States in extracting coal, metals and nonmetallic ores. Over one-fourth of this area, or approximately 8100 km^2, has been disturbed by subsidence, with underground mining of bituminous coal accounting for 7700 km^2 and metal and nonmetallic ores accounting for 68 km^2 of disturbed land. Thus, over 99 percent of all subsidence incidents are attributed to underground coal mining. Moreover, the Bureau of Mines estimates that an additional 10,000 km^2 will be undermined in the United States by the year 2000 (Chen et al., 1982), thus increasing considerably the number of areas in the country affected by subsidence.

Even though, under present technological and economic conditions, subsidence prevention is not feasible, it has been demonstrated in many coalfields that surface subsidence can be predicted and controlled, thus minimizing the deleterious effects of ground movement. Therefore, it is imperative that reliable methods of surface movement prediction and control be established for the United States. With such techniques available, ground movements can be predicted as part of the mining plan, and if environmentally, economically or legally unacceptable situations are foreseen, remedial measures can be implemented.

2 TYPES OF MINING SUBSIDENCE EXPERIENCED IN THE UNITED STATES

Underground excavations disturb the natural equilibrium of the rock mass, causing redistribution of loads in the medium and thus producing horizontal and vertical displacements. Subsidence occurs when these displacements propagate from the mine opening, through the overlying strata, to the surface and can manifest two principle modes of ground settlement: sinkhole and trough subsidence (Figure 1).

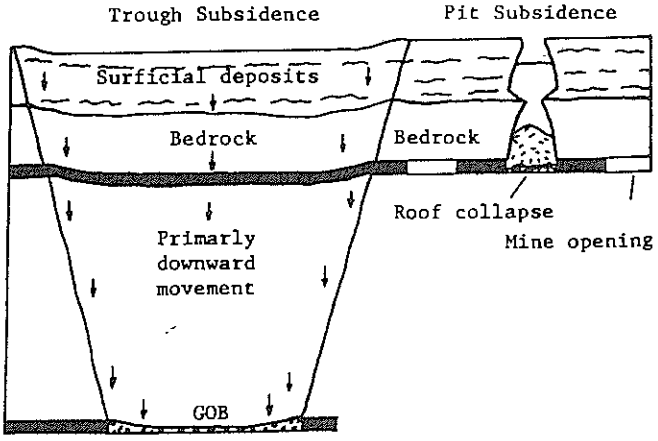


Figure 1 Trough and pit subsidence (after Wildanger et al., 1980).

2.1 Sinkholes, or Pit Subsidence

Sinkholes, or pit subsidence, are characterized by a sudden and sometimes violent collapse of the surface and usually occur above shallow, abandoned room and pillar mines with incompetent overburden; in rare instances, however, this type of subsidence

can also occur over active mines, given the proper mining and geological conditions. Pit subsidence is expressed by an abrupt drop in the surface and has vertical to bell-shaped walls. The washing of bedrock and surficial deposits into the mine void may cause the depth of sinkhole to exceed the mining height.

Obviously, the effects of pit subsidence can be serious. The damage caused is the result of a loss of support over all or part of the structure. Also, due to the uncertainty of mine and geologic parameters, the time, location and extend of such a subsidence event is very difficult to predict. Since the goal of subsidence and strain prediction is to minimize the cost of extracting coal in active mines that are below structures, the characteristics of trough subsidence have been studied more extensively than those of sinkholes.

2.2 Trough Subsidence

Trough subsidence is expressed by a gradual and general movement over an observed area with a subsidence basin being formed. Trough theory considers the phenomenon of subsidence to be represented by a complicated combination of material movement and interaction, as depicted in Figure 2. Caving occurs above the mine opening (zone a). The strata above the caving zone moves toward the excavation, experiencing fracturing (zone b) and beam bending phenomena (zone c). This representation of ground movement around a mining excavation is considerably complex to analyze and model; therefore, this concept is simplified by treating only the effects of underground excavation on the surface, or other strata levels within the bending zone.

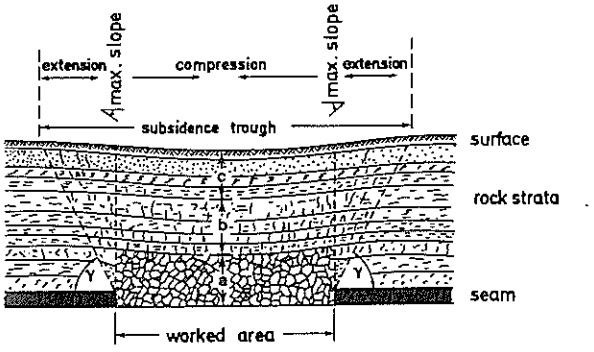


Figure 2 Strata movements above an extracted area (after Kratzsch, 1983)

Trough theory considers a zone of influence in which movement occurs and which spreads from the excavation to the surface, forming a subsidence trough. When an excavation is made at depth, the movement of the strata extends to the surface and manifests itself as vertical displacement (subsidence) and horizontal displacement within a zone of influence. The zone of influence is bounded by a plane that extends from the edge of extraction to the line on the surface where movement ceases. A vertical cross-section of the subsidence trough along with its associated parameters is shown in Figure 3. The angle defined by the vertical from the rib and the line of influence is the angle of draw (or limit angle).

3 DEVELOPMENT OF SUBSIDENCE PREDICTION METHODS

A number of different methods have been proposed for or applied to prediction of surface ground movements due to underground mining. These

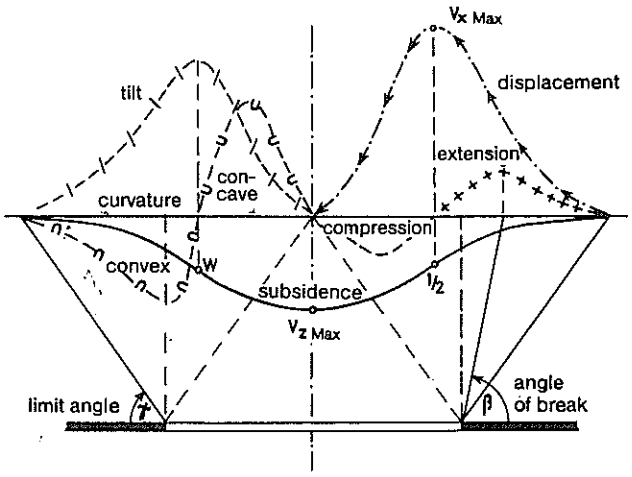


Figure 3 Components of ground movement (after Kratzsch, 1983)

approaches can be broadly divided into three groups. The first two are:

- Theoretical models based on the elastic, plastic, viscoelastic or other phenomenological models which are widely used in other engineering fields (Voight and Pariseau, 1970).

- Numerical methods, mostly used as solutions to complex situations involving the phenomenological methods.

Both these approaches assume that the strata in the overburden behaves in a specific and predictable manner. In using these models, considerable information describing the behavior of the overburden is required, which has often limited the applicability of these methods. Furthermore, in order to adapt their results to field data, a large number of adjusting coefficients may have to be determined.

The third approach can be defined as:

- Empirical or semi-empirical methods such as profile functions, influence functions, the zone area method (Brauner, 1973; Karmis et al., 1981b and 1983).

In this research, the latter approach was pursued since empirical methods are realistic, flexible, and easy to use. Their application, however, requires that a significant number of field measurements be made in order to determine the essential input parameters of the equations.

3.1 Data Collection and Analysis

During the initial stages of this research effort, a large number of subsidence case studies were collected from literature, the coal industry and government agencies. In total, data from 45 longwall panels and 70 room and pillar panels were collected. The limitations of the collected case studies data, i.e. accuracy of surveys, frequency of monitoring, lack of horizontal movement measurements, etc, led Virginia Polytechnic Institute and State University to the initiation of a detailed subsidence and strain monitoring program

above a number of active mines, located in three major coal producing counties of Virginia. The aim of this program was to enhance the data base with accurate and complete measurements of surface movements and to subsequently allow the refinement of the prediction techniques.

In this major monitoring effort, a total of sixteen room and pillar sections and seven longwall panels, in nine mines, were instrumented. Above each panel or section a number monument lines were installed. The lines were extended on either side of the panel well beyond the maximum expected area of influence. The final effort included approximately 1,200 stations over 35,000 feet of monitoring lines (Schilizzi et al., 1986).

This data bank was used to determine some basic ground movement relationships between the basic mining and subsidence parameters, in order to allow the evaluation of the various prediction methods for the Appalachian coal region.

Analysis of the subsidence information has revealed some interesting subsidence characteristics for Appalachian longwall panels. The observed angles of draw varied considerably; however, the angle of draw appears to approach a constant value of approximately 30 degrees at width-to-depth (W/h) ratios in excess of 1.2 (Figure 4). The range of maximum subsidence factors for the collected case studies is shown in Figure 5. It shows two lines constructed from the data. Line (1) represents the average values S_{max}/m, whereas line (2) is an envelope line, covering all data points. The figure also shows that this parameter asymptotes to a constant value at a width-to-depth ratios greater than 1.2. These results suggest that critical conditions are reached for W/h ratios of about 1.2,

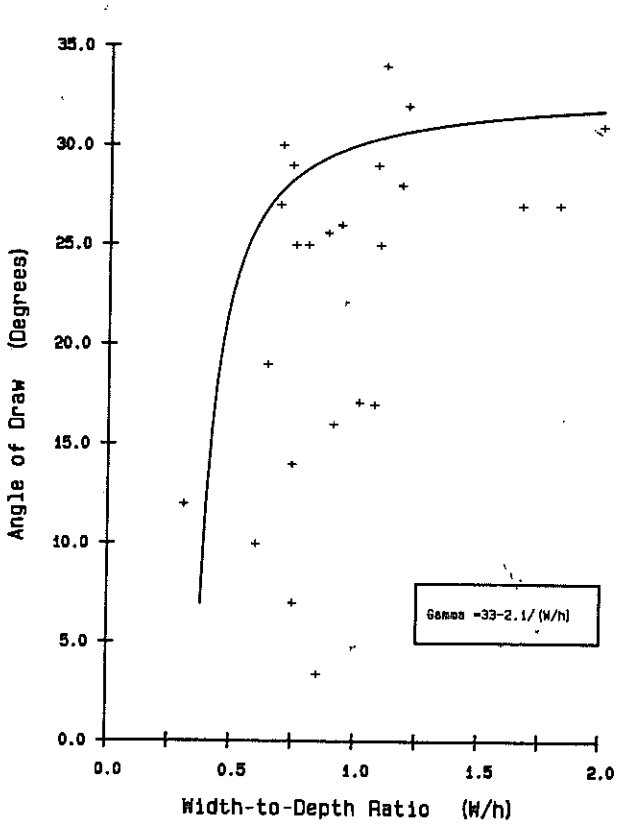


Figure 4 Observed angles of draw for various case studies

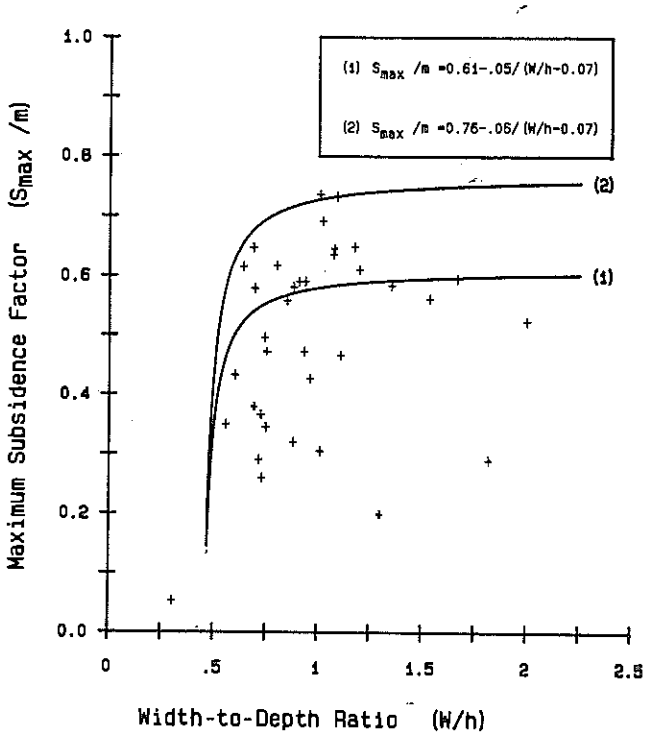


Figure 5 Influence of W/h ratio on maximum subsidence factor

as confirmed by the relationship between the position of the inflection point and the width-to-depth ratio of the panel shown on Figure 6.

According to the collected data and their dispersion, it was hypothesized that two factors influenced the subsidence: geology of the overburden and geometry of the panel. In order to establish the relationship between geology (lithology) and subsidence, the subsidence factor was plotted against the percent of hardrock (percent of limestone and sandstone) in the overburden for critical and supercritical panels only (Figure 7). Since the effect of panel geometry was thus eliminated, a relationship between subsidence and geological conditions was established. Once this correlation was possible, a complete relationship between subsidence and panel geometry was developed for varying lithologies (Figure 8).

To determine characteristic subsidence profiles, different empirical or semi-empirical methods were tested and adopted. Data collected during the monitoring program were primarily used, because of their completeness and accuracy.

3.2 Profile Function Methods

A profile function method defines the distribution of subsidence or strain values on the surface along a profile, orthogonal to the boundary of (theoretically) an infinitely long underground excavation. In general, a function which is tangent or asymptotic to two horizontal lines is required. The parameters to be used for this equation must be determined from field data.

The advantage of such a method is that it can be implemented easily through the use of a computer, or of pre-calculated tables. The main disadvantage is that it cannot negotiate excavations of complex shape or significant variations in mining

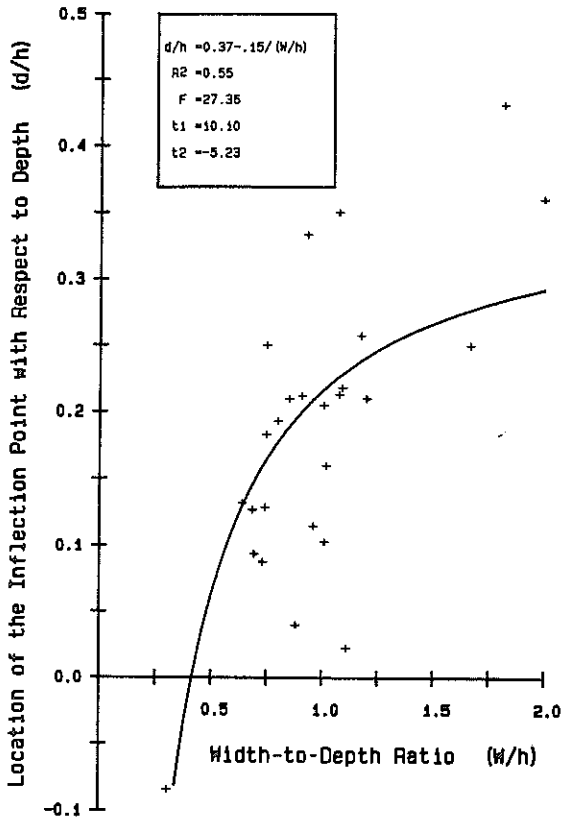


Figure 6 Effect of W/h ratio on inflection point location

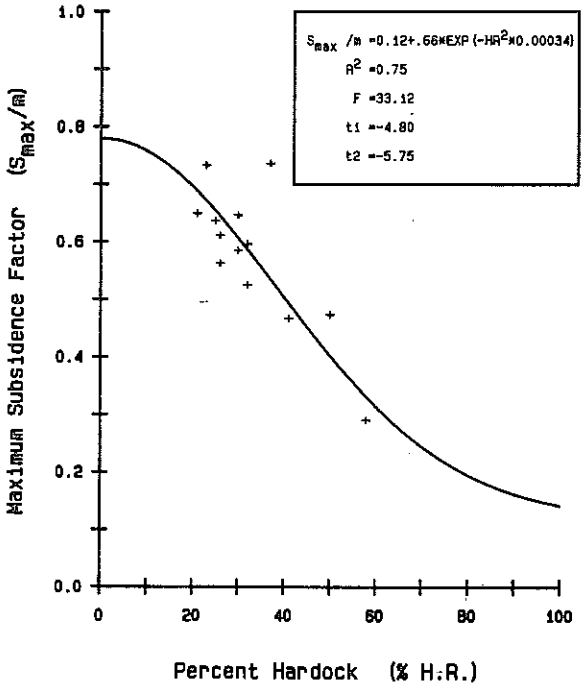


Figure 7 Effect of lithology on maximum subsidence factor

Parameters such as mining height, percent of extraction, and depth of the excavation (Brauner, 1973; Karmis et al., 1981a).

In this approach, a number of accepted profile functions were fitted to the subsidence profiles

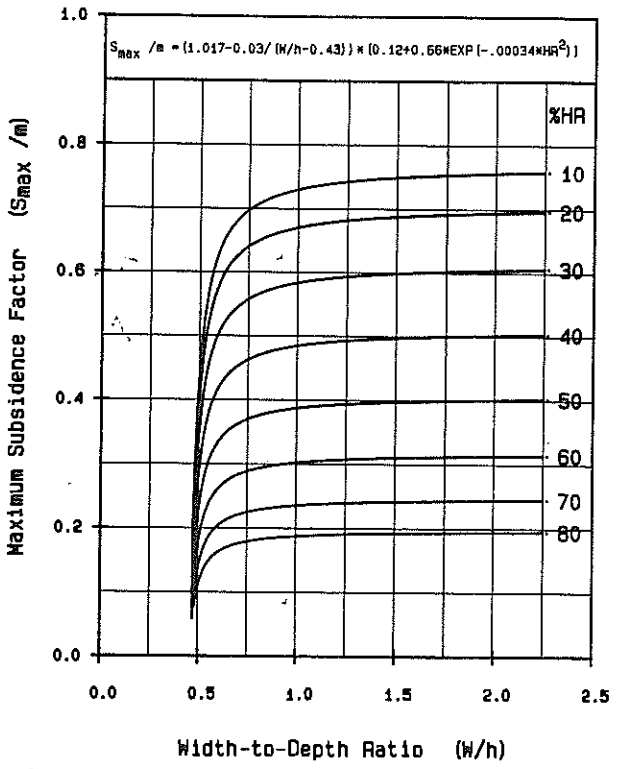


Figure 8 Nomograms for maximum subsidence prediction

developed from collected case studies. This analysis demonstrated that the hyperbolic tangent function given by the following equation, provided the best fit curve (Karmis et al., 1981b and 1984):

$$S(x) = 0.5\ S_{max}[1-\tanh(cx)/B] \qquad (1)$$

where,

S(x) = subsidence at a given point on the surface;
S_{max} = maximum subsidence (obtained from a table [Table 1] or nomogram [Figure 8]);
c = constant, calculated as 1.8 for critical or supercritical panels and 1.4 for subcritical panels;
x = distance from the inflection point to the point in question; and,
B = distance from the inflection point to S_{max} (which can be assessed from tables or nomograms [Figure 6] as a function of panel geometry and width-to-depth ratio).

The latter equation can be used in conjunction with predictions of S_{max} (Figure 8) and position of the inflection point (Figure 6) to allow for complete subsidence pre-calculation.

3.3 Influence Function Methods

This approach to subsidence prediction was initially developed by Dutch and German engineers (Bals, 1932) and has been extensively used in the Central and Eastern European coalfields. An influence function describes the distribution of vertical ground movement, i.e. subsidence, on the surface or other levels of the overburden, caused by an infinitesimal underground excavation. Considering the two dimensional situation:

$$dS(x_1,z) = f(x_1-x_2,z)dV \qquad (2)$$

where,

$dS(x_1,z)$ = subsidence at point $P(x_1,z)$;
dV = infinitesimal underground excavation (void);
$f(x_1-x_2,z)$ = influence function;
x_1 = coordinate of surface point;
x_2 = coordinate of infinitesimal excavation; and,
z = vertical distance from excavation to prediction point $P(x_1,z)$.

The Budryk-Knothe influence function method (Knothe, 1957), developed in Poland, was selected for this research as the most appropriate function for use in the Eastern U.S. coalfields. Initially, a two-dimensional situation was considered for the analysis of data obtained from panels of an almost orthogonal shape and with uniform mining conditions i.e. mining height, percent extraction, depth. The equation used is as follows:

$$f(x,z) = -\frac{1}{r}\exp(-\pi\frac{x^2}{r^2}) \qquad (3)$$

where,

r = the radius of influence (r=z/tan(b));
b = angle of influence; and,
x,z = coordinates of surface point on a system where the origin is located at the infinitesimal excavation.

For the three-dimensional approach:

$$f(x,y,z) = \frac{1}{r^2}\exp[-\pi\frac{(x^2+y^2)}{r^2}] \qquad (4)$$

where,

r = the radius of influence; and,
x,y,z = coordinates of a surface point on a system where the origin is located at the infinitesimal excavation.

Subsidence at any point will be:

$$S(x,y,z) = \frac{S_{max}}{r^2}\iint_A \exp[-\frac{\pi}{r^2}(x^2+y^2)]dxdy \qquad (5)$$

where,

$S(x,y,z)$ = subsidence at a point having coordinates x,y,z;
S_{max} = maximum subsidence for supercritical excavation;
r = the radius of influence; and,
A = the area of excavation.

The above integral was transformed and solved in polar coordinates, for polygonal excavations.

For this method, as with most mathematical models, the inflection point of the subsidence profile is located above the rib of the excavation. In practice, however, the inflection point is displaced at a distance, d, from the rib. In order to accommodate this, the outer boundaries of the excavation have been adjusted accordingly.

3.4 Zone Area Method

This method was initially developed in Britain for irregular longwall or room and pillar panels (Marr, 1975). It assumes that movement at a specific point on the surface is affected by the excavation of a circular underground area which is further sub-divided into a series of angular rings. To determine the amount of movement caused by each ring, the extracted area of the ring is calculated and multiplied by the zone factor of the respective ring. Appropriate zone factors for Appalachia have been calculated from the field data (Goodman, 1980; Karmis et al., 1981b and 1984). The same procedure is followed for all rings, and the superimposed results will yield total movement.

4 DEVELOPMENT OF STRAIN PREDICTION METHODS

One of the most damaging manifestations of surface subsidence is the development of horizontal strains. As noted previously, subsidence measured in Appalachia is smaller than that found in certain other coalfields, such as the U.K. However, the strains experienced in the U.S. often appear to be greater than those predicted for British conditions. Thus, an effort was directed toward the identification of the cause of these higher strains and toward the subsequent formulation of an acceptable strain prediction model for Appalachia.

As a first step, the relationship between strain and curvature had to be determined. Factor B was used to calculate horizontal strain as a function of curvature, i.e.:

$$\text{Horizontal Strain} = -B * \text{Curvature} \qquad (6)$$

In the original stages of this research a direct relationship between strain and curvature was sought which could describe B independent of any other mining parameters (Karmis et al., 1983). As more case studies were made available through this project, it became apparent that such a relationship will be difficult to establish (Figure 9). As a result, a different approach was adopted, based on the work of Awershin (1947), Budryk (1953) and Akimov and Zemicev (1970), which suggested that the magnitude of the horizontal strain factor (B) is a function of the excavation depth or the radius of principal influence (r).

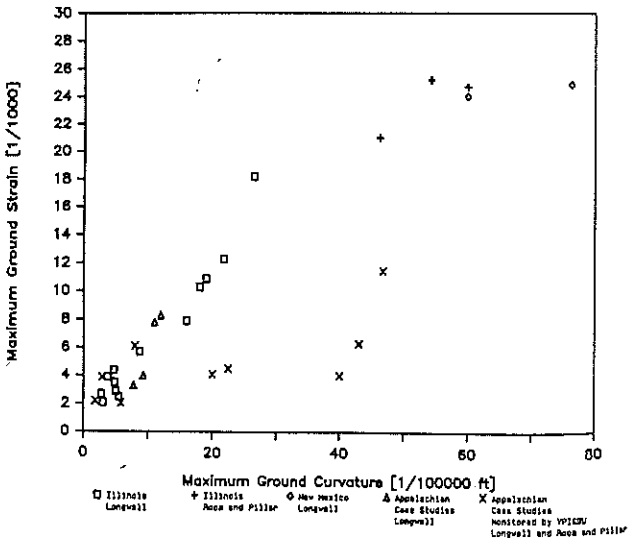


Figure 9 Maximum ground strain and curvature data

For each of the collected case studies, factor B was determined by comparing the measured strains and the fitted curvature profiles.

Using the established values of parameter B and the corresponding values of excavation depth (h), radius of influence (r), and angle of principal influence (b), a statistical relationship was found (Figure 10) as expressed by the equation:

$$B = (0.35 \pm 0.05)\ r \qquad (7)$$

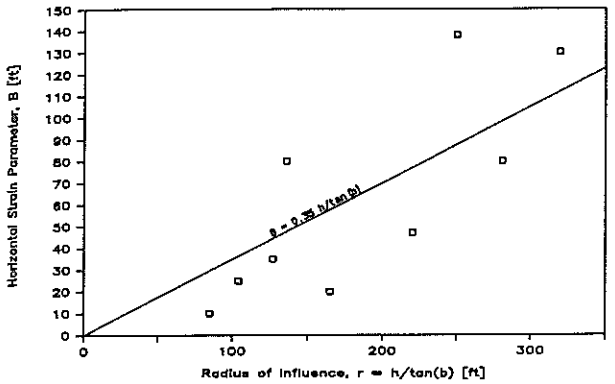


Figure 10 Effect of radius of influence on the horizontal strain parameter

or

$$B = (0.35 \pm 0.05)\ h/\tan(b) \qquad (8)$$

where,

r = radius of the principal influence;
h = depth of the excavation; and,
b = angle of the principal influence.

5 DEVELOPMENT OF COMPUTER SOFTWARE

The development of a comprehensive software package was necessary in order to facilitate the analysis of the field measurements. All field data were stored in an 880-line memory incorporated in the surveying instrument, and then transferred to magnetic diskettes for further processing on an HP micro-computer system. Stored field data included coordinates, sometimes on a localized system, elevations and the values of subsidence and strain for individual stations on the monitoring lines for each date.

Computer software for the application of the prediction methods under consideration was developed for two widely used personal computer systems.

For the profile function, the program is rather simple and involves the calculation of subsidence values along a line orthogonal to the rib of the excavation. The parameters used for this calculation depend on the given geologic conditions, width-to-depth ratio and mining height, and must be obtained from tables or nomograms and entered manually. The origin of the coordinates can be adjusted manually if necessary.

For the application of the influence function method, a number of programs were developed, each of them for specific conditions. For general cases involving complex mining conditions, where the mining section under consideration must be divided into polygons of uniform conditions, the influence function equation was converted to polar coordinates and was used in the program in this form. The computer program calculates subsidence at any point along a polygonal line or on a grid. For mine sections of irregular shape or where areas of different mining height, extraction ratio or seam elevation exist, the section is separated into homogeneous polygonal sub-sections. Subsidence and other related indices of deformation, in any given direction, caused by each of these sub-sections is calculated and their total value is determined by superposition. This procedure, however, requires considerable computational time for each point.

For simple conditions, however, where areas of different mining height, extraction ratio or seam elevation can be described by rectangular homogeneous sub-sections, different programs have been written for considerably faster execution on a microcomputer, yielding comparable results. Furthermore, a program using the two dimensional approach has been written for single panels of uniform overall parameters.

The program for the zone area method was initially developed for mainframe computers (Karmis et al., 1982); however, it is currently being adapted for use with personal computers.

It should be noted that these programs also produce data compatible with commercially available plotting and contouring software packages. Mine plan coordinates and the corresponding parameters can be entered manually or by a digitizer or by a plotter with digitizing capabilities.

6 APPLICATION OF PREDICTION METHODS

In this paper, data obtained from three case studies are presented to demonstrate and compare the prediction methods. The first two are from room and pillar mining operations, whereas the last one is from a longwall case study.

In the first example, the two dimensional approach was used. Predicted and fitted subsidence curves, using the profile and influence function methods, are presented in Figure 11.

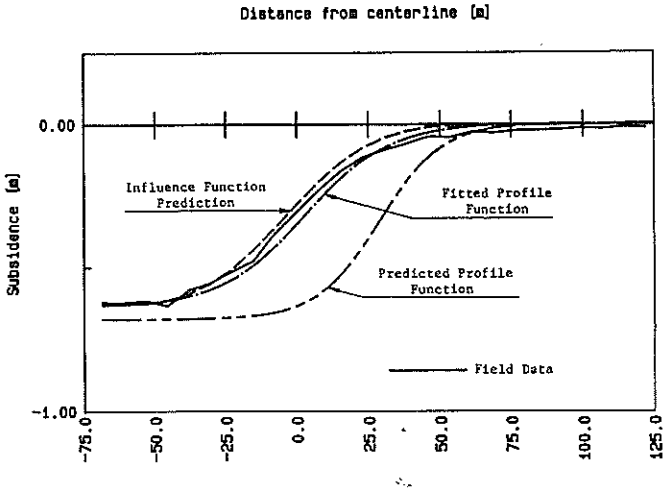


Figure 11 Example #1: Field data and prediction curves

In the second example (Figure 12), a three dimensional influence function approach was used to take into account a number of pillars left in place for roof control purposes. This case demonstrates the accuracy which can be obtained through adjustment of the influence function parameters, especially for subsidence predictions.

In the last example (Figure 13), a three dimensional influence function method was used for a longwall operation with considerable variation in overburden depth. Subsidence and horizontal strain values, calculated using this technique, show excellent correlation with the corresponding measured values.

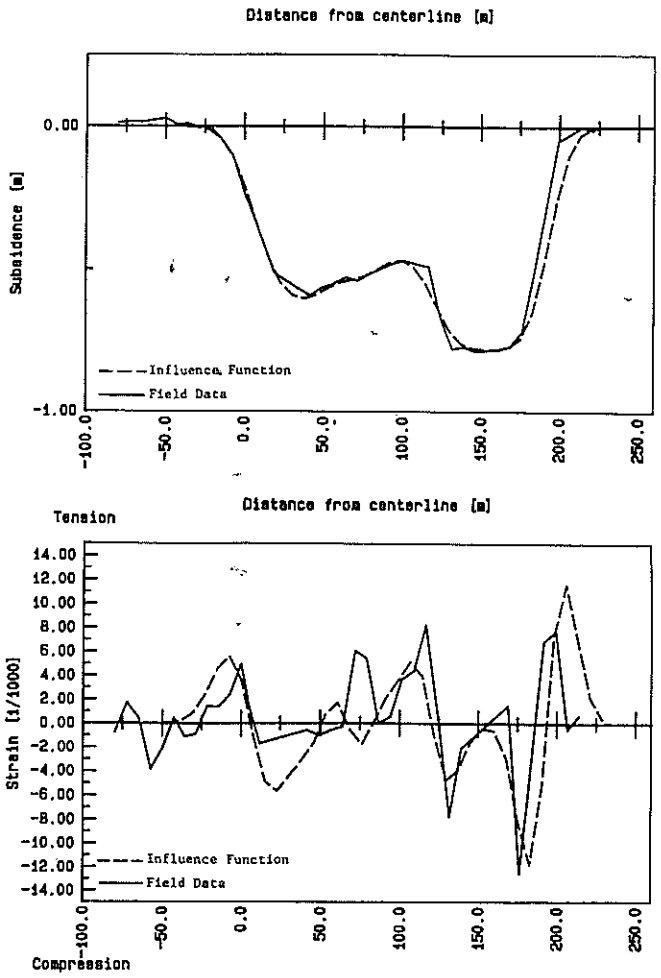


Figure 12 Example #2: Field data and prediction curves for subsidence and horizontal strain

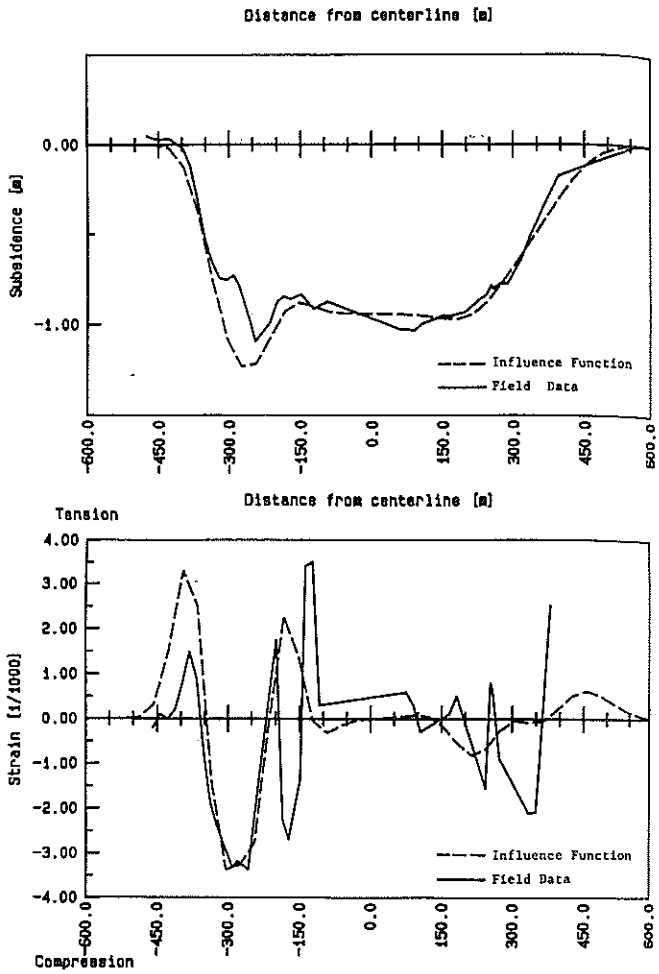


Figure 13 Example #3: Field data and prediction curves for subsidence and horizontal strain

7 CONCLUSIONS

The expansion of underground mining into more populous areas, and the resultant increase in the potential for surface and structural damage, have rendered the formulation of accurate surface deformation models an important requisite. To meet this demand, accurate subsidence and strain prediction techniques have been formulated for the Eastern U.S. coalfield. The semi-empirical subsidence prediction techniques discussed in this paper were developed from a substantial number of case studies collected within the Appalachian coalfield. Using the subsidence model as a base, the strain model was formulated using empirically and mathematically derived relationships. These models can greatly facilitate mine planning and allow the amount of coal lost due to the protection of surface structures to be minimized.

8 ACKNOWLEDGEMENTS

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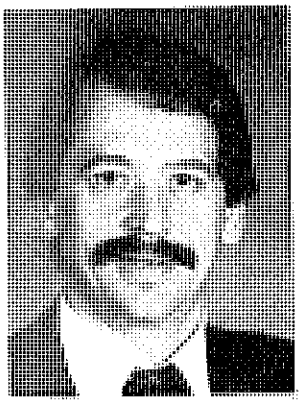
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APPENDIX B – Pillar Stability Calculations

UNSW Pillar Design Spreadsheet

	0.36H Barrier	0.36H Barrier	0.36H Barrier	0.36H Barrier	0.36H Barrier	0.36H Barrier	0.36H Barrier	0.36H Barrier	0.5H Barrier	0.5H Barrier	0.5H Barrier	0.5H Barrier	0.7H Barrier	0.7H Barrier	0.7H Barrier	0.7H Barrier
Location:	**Alcorn**	**Alcorn**	**Alcorn**	**Belbin**	**Belbin**	**Renahan**	**Renehan**	**Renehan**	**Renehan**	**Renahan**	**Renehan**	**Renehan**	**Renehan**	**Renahan**	**Renehan**	**Renehan**	**Renehan**
INPUT DATA	**Ribs**	**House & tank**	**House & tank**	**Ribs**	**House**	**House**	**Shed**	**Cottage**	**Barrier Edge**	**House**	**Shed**	**Cottage**	**Barrier Edge**	**House**	**Shed**	**Cottage**	**Barrier Edge**
Depth of Cover (m)	**137**	**137**	**137**	**140**	**145**	**175**	**165**	**178**	**180**	**175**	**165**	**178**	**180**	**175**	**165**	**178**	**180**
Mining Height (m)	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**
Pillar Length - centres (m)	33.5	33.5	33.5	26.3	30.1	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
Pillar Width - centres (m)	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	26.0	25.0	25.0	25.0	25.0
Roadway Width for maximum pillar dimension	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**
Roadway Width for minimum pillar dimension	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**
Cut-Through Angle (degrees)	**90**	**90**	**90**	**90**	**90**	**90**	**90**	**90**	**90**	**90**	**90**	**90**	**90**	**90**	**90**	**90**	**90**
Average Panel Span (m) {rib-rib width}	**210**	**210**	**210**	**67**	**67**	**210**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**
SG (tonnes/m^3)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Conversion (tonnes to N)	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Abutment Angle (^{o})	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
INTERMEDIATE CALCULATIONS																	
Maximum Rib to Rib Pillar Length (w_2)	**28.0**	**28.0**	**28.00**	**24.6**	**24.6**	**32.0**	**32.0**	**32.0**	**32.0**	**32.0**	**32.0**	**32.0**	**32.0**	**32.0**	**32.0**	**32.0**	**32.0**
Minimum Rib to Rib Pillar Width (w_1)	**19.5**	**19.5**	**19.50**	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**	**20.5**	**19.5**	**19.5**	**19.5**	**19.5**
w, Minimum Rib to Rib Pillar Width (ie $w_1 \sin\theta$)	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**	**20.5**	**19.5**	**19.5**	**19.5**	**19.5**
Minimum Pillar Width/Height Ratio	**8.5**	**8.5**	**8.5**	**8.5**	**8.5**	**8.5**	**8.5**	**8.5**	**8.5**	**8.5**	**8.5**	**8.5**	**8.9**	**8.5**	**8.5**	**8.5**	**8.5**
Extraction Ratio (%)	**34.8%**	**34.8%**	**34.8%**	**27.0%**	**36.3%**	**33.4%**	**33.4%**	**33.4%**	**33.4%**	**33.4%**	**33.4%**	**33.4%**	**32.7%**	**33.4%**	**33.4%**	**33.4%**	**33.4%**
Abutment Angle (Radians)	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367
Cut-Through Angle (Radians)	1.571	1.571	1.571	1.571	1.571	1.571	1.571	1.571	1.571	1.571	1.571	1.571	1.571	1.571	1.571	1.571	1.571
Is the Panel Super-Critical?	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
D (Peng & Chiang Loading Factor)	60.045	60.045	60.045	60.699	61.773	67.864	65.896	68.443	68.826	67.864	65.896	68.443	68.826	67.864	65.896	68.443	68.826
R (Pillar 2nd Abutment Component)	**0.80**	**0.40**	**0.40**	**0.80**	**0.200**	0.238	0.238	0.238	0.74	0.000	0.000	0.000	0.76	0.000	0.000	0.000	0.74
Dimensionless Pillar 'Rectangularity'	1.179	1.179	1.18	1.12	1.12	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.22	1.24	1.24	1.24	1.24
Width/Height Ratio Exponent	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Effective Width Factor (Omega)	1.18	1.18	1.18	1.12	1.12	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.22	1.24	1.24	1.24	1.24
Effective Width Interim	22.99	22.99	22.99	21.76	21.76	24.23	24.23	24.23	24.23	24.23	24.23	24.23	24.99	24.23	24.23	24.23	24.23
Effective Pillar Width (m)	22.99	22.99	22.99	21.76	21.76	24.23	24.23	24.23	24.23	24.23	24.23	24.23	24.99	24.23	24.23	24.23	24.23
Effective Pillar Loading Height (m)	137.00	137.00	137.00	91.40	91.40	175.00	165.00	178.00	180.00	175.00	165.00	178.00	180.00	175.00	165.00	178.00	180.00
RESULTS																	
Tributary Area Loading (MPa)	**5.25**	**5.25**	**5.25**	**4.80**	**5.69**	**6.57**	**6.20**	**6.69**	**6.76**	**6.57**	**6.20**	**6.69**	**6.69**	**6.57**	**6.20**	**6.69**	**6.76**
Pillar Strength (UNSW Squat Pillar 1999)	**25.62**	**25.62**	**25.62**	**24.90**	**24.90**	**26.31**	**26.31**	**26.31**	**26.31**	**26.31**	**26.31**	**26.31**	**27.85**	**26.31**	**26.31**	**26.31**	**26.31**
Pillar Strength (UNSW w/h<5)	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Safety Factor under FTA Loading (Squat Pillar)	**4.88**	**4.88**	**4.88**	**5.19**	**4.38**	**4.00**	**4.25**	**3.94**	**3.89**	**4.00**	**4.25**	**3.94**	**4.16**	**4.00**	**4.25**	**3.94**	**3.89**
Safety Factor under FTA Loading (w/h<5)	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Single Abutment Loading (3D) - full	5.53	5.53	5.53	4.21	5.06	8.83	7.85	9.14	9.34	8.83	7.85	9.14	8.89	8.83	7.85	9.14	9.34
Single Abutment Loading (3D) - pillar	**4.43**	**2.21**	**2.21**	**3.36**	**1.01**	**2.10**	**1.87**	**2.17**	**6.93**	**0.00**	**0.00**	**0.00**	**6.75**	**0.00**	**0.00**	**0.00**	**6.93**
Single Abutment Loading (3D) - solid	1.10	3.32	3.32	0.86	4.05	6.73	5.98	6.96	2.41	8.83	7.85	9.14	2.14	8.83	7.85	9.14	2.41
Total Pillar Loading with Single Abutment Loading	9.68	7.46	7.46	8.15	6.70	8.67	8.07	8.86	13.69	6.57	6.20	6.69	13.43	6.57	6.20	6.69	13.69
Safety Factor (under Single Abutment Loading)	**2.65**	**3.43**	**3.43**	**3.05**	**3.72**	**3.03**	**3.26**	**2.97**	**1.92**	**4.00**	**4.25**	**3.94**	**2.07**	**4.00**	**4.25**	**3.94**	**1.92**
Total Pillar Loading @ 1.5A	13.54	13.54	13.54	11.12	13.28	19.82	17.97	20.39	20.78	19.82	17.97	20.39	20.02	19.82	17.97	20.39	20.78
Safety Factor @ 1.5A	**1.89**	**1.89**	**1.89**	**2.24**	**1.88**	**1.33**	**1.46**	**1.29**	**1.27**	**1.33**	**1.46**	**1.29**	**1.39**	**1.33**	**1.46**	**1.29**	**1.27**
Total Pillar Loading under Double Abutment Loading	16.30	16.30	16.30	13.22	15.81	24.24	21.90	24.96	25.45	24.24	21.90	24.96	24.46	24.24	21.90	24.96	25.45
Safety Factor (under Double Abutment Loading)	**1.57**	**1.57**	**1.57**	**1.88**	**1.58**	**1.09**	**1.20**	**1.05**	**1.03**	**1.09**	**1.20**	**1.05**	**1.14**	**1.09**	**1.20**	**1.05**	**1.03**
Elastic Model Subsidence																	
Ecoal(GPa)	**3.00**	**3.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**
Efloor(GPa)	**3.50**	**3.50**	**3.50**	**3.50**	**3.50**	**3.50**	**3.50**	**3.50**	**3.50**	**3.50**	**3.50**	**3.50**	**3.50**	**3.50**	**3.50**	**3.50**	**3.50**
Eroof(GPa)	**6.00**	**6.50**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**
Poissons Ratio floor/roof	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**
initial vertical stress (MPa)	**3.43**	**3.43**	**3.43**	**3.50**	**5.69**	**4.38**	**4.13**	**4.45**	**4.50**	**4.38**	**4.13**	**4.45**	**4.50**	**4.38**	**4.13**	**4.45**	**4.50**
increase in vertical stress (MPa)	**6.26**	**4.04**	**4.04**	**4.65**	**1.01**	**4.30**	**3.94**	**4.41**	**9.19**	**2.20**	**2.07**	**2.24**	**8.93**	**2.20**	**2.07**	**2.24**	**9.19**
Pillar Compression (m)	**0.004**	**0.003**	**0.004**	**0.005**	**0.001**	**0.005**	**0.004**	**0.005**	**0.010**	**0.002**	**0.002**	**0.002**	**0.010**	**0.002**	**0.002**	**0.002**	**0.010**
Roof Compression (m)	**0.019**	**0.011**	**0.012**	**0.014**	**0.003**	**0.013**	**0.012**	**0.013**	**0.028**	**0.007**	**0.006**	**0.007**	**0.029**	**0.007**	**0.006**	**0.007**	**0.028**
Floor Compression (m)	**0.033**	**0.021**	**0.021**	**0.024**	**0.005**	**0.022**	**0.021**	**0.023**	**0.048**	**0.011**	**0.011**	**0.012**	**0.049**	**0.011**	**0.011**	**0.012**	**0.048**
Total FTA Compression (m)	**0.056**	**0.035**	**0.038**	**0.043**	**0.009**	**0.040**	**0.037**	**0.041**	**0.086**	**0.021**	**0.019**	**0.021**	**0.087**	**0.021**	**0.019**	**0.021**	**0.086**
2 times FTA Compression (m)	**0.112**	**0.071**	**0.076**	**0.087**	**0.019**	**0.080**	**0.074**	**0.082**	**0.172**	**0.041**	**0.039**	**0.042**	**0.175**	**0.041**	**0.039**	**0.042**	**0.172**
Floor Bearing Capacity																	
Weakest Floor Unit UCS (MPa)	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
Weakest Unit Thickness (m)	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**
Floor Bearing Capacity (MPa)	**45.1**	**45.1**	**37.9**	**42.8**	**42.8**	**42.8**	**42.8**	**42.8**	**42.8**	**42.8**	**42.8**	**42.8**	**43.6**	**42.8**	**42.8**	**42.8**	**42.8**
Pillar Stress (MPa)	**5.3**	**5.3**	**5.3**	**4.8**	**5.7**	**6.6**	**6.2**	**6.7**	**6.8**	**6.6**	**6.2**	**6.7**	**6.7**	**6.6**	**6.2**	**6.7**	**6.8**
Floor Bearing Failure FoS	**8.6**	**8.6**	**7.2**	**8.9**	**7.5**	**6.5**	**6.9**	**6.4**	**6.3**	**6.5**	**6.9**	**6.4**	**6.5**	**6.5**	**6.9**	**6.4**	**6.3**
Roof Bearing Capacity																	
Weakest Roof Unit UCS (MPa)	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
Weakest Unit Thickness (m)	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**
Roof Bearing Capacity (MPa)	**31.5**	**31.5**	**31.5**	**31.5**	**31.5**	**31.5**	**31.5**	**31.5**	**31.5**	**31.5**	**31.5**	**31.5**	**32.1**	**31.5**	**31.5**	**31.5**	**31.5**
Pillar Stress (MPa)	**5.3**	**5.3**	**5.3**	**4.8**	**5.7**	**6.6**	**6.2**	**6.7**	**6.8**	**6.6**	**6.2**	**6.7**	**6.7**	**6.6**	**6.2**	**6.7**	**6.8**
Roof Bearing Failure FoS	**6.0**	**6.0**	**6.0**	**6.6**	**5.5**	**4.8**	**5.1**	**4.7**	**4.7**	**4.8**	**5.1**	**4.7**	**4.8**	**4.8**	**5.1**	**4.7**	**4.7**

UNSW Pillar Design Spreadsheet

			z = 47m	65m	91m
Location:	**0H**	**0H**	**0.36H**	**0.5H**	**0.7H**
INPUT DATA	**Dam**	**Dam**	**Dam**	**Dam**	**Dam**
Depth of Cover (m)	**130**	**130**	**130**	**130**	**130**
Mining Height (m)	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**
Pillar Length - centres (m)	30.5	38.0	30.5	30.5	30.5
Pillar Width - centres (m)	25.0	25.0	25.0	25.0	25.0
Roadway Width for maximum pillar dimension	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**
Roadway Width for minimum pillar dimension	**5.5**	**5.5**	**5.5**	**5.5**	**5.5**
Cut-Through Angle (degrees)	**90**	**90**	**90**	**90**	**90**
Average Panel Span (m) {rib-rib width}	**210**	**210**	**210**	**210**	**210**
SG (tonnes/m^3)	2.5	2.5	2.5	2.5	2.5
Conversion (tonnes to N)	10000	10000	10000	10000	10000
Abutment Angle (^{o})	21	21	21	21	21

INTERMEDIATE CALCULATIONS					
Maximum Rib to Rib Pillar Length (w_2)	**25.0**	**32.5**	**25.0**	**25.0**	**25.0**
Minimum Rib to Rib Pillar Width (w_1)	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**
w, Minimum Rib to Rib Pillar Width (ie $w_1 \sin\theta$)	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**
Minimum Pillar Width/Height Ratio	**8.5**	**8.5**	**8.5**	**8.5**	**8.5**
Extraction Ratio (%)	**36.1%**	**33.3%**	**36.1%**	**36.1%**	**36.1%**
Abutment Angle (Radians)	0.367	0.367	0.367	0.367	0.367
Cut-Through Angle (Radians)	1.571	1.571	1.571	1.571	1.571
Is the Panel Super-Critical?	Yes	Yes	Yes	Yes	Yes
D (Peng & Chiang Loading Factor)	58.491	58.491	58.491	58.491	58.491
R (Pillar 2nd Abutment Component)	**0.81**	**0.81**	**0.01**	**0.00**	**0.00**
Dimensionless Pillar 'Rectangularity'	1.124	1.250	1.124	1.124	1.124
Width/Height Ratio Exponent	1.00	1.00	1.00	1.00	1.00
Effective Width Factor (Omega)	1.12	1.25	1.12	1.12	1.12
Effective Width Interim	21.91	24.38	21.91	21.91	21.91
Effective Pillar Width (m)	21.91	24.38	21.91	21.91	21.91
Effective Pillar Loading Height (m)	130.00	130.00	130.00	130.00	130.00

RESULTS					
Tributary Area Loading (MPa)	**5.08**	**4.87**	**5.08**	**5.08**	**5.08**
Pillar Strength (UNSW Squat Pillar 1999)	**24.99**	**26.39**	**24.99**	**24.99**	**24.99**
Pillar Strength (UNSW w/h<5)	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Safety Factor under FTA Loading (Squat Pillar)	**4.92**	**5.42**	**4.92**	**4.92**	**4.92**
Safety Factor under FTA Loading (w/h<5)	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Single Abutment Loading (3D) - full	5.07	4.86	5.07	5.07	5.07
Single Abutment Loading (3D) - pillar	**4.12**	**3.95**	**0.04**	**0.00**	**0.00**
Single Abutment Loading (3D) - solid	0.95	0.91	5.03	5.07	5.07
Total Pillar Loading with Single Abutment Loading	9.20	8.82	5.12	5.08	5.08
Safety Factor (under Single Abutment Loading)	**2.72**	**2.99**	**4.88**	**4.92**	**4.92**
Total Pillar Loading @ A	10.16	9.73	10.16	10.16	10.16
Safety Factor @ 1A	**2.46**	**2.71**	**2.46**	**2.46**	**2.46**
Total Pillar Loading under Double Abutment Loading	15.23	14.60	15.23	15.23	15.23
Safety Factor (under Double Abutment Loading)	**1.64**	**1.81**	**1.64**	**1.64**	**1.64**
Elastic Model Subsidence					
Ecoal(GPa)	**3.00**	**3.00**	**3.00**	**3.00**	**3.00**
Efloor(GPa)	**3.50**	**3.50**	**3.50**	**3.50**	**3.50**
Eroof(GPa)	**6.00**	**6.00**	**6.00**	**6.00**	**6.00**
Poissons Ratio floor/roof	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**
initial vertical stress (MPa)	**3.25**	**3.25**	**3.25**	**3.25**	**3.25**
increase in vertical stress (MPa)	**5.95**	**5.57**	**1.87**	**1.83**	**1.83**
Pillar Compression (m)	**0.004**	**0.004**	**0.001**	**0.001**	**0.001**
Roof Compression (m)	**0.018**	**0.017**	**0.006**	**0.006**	**0.006**
Floor Compression (m)	**0.031**	**0.029**	**0.010**	**0.010**	**0.010**
Total FTA Compression (m)	**0.054**	**0.050**	**0.017**	**0.016**	**0.016**
2 times FTA Compression (m)	**0.107**	**0.100**	**0.034**	**0.033**	**0.033**
Floor Bearing Capacity					
Weakest Floor Unit UCS (MPa)	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
Weakest Unit Thickness (m)	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**
Floor Bearing Capacity (MPa)	**45.1**	**45.1**	**45.1**	**45.1**	**45.1**
Pillar Stress (MPa)	**9.2**	**8.8**	**5.1**	**5.1**	**5.1**
Floor Bearing Failure FoS	**4.9**	**5.1**	**8.8**	**8.9**	**8.9**
Roof Bearing Capacity					
Weakest Roof Unit UCS (MPa)	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
Weakest Unit Thickness (m)	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**
Roof Bearing Capacity (MPa)	**31.5**	**31.5**	**31.5**	**31.5**	**31.5**
Pillar Stress (MPa)	**9.2**	**8.8**	**5.1**	**5.1**	**5.1**
Roof Bearing Failure FoS	**3.4**	**3.6**	**6.2**	**6.2**	**6.2**

Appendix D

Groundwater Study













Australasian Groundwater & Environmental Consultants Pty Ltd

REPORT on

BERRIMA COLLIERY - CONTINUATION OF OPERATIONS

GROUNDWATER ASSESSMENT

prepared for
BORAL CEMENT

Project No. G1491
September 2010

ABN:64 080 238 642

Australasian
Groundwater & Environmental
Consultants Pty Ltd

REPORT on

BERRIMA COLLIERY - CONTINUATION OF OPERATIONS

GROUNDWATER ASSESSMENT

prepared for
BORAL CEMENT

Project No. G1491
September 2010

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Appendix A – Summary of Water Quality Analyses

JST:ae (Berrima)
Project No. G1491
September 2010

REPORT ON

BERRIMA COLLIERY – CONTINUATION OF OPERATIONS GROUNDWATER ASSESSMENT

1.0 INTRODUCTION

Berrima Colliery, which is owned by Boral and managed by Boral Cement, is located approximately 7km west of the township of Berrima in the Southern Coal Fields of New South Wales.

Boral Cement is applying to the Minister for Planning for a new Project Approval under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act) to gain planning approval for the continuation of mining within the current Mining Lease CCL748 (the Project). The Project area is shown on Drawing No. 1.

EMGA Mitchell McLennan has been commissioned by Boral Cement to prepare an Environmental Assessment (EA) in support of the Project Application. This groundwater impact assessment has been completed by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) at the request of EMGA Mitchell McLennan, on behalf of their client Boral Cement.

2.0 PROJECT OVERVIEW

Operations at Berrima Colliery involve the underground mining of the basal section of the Wongawilli Seam using the bord and pillar method. The pillars of coal are extracted from the Wongawilli Seam utilising breaker line supports and a continuous miner.

The colliery has a single portal located at the pit top facilities in Medway about 6km west of Berrima township. Currently coal is transported from underground by conveyor to an on-site crusher and loaded onto trucks to be transported to the Berrima Cement Works or stockpiled at Loch Catherine.

The Project continues all aspects of Berrima Colliery's current activities and specifically, seeks approval to:

- continue underground mining of coal using the bord and pillar method;
- maintain maximum production rates of up to 460,000 tonnes per annum (tpa) of ROM coal;
- operation of existing mining facilities and support structures, with the possibility to upgrade these within the future; and
- transport product by road using trucks to current and future markets, or to stockpiling areas.

3.0 SCOPE OF WORK

The objective of the groundwater study was to fully assess the impact of the proposed continuation of mining operations on the hydrogeological regime. To achieve this objective, a scope of work was developed and is outlined in this report, which included data review, field investigations and analytical impact assessment.

4.0 LEGISLATION, POLICY AND GUIDELINES

The following section outlines New South Wales State Government legislation, policy and guidelines with respect to groundwater that must be addressed when assessing a mining proposal.

4.1 Water Act 1912 and Water Management Act 2000

The Water Management Act 2000 is progressively replacing the *Water Act 1912* in New South Wales but some provisions of the *Water Act 1912* are still in force. Areas of the state where water sharing plans have commenced are covered by the *Water Management Act 2000*, with the remaining areas regulated under the *Water Act 1912.*

The *Water Management Act 2000* has not yet commenced in the Hawkesbury Napean Region which covers the Southern Coalfields, and therefore the *Water Act 1912* still applies at the Berrima Colliery. When the NSW Government has developed a Hawkesbury Napean Region Water Sharing Plan, the *Water Management Act 2000* will replace the *Water Act 1912.*

Boral Cement has submitted an application for a licence from the NSW Office of Water (NOW) to extract groundwater at Berrima Colliery under Part 5 of the *Water Act 1912*. This licence will allow Berrima Colliery to extract groundwater which flows into the underground workings. The application was submitted in early 2009 and at the time of writing, the draft licence conditions had been received from NOW.

4.2 State Groundwater Policy

The NSW State Government (1997) Groundwater Policy Framework Document was adopted in 1997 and aims to manage the State's groundwater resources to sustain their environmental, social and economic uses. The policy has three parts, namely the:

- NSW Government (1998a) Groundwater Quality Protection Policy, adopted in December 1998;
- NSW Government (2002) State Groundwater Dependent Ecosystems Policy adopted in 2002; and
- NSW Government (undated) Groundwater Quantity Management Policy advice.

4.2.1 Groundwater Quality Protection

The NSW Groundwater Quality Protection Policy (1998), states that the objectives of the policy will be achieved by applying the management principals listed below.

1. *"All groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained.*
2. *Town water supplies should be afforded special protection against contamination.*
3. *Groundwater pollution should be prevented so that future remediation is not required.*
4. *For new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource.*
5. *A groundwater pumper shall bear the responsibility for environmental damage or degradation caused by using groundwaters that are incompatible with soil, vegetation and receiving waters.*
6. *Groundwater dependent ecosystems will be afforded protection.*
7. *Groundwater quality protection should be integrated with the management of groundwater quality.*
8. *The cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource.*
9. *Where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored."*

4.2.2 Groundwater Dependent Ecosystems

The NSW Groundwater Dependent Ecosystems Policy is specifically designed to protect valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of these dependent ecosystems are maintained or restored for the benefit of present and future generations. The policy defines Groundwater Dependent Ecosystems (GDEs) as *"communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater".*

Five management principles establish a framework by which groundwater is managed in ways that ensure, whenever possible, that ecological processes in dependent ecosystems are maintained or restored. A summary of the principles is as follows:

- GDEs can have important values. Threats should be identified and action taken to protect them;
- groundwater extractions should be managed within the sustainable yield of aquifers;
- priority should be given to GDEs, such that sufficient groundwater is available at all times to meet their needs;
- where scientific knowledge is lacking, the precautionary principle should be applied to protect GDEs; and
- planning, approval and management of developments should aim to minimise adverse affects on groundwater by maintaining natural patterns, not polluting or causing changes to groundwater quality and rehabilitating degraded groundwater ecosystems where necessary.

4.2.3 Groundwater Quantity Protection

The objectives of managing groundwater quantity in New South Wales are:

- *"to achieve the efficient, equitable and sustainable use of the State's groundwater;*
- *to prevent, halt and reverse degradation of the State's groundwater and their (sic) dependent ecosystems;*
- *to provide opportunities for development which generate the most cultural, social and economic benefits to the community, region, state and nation, within the context of environmental sustainability; and*
- *to involve the community in the management of groundwater resources."*

4.3 Aquifer Risk

The NSW Government (1998b) "Aquifer Risk Assessment Report" used a number of criteria to classify risks to various significant groundwater resources across the State. It classified the Southern Highlands Fractured Rock and Sydney Basin Sandstone as a "medium risk aquifer".

5.0 REGIONAL SETTING

5.1 Location, Topography and Drainage

The Berrima Colliery is located approximately 7km west of the town of Berrima on mining lease CCL748 which covers an area of 6,263 hectares. The mining lease and existing underground workings are shown in Figure 1 below and in Drawing No. 2.

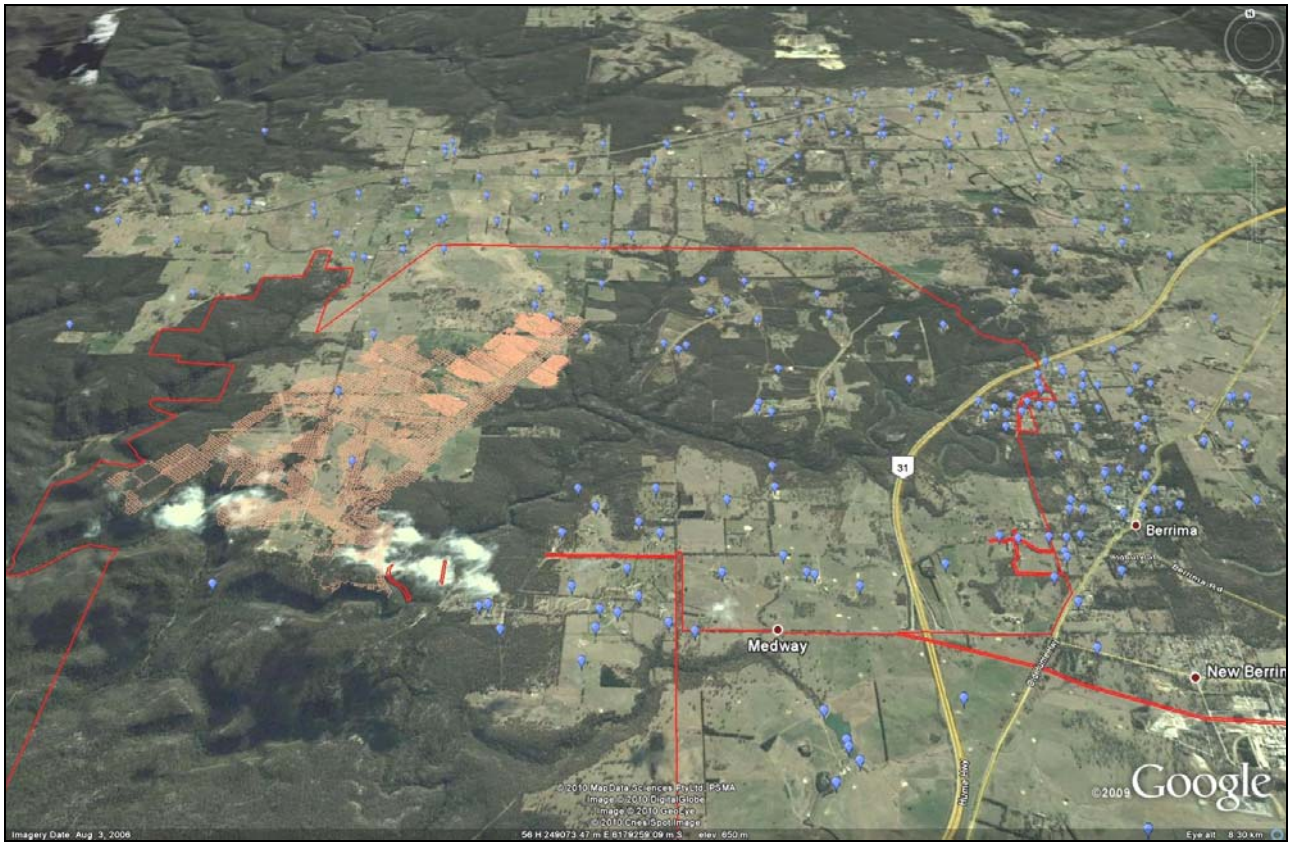


Figure 1: 3D View showing mining lease, existing workings (orange) and registered water bores (blue dots) (2010 © Google Earth)

The land around the town of Berrima forms a gently sloping plateau with Berrima Colliery located at the western limit. Ground surface level above the mine ranges from about 680m to 750m AHD at a small hill in the northern area of the workings. The plateau is incised by the Wingecarribee River that flows from the township of Berrima in a westerly direction, and then turns and runs south-westerly adjacent to the colliery. The bed of the Wingecarribee River falls almost 100m, from about 620m AHD in the northern area of the colliery, to 520m AHD on the south western boundary. The river forms an eroded gorge with precipitous side slopes in areas adjacent to the colliery.

The land use in the vicinity of the mine workings is a mixture of rural residential and agricultural land in the cleared areas where the topography is relatively gentle, and remnant native bushland along the riparian zone of the Wingecarribee River and the western edge of the plateau where slopes steepen (refer Figure 1).

5.2 Climate

The climate in the vicinity of Berrima Colliery is temperate and characterised by warm summers and cold winters. Average rainfall data was obtained for Berrima West Station (068186) located in the town of Medway, immediately to the east of the colliery, as presented in Table 1. No other climatic data was available for the Berrima West Station so the average temperature was obtained from Bowral Station (68102). The closest meteorological station with evaporation data was from Goulburn TAFE (070263).

Table 1: CLIMATE AVERAGES

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Mean max temp (ºC)	25.4	24.5	22.4	19.4	15.4	12.4	11.6	13.4	16.2	19.1	21.3	24	18.8
Mean min temp (ºC)	13.3	13.5	11.5	8	5.3	3.3	1.9	2.9	5.1	7.6	9.6	11.6	7.8
Mean rainfall (mm)	70.8	84.3	78	61.2	57.3	63.2	46	52.5	53.9	61.8	71.9	58.1	782.8
Mean Evaporation	198	167	127	78	50	33	37	59	84	121	150	189	1294
Rainfall-Evaporation	-128	-83	-49	-17	8	30	9	-6	-30	-59	-78	-131	-511

Rainfall from Berrima West 068186
Temperature from Bowral 068102
Evaporation from Goulburn TAFE 070263

The average annual rainfall is 783mm, with February being the wettest month (84.3mm). Average evaporation is 1294mm/year at Goulburn about 60km to the south-west of Berrima. Rainfall exceeds evaporation during the period May to July which is when the majority of the recharge to the aquifers is expected to occur.

Monthly rainfall records were used to calculate the Cumulative Rainfall Deficit (CRD), (also commonly referred to as the Rainfall Residual Mass) for the Berrima West Station (Figure 2). The CRD is a summation of the monthly departure of rainfall from the long-term average monthly rainfall and provides a historical record of relatively wet and dry periods. A rising trend in slope in the CRD plot indicates periods of above average rainfall, whilst a declining slope indicates periods when rainfall is below average.

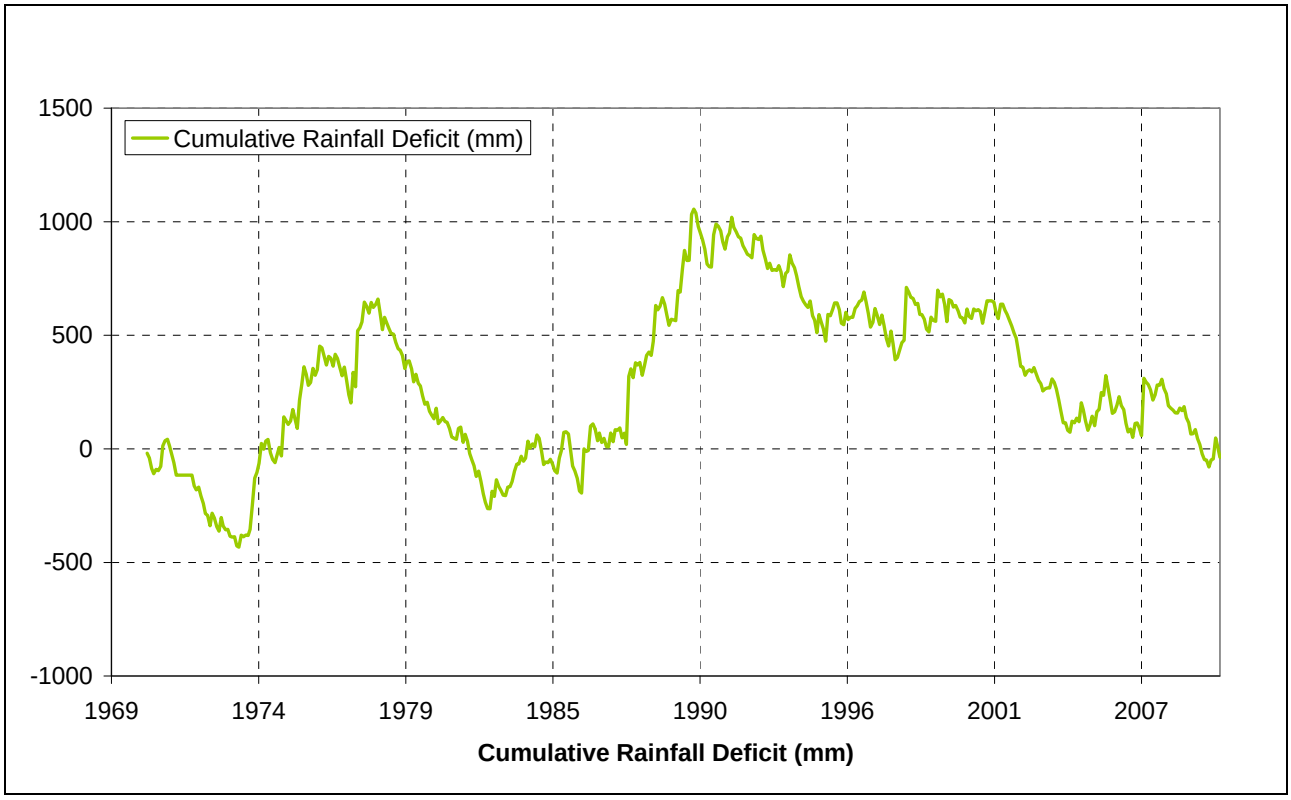


Figure 2: Cumulative Rainfall Departure Graph – Berrima West Station (061086)

The CRD indicates a period of below average rainfall between 2001 and 2005, and then a relatively stable rainfall from 2005 to present with no indication of a significant period of drought.

5.3 Current and Historical Operations

EMGA Mitchell McLennan (2010) describes the current and historical operations at Berrima Colliery as follows:

Operations at Berrima Colliery involve the underground mining of the basal section of the Wongawilli seam using the bord and pillar method. The pillars of coal are extracted using the Wongawilli method utilising breaker line supports and a continuous miner.

The colliery has a single entry point [or portal] located at the pit top facilities in Medway. Currently coal is transported from underground by conveyor to an onsite crusher and loaded on to trucks to be transported to the Berrima Cement Works or stockpiled at Loch Catherine.

No beneficiation of the coal is undertaken other than crushing to meet product requirements. Coal mined from the colliery is the only current source of fuel for the Berrima Cement Works' cement kiln which currently consumes approximately 220,000 tpa. The kiln is the main production unit of the cement works and requires fuel to create very high temperatures to transform raw materials into cement.

The Berrima Colliery employs 38 people. It currently operates two production shifts from Monday to Friday; a day shift commencing at 6.00am and finishing at 4.00pm and an afternoon shift commencing at 2.45pm and finishing at 12.45am. When required, a third production shift is undertaken. The colliery also undertakes maintenance shifts on weekdays from 11.30pm to 8.15am and occasionally on weekends.

Past production levels of the Berrima Colliery have varied between 125,000 tpa and 460,000 tpa. While the colliery has traditionally supplied the Berrima Cement Works, it has historically supplied other customers as well, including but not limited to the Berrima Power Station, Tallawarra Power Station and Maldon Cement Plant.

In regard to subsidence EMGA Mitchell McLennan (2010) indicate that *"historically, subsidence associated with mining at Berrima Colliery has been low and there has been little or no evidence of surface cracking. This is, in part, due to overlying geological conditions and protection measures [subsidence control zones] that can be employed utilising the bord and pillar extraction method."*

5.4 Proposed Continuation of Mining

It is proposed to continue mining generally in accordance with the approved SMP, including extraction within 59 panel, Southwest 1 and 406 Panels (refer Drawing No. 2). Mining will advance in a north easterly direction with panels extending off the main roadways to the west and east.

6.0 HYDROGEOLOGICAL REGIME

6.1 Regional Geology

Permo-Triassic rocks of the Sydney Basin crop out over most of the Southern Coalfield area and consist of relatively undeformed marine to terrestrial sedimentary rocks with some formations containing the economic deposits of coal.

The regional geology is described by Moffit (2000) and is shown in the Southern Coalfield geology map presented in Drawing No. 3. The major stratigraphic units are presented in Table 2 and described below largely based on information presented by Moffit (2000).

Table 2: SUMMARY OF STRATIGRAPHIC SEQUENCE AT PROJECT SITE

Age	Formation	Lithologic Units	Berrima Colliery Thickness
Tertiary	Robertson basalt (T-Rb)	Alkali olivine basalt	unknown
Jurassic	Unnamed dykes (Jld)	Olivine dolerite and gabbro	3m to 10m
Triassic	Wianimatta Group (Rw)	Undifferentiated shale, laminite and sandstone	~20m
	Hawkesbury Sandstone (Rh)	Quartzose sandstone, conglomerate	~110m
Permian	Illawarra Coal Measures (Pi)	Coal interbedded with siltstone, claystone, quartz-lithic sandstone and minor conglomerate	-
	Shoalhaven Coal Measures (Ps)	Sandstone, siltstone minor coal	-

6.1.1 Sydney Basin Sediments

The Triassic Wianamatta Group is the topmost unit of the Permo-Triassic sequence in the Southern Coalfield and represents the last phase of sedimentation in the development of the Sydney Basin. The Wianamatta Group is subdivided into a number of subgroups being the Ashfield Shale, Michinbury Sandstone and Bringelly Shale which are predominately fine grained argillaceous sediments. The Wianamatta Group is exposed at the surface in the northern area of the colliery (refer Drawing No. 3).

The Triassic Hawkesbury Sandstone outcrops over much of the project area. The Hawkesbury Sandstone is predominantly a quartzose sandstone, with some siltstone and claystone interbeds. The sandstone is largely medium grained, rounded quartz and rare lithic pebbles. The interbeds are lensiod from a few metres up to 10m in thickness and are commonly several kilometres in length. The Hawkesbury Sandstone outcrops over much of the Project area (Drawing No. 3).

The Illawarra Coal Measures is a sequence of interbedded sandstone, siltstone, claystone and coal with minor tuff, conglomerate and intrusions. It ranges in thickness from greater than 500m in the depositional centre of the Southern Coalfield, to less than a few metres along the western edge of the basin. The Illawarra Coal Measures consists of two subgroups: the basal Cumberland Subgroup; and the Sydney Subgroup, which contains all of the economic coal seams including the Wongawilli Seam mined at Berrima Colliery.

The Illawarra Coal Measures are underlain by the Shoalhaven Coal Measures.

6.1.2 Igneous Extrusives and Intrusions

A large number of dykes occur in the Southern Coalfield, either separately or in swarms. Some are up to 5km in length and generally less than 3m in width. In the area of the Berrima Colliery, the dykes have approximately the same strike direction as most of the faults and are along the most dominant joint directions – that is, west north-west to north north-west. Several zones of dykes and dyke swarms have been intersected during mining at Berrima Colliery and can be up to 10m in thickness. The dykes are highly weathered and are therefore relatively weak, but can have a hard cindered crust.

The Robertson Basalt is the youngest igneous formation in the project area and forms a capping on hills to the immediate north of the existing Berrima workings (refer Drawing No. 3). The thickness or nature of the basalt is not well known as it has not been intersected in any water bores or exploration drill holes.

6.2 Coal Seam Geology

The Wongawilli Seam is the coal seam targeted for mining and ranges in thickness from about 6m to 10m. The upper part of the seam hosts interbedded carbonaceous shale, mudstone and shaly coal and therefore coal extraction is concentrated in the basal 2m to 3m of the seam which comprises banded bright coal with minor thin tuff and mudstone interbeds.

A second coal seam known as the Tongarra (or American Creek) Seam has been identified underlying the Wongawilli Seam, but is thinner and not targeted for extraction.

The Wongawilli Seam strikes in a northerly direction and dips gently to the east at 1.5 degrees. Structure contours for the Wongawilli Seam floor are presented in Drawing No. 4.

6.3 Structures and Faults

Cement works fault is the largest known fault in the project area, located to the south of the township of Berrima, striking north-west with a measured displacement of 65m (refer Drawing No. 3). The cement works fault has not been mapped beyond the Wingecarribee River and a large displacement has not been encountered at the colliery. Several segments of the Wingecarribee River run parallel to the Cement Works Fault suggesting geological structures control the alignment of the river to some degree.

6.4 Previous Groundwater Investigations

Larry Cook and Associates (2008) undertook the only known groundwater investigation at the Berrima Colliery as part of the Subsidence Management Plan (SMP) in order to assess the potential impact of 59 Panel, Panel 406 and South West Panel 1. The investigation included a desktop review of the local hydrogeology and test pumping at two bore sites. Due to a paucity of data, the assessment did not include a detailed assessment of the impact of the mining operations on surrounding groundwater users. The results of the investigation are detailed in relevant sections below.

6.5 Registered Bores

A search of the NOW water bore database was undertaken as part of the project. The search area encompassed approximately 260km^2 around the Berrima Colliery as shown in Drawing No. 5. A total of 11 registered bores were identified with a 2km radius of the SMP area, with 66 bores within 2km to 4km and 78 bores from 4km to 6km (refer Drawing No. 5).

Data on the database indicated that of the 151 bores within 6km of the SMP area there were 108 active water licences, mainly for stock and domestic purposes. Sixteen of the licences were for irrigation.

The available water quality information on the database indicates the groundwater is typically fresh with low salinity, as indicated by electrical conductivity records typically less than 1,000µS/cm, with a relatively low median value of 120µS/cm. Bores yields ranged from 0.1L/s to 16.5L/s with a median yield of 1.8L/s for the registered bores.

The median bore depth was 85m suggesting the majority of the bores are likely to be constructed in the Hawkesbury Sandstone and/or the underlying Illawarra Coal Measures.

6.6 Hydraulic Parameters

Larry Cook and Associates (2008) undertook two pumping tests on two bores located to the north of the colliery. The location of the Belbin Bore (replacement bore) and the Culpepper monitoring bore are shown in Drawing No. 6.

A 24-hour pumping test was undertaken on the Belbin Bore (GW106501) at a constant rate of 0.8L/s. The bore is cased to a depth of 144m, and then open hole to a depth of 186m. The bore intersected groundwater in sandstone at 119m to 120m and in the base of the Wongawilli Seam at 137m to 138m, and is screened across both of these water bearing zones.

The constant rate and recovery data was analysed and indicated a transmissivity of about 14m^2/day and a storativity of 1 x 10^{-4}. The hydraulic conductivity was estimated at 0.2m/day for a 73m thick aquifer zone. If it is assumed the main aquifer zone was the 10m thick coal seam aquifer a hydraulic conductivity of the coal would be higher at 1.4m/day.

A second shorter 107 minute pumping test was undertaken in the Culpepper monitoring bore constructed on the De Rossa property to determine if the bore was constructed in a perched aquifer. The bore, an old coal exploration drill hole was pumped at a rate of 0.3L/s with the analysis indicating a transmissivity of about 55.7 m^2/day and a storativity of 1 x 10^{-4}. The hydraulic conductivity was estimated at 0.46 m/day based on the saturated thickness of the bore. It was concluded that the bore was not constructed in a perched aquifer.

6.7 Groundwater Level and Hydraulic Gradients

Larry Cook and Associates (2008) describe the implementation of a groundwater monitoring program which commenced at the colliery in 2007. The program included inspection of three registered bores within the area of the proposed underground workings on the Belbin, De Rosa ("Culpepper") and Ranahan properties. Construction details for the bores are summarised in Table 3. Electronic water level loggers were installed in three bores, the Belbin production bore, Culpepper production bore and the Culpepper monitoring bore as shown in Drawing No. 6.

Table 3: MONITORED BORE DETAILS

Bore	Coordinates[1]		Collar RL m AHD	Depth (m)	Year	Bore Yield (L/s)	Water Level (m)	Aquifer
	mE	mN						
GW038518 "Ranahan"	250096	6184456	-	60.7	1973	49.3-60.5m - 0.8L/s	44.5	Sandstone
GW101581 "DeRosa – Culpepper Production"	250090	6185209	693.0	41.2	1950?	0.76L/s	33.5	-
GW106150 "Belbin Production"	250023	6184174	-	115.0	2005	90-91m - 0.3L/s 95-96 - 1.3L/s 109-110m - 1.4L/s	88.0	Sandstone
Replacement of GW106150	250021	6184183	691.4	186.0	2008	119-120m - 0.66L/s 137-138m - 0.17L/s	109.6	Sandstone/ Coal
Culpepper Monitoring Bore	250600	6184515	677.9	-	-	-	-	-

1- Projection MGA94 Zone 56

The water levels recorded by the electronic water level loggers are presented as hydrographs in Figure 3.

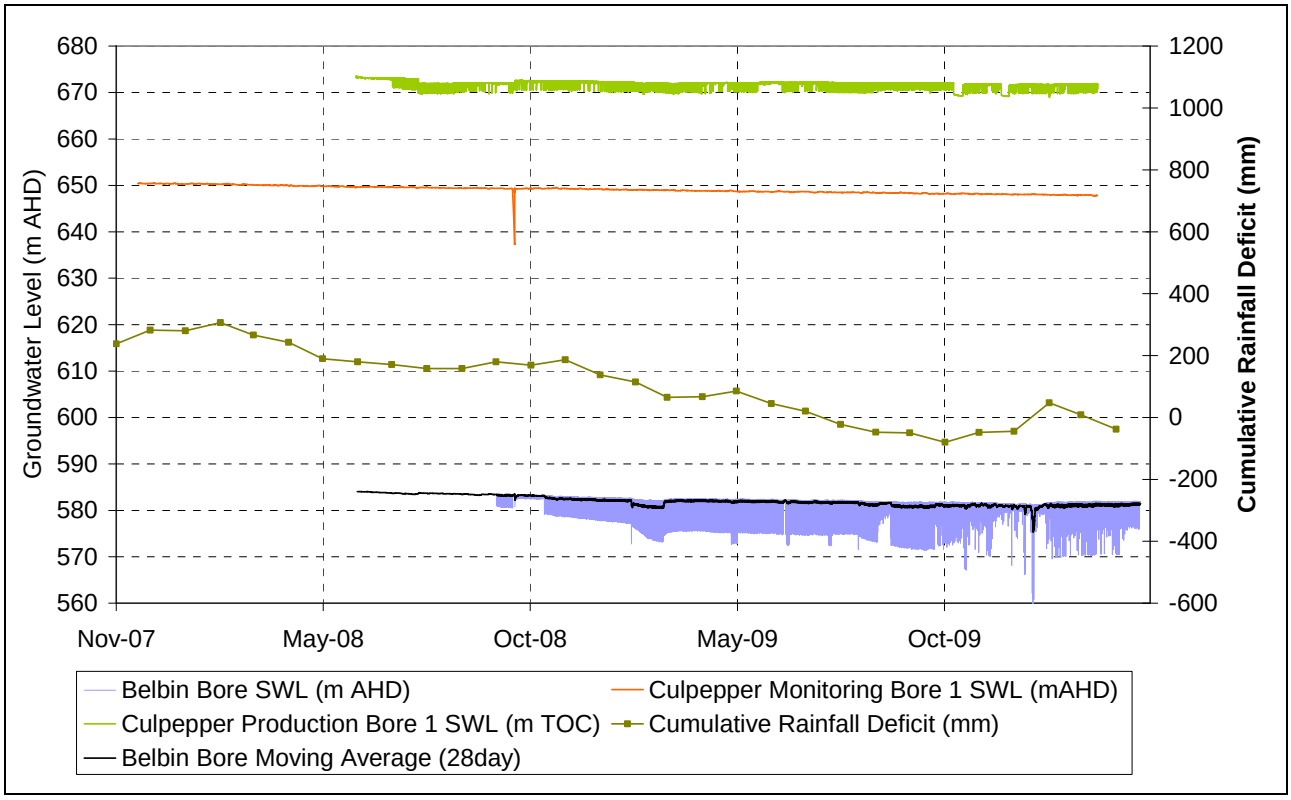


Figure 3: Hydrographs

The Culpepper production bore shows a relatively stable water level with a 2m fluctuation range due to pumping. The Culpepper monitoring bore and Belbin production bore show a slight reduction in groundwater levels over the 2-year monitoring period, with a 10m fluctuation range due to pumping in the Belbin production bore.

The CRD was also plotted with the groundwater levels in Figure 3 and indicates rainfall recorded from November 2007 to April 2010 was in total about 400mm below average. Groundwater levels typically fluctuate in a pattern similar to the CRD and the declining trend in groundwater levels in the monitoring bores is likely related to the below average rainfall over the monitoring period.

Publicly available digital elevation data (Shuttle Radar Topography Mission), was used to estimate the surface level at each registered water bore, and the water level record subtracted to determine the groundwater surface elevation. The groundwater elevation was then contoured to produce a map of the potentiometric surface as is shown in Drawing No. 7. The floor level of the underground workings was used in the interpolation process to represent the potentiometric surface in the mining area.

The resultant water level contour map should be treated with caution as it presents water levels over a long period of time, from bores installed in different aquifers, that potentially have different water levels. There is also a level of inaccuracy in the digital elevation data that can be ±6m based on previous experience. Despite these limitations the contour map is considered to provide a broad indication of likely hydraulic gradients and flow directions, and indicates that the potentiometric surface is generally a subdued reflection of the topography. The exception is the area immediately around the colliery where a steeper inward hydraulic gradient is present due to depressurisation of the coal seam. The extent of the zone of depressurisation created by the mining operations is difficult to ascertain as there are very few bores in the immediate vicinity of

the underground mining operations, particularly to the east, due to the presence of the Wingcarribee River.

The monitoring data from the Culpper production bore and Belbin bore, which have been surveyed accurately, indicate a relatively steep hydraulic gradient to the north, with a decline in groundwater level of 90m over 1000m (0.09). Again, there is some uncertainty associated with this data as the Belbin bore is constructed in the coal measures, whereas Culpper production bore is relatively shallow and expected to be constructed in the Hawkesbury Sandstone aquifer overlying the coal measures.

6.8 Water Quality

The groundwater study included collection and analysis of several rounds of groundwater and surface water samples. The samples were collected from the following locations:

- the Wingecarribee River:
  - at the location of the main mine entry portal (sample point 2)
  - upstream of the mine at the Hume Highway bridge (sample point 3)
  - downstream of the mine and the colliery seepage discharge point (sample point 4)
- seepage samples in the colliery underground workings:
  - from the V-north weir in the southern area of the colliery where groundwater discharge from the colliery is measured prior to being discharged into the Wingecarribee River (sample point 1)
  - at a sump in the colliery workings where groundwater ingress collects, known as 2 belt sump (sample point 5)
  - dyke intersected in 406 panel (sample point 6)
  - the advancing face in south-west 1 panel (sample point 7)
  - a fault located in panel south-west 2 (sample point 8)

The sample locations are shown in Drawing No. 8.

The samples were analysed at Australian Laboratory Services (ALS) for the presence of:

- pH, EC, TDS
- Major cations (Ca, Mg, Na, K) and anions (Br, Cl, SO_4, HCO_3, CO_3)
- Metals - Al, As, Cd, Co, Cu, Fe, Mn, Ni, Zn
- Nutrients – NH_3, NO_2, NO_3, Total P

The results of the analyses are summarised in Table A1 included in Appendix A.

6.8.1 Salinity and Major Ion Chemistry

The salinity of water samples can be categorised based on TDS concentrations as follows:

- Fresh water <500mg/L
- Slightly Brackish 500 to 1,000mg/L
- Brackish 1,000 to 3,000mg/L

- Moderately saline 3,000 to 7,000mg/L
- Saline 7,000 to 14,000mg/L
- Highly saline 14,000 to 35,000mg/L
- Brine >35,000mg/L

All the water samples collected reported TDS concentrations in the <500mg/L range indicating fresh water, with most samples from the coal face and Wingecarribee River in the range 100mg/L to 300mg/L. The exceptions were the samples collected from the colliery discharge point of the V-notch weir and the belt sump which typically recorded TDS concentrations nearly double the other samples, at slightly above 500mg/L.

The increase in the salinity from the seepage points in the coal face roof to the discharge point appears to be largely related to an increase in sulphate concentration, which may be due to the oxidation of sulphide minerals in the coal or roof/floor units.

The sulphate enrichment and the different water types are depicted in the Piper diagram presented as Figure 4.

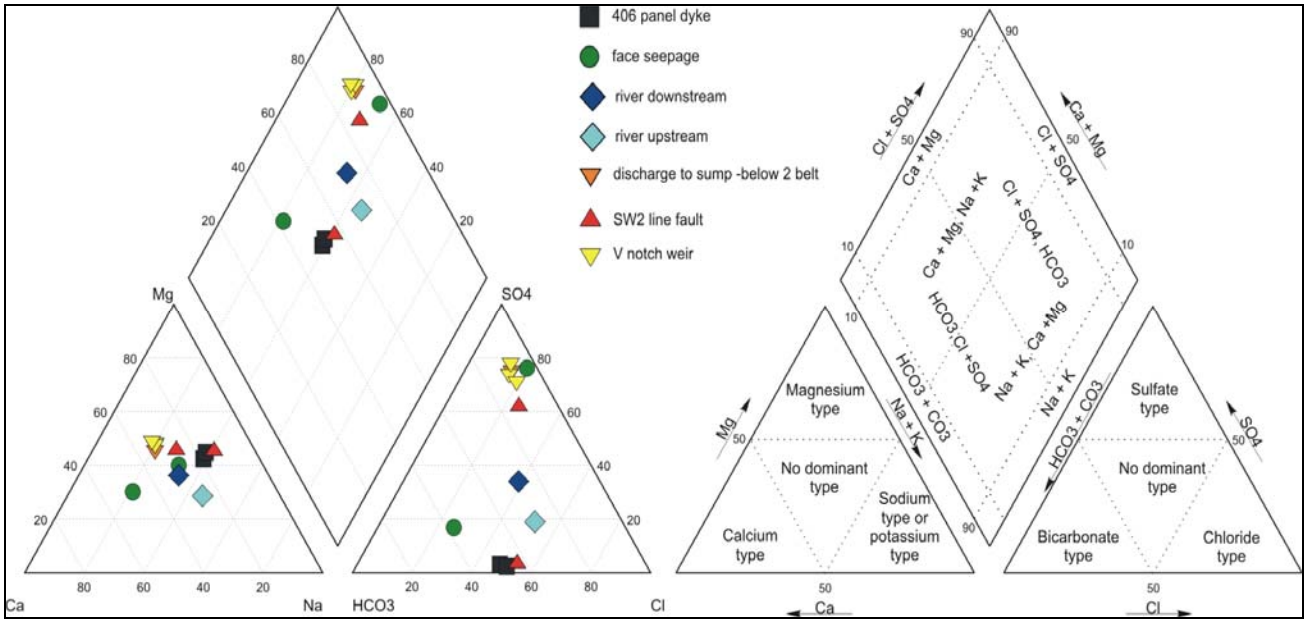


Figure 4: Piper Diagram

The Piper diagram indicates:

- oxidation of pyrite is buffered by carbonates as indicated by a increased calcium dominance on the cation triangle and the fact that the pH of the water samples does not reduce significantly when sulfate concentrations increase,
- a similar water type in the samples collected from the south-west 2 fault and the 406 dyke – the fact that the dyke and fault water have the same chemistry supports the theory that the dykes have intruded the zones of higher permeability created by the faults,
- the face seepage has a highly variable chemistry, and may relate to the fact that the face is constantly advancing and the geology therefore also changing.

6.8.2 Metals

The metals analyses indicated that the highest concentrations of trace metals were detected in the V-notch weir and 2 belt sump samples, likely due to the oxidation of pyrite as the seepage is oxygenated as it enters the workings, as discussed above. However the concentrations of metals were within the acceptable levels for stock water and potable drinking water.

6.8.3 Water Environmental Value

An assessment was made of the groundwater quality in terms of ANZECC (2000) criteria and environmental value. The following environmental values are recognised by ANZECC (2000).

- aquatic ecosystems;
- primary industries (irrigation and general water uses, stock drinking water, aquaculture and human consumption of aquatic foods);
- recreation and aesthetics;
- drinking water;
- industrial water; and
- cultural and spiritual values.

ANZECC states that *"where two or more agreed environmental values are defined for a water body, the more conservative of the associated guidelines should prevail and become the water quality objective".* The assessment of "environmental value" given in this report is based on this guideline.

The groundwater has a low salinity and is locally used for stock, domestic and irrigation purposes. It also provides baseflow to the Wingecarribee River downstream of the colliery, which supports ecosystems, potable water supply and recreation. However the significance of the base flow contribution is not known at this stage.

Based on the available information the prime environmental value is considered to for primary industry usage. The cultural and spiritual value is not known.

6.9 Groundwater Ingress to Underground Mine

Groundwater flow pumped from the colliery is recorded at the V-notch weir discharge point on a daily basis. The recorded seepage is shown in Figure 5 along with the cumulative rainfall deficit.

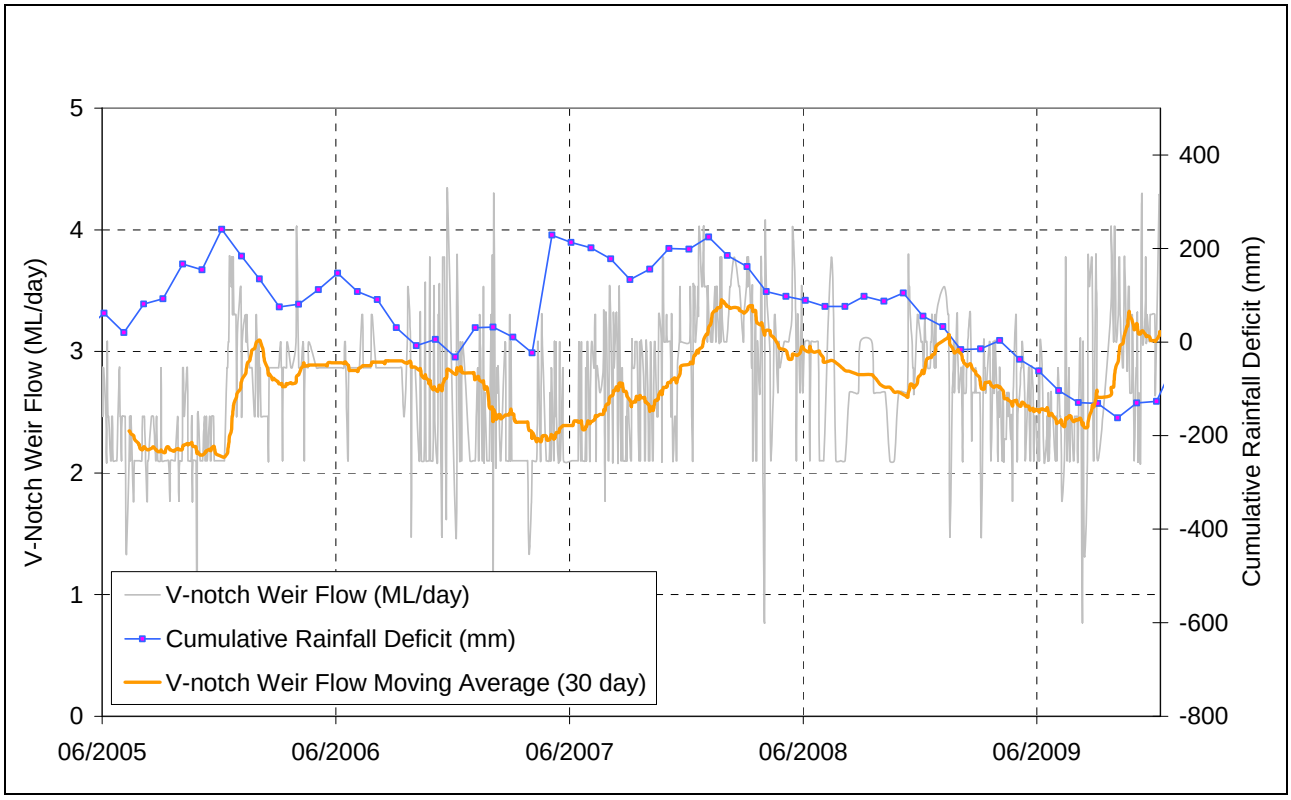


Figure 5: Recorded Pumped Seepage from Berrima Colliery Workings

The average inflow rates to the colliery appear to be correlated with the rainfall, as represented via the cumulative rainfall deficit, although there does appear to be a time lag of several months between above average rainfall and increased inflows to the colliery. Anecdotal information from the colliery operators indicates that increases in inflow to the colliery are primarily related to the periods when dykes are intersected in the underground workings. The seepage rate to the colliery is expected to be controlled by the geology, mining rate and groundwater levels which are influenced by rainfall and the Wingecarribee River.

6.10 Recharge and Discharge

The Department of Environment, Water, Heritage and the Arts (2009) report that in calculation of the aquifer sustainable yield on a regional scale *"for the Southern Highlands GMU, recharge has been taken as 10% of rainfall on exposed sandstone or basalt aquifer areas, and 0.5% of rainfall in areas where the sandstone aquifer does not crop out but is covered by shale of the Wianamatta Group".*

The chloride mass balance method can be used to estimate rainfall recharge rates locally in the Project area by comparison of the chloride concentrations in rainwater, with chloride concentrations in the groundwater samples. Assuming a concentration of 4mg/L chloride in rainfall, and an average of about 40mg/L in groundwater samples collected from the colliery, this equates to a recharge rate of about 10% of annual rainfall. This confirms the Department of Environment, Water, Heritage and the Arts (2009) regional estimate is representative of the Project area where the Hawkesbury Sandstone outcrops over much of the surface. An annual average rainfall rate of 782mm indicates a rainfall recharge rate of about 78mm/yr.

The hydrograph for the Culpepper monitoring bore was examined to determine if the rainfall recharge was evident in the groundwater levels recorded in this bore. Figure 6 shows the daily rainfall recorded at Medway Station, close to the colliery and the water level in the monitoring bore. The hydrograph does not show any rapid increases in water level due to rainfall, and suggests rainfall recharge to the coal measures, which the bore is assumed to be monitoring, occurs via a slow leakage from the overlying Hawkesbury Sandstone.

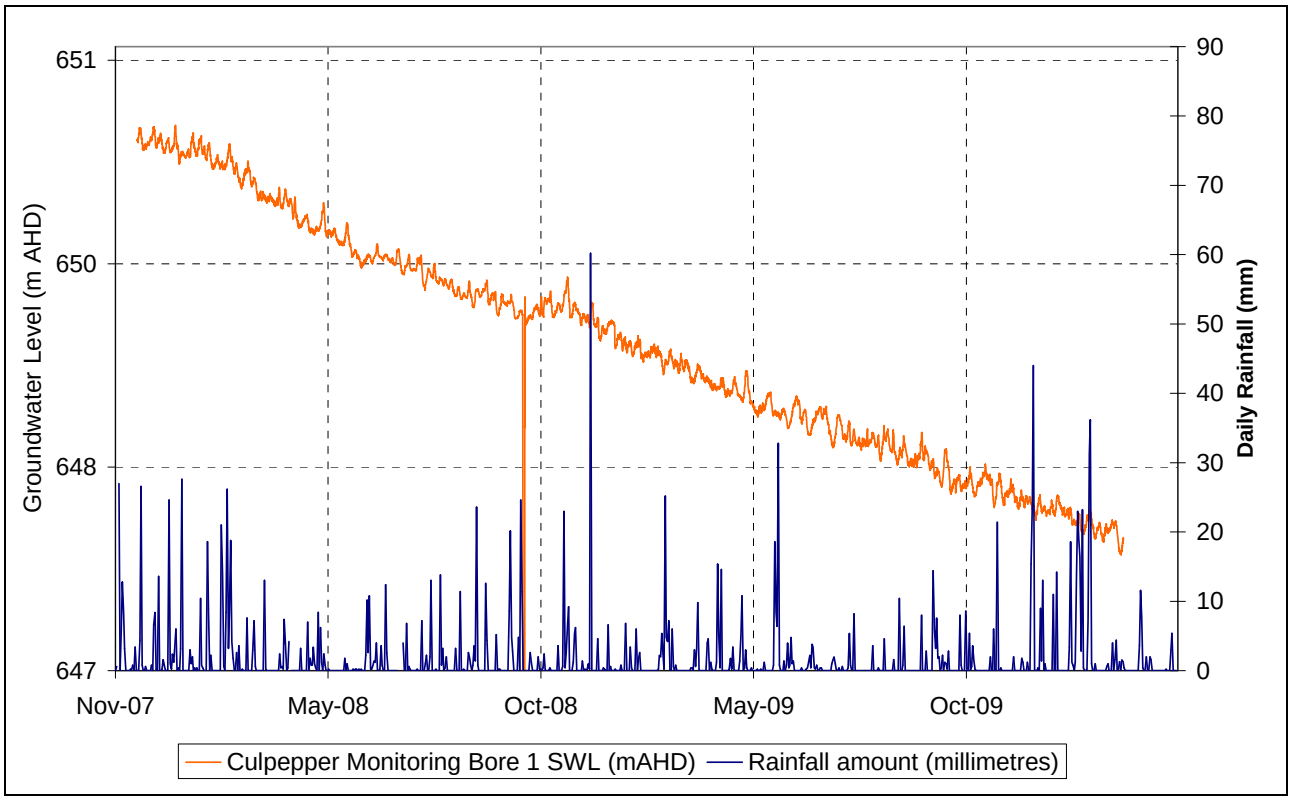


Figure 6: Groundwater Level and Rainfall – Culpepper Monitoring Bore

6.11 Groundwater Dependent Ecosystems

The terms of reference for the Southern Coal Fields Inquiry (NSW Department of Planning 2008) included an assessment of 'aquatic ecosystems' which was considered by the Panel to also include GDEs.

The Inquiry noted that *"runoff is impeded in upland areas where swamps are prevalent, or in areas where a soil or regolith profile is well developed and rainwater can infiltrate and surcharge groundwater. These areas act as water stores and provide a base flow component to stream flow runoff. They also support groundwater dependent ecosystems (GDE)."*

The Inquiry provided a map of upland swamps which were considered to be the main groundwater dependent ecosystems in the area, but did not identify any upland swamps in the Wingecarribee River Catchment, in proximity to the Berrima Colliery. Field inspections undertaken by EGMA Mitchell McLennan in and surrounding the SMP area did not identify any upland swamps.

6.12 Conceptualisation of Groundwater Regime

The existing information and data collected for the current study was used to develop a conceptual understanding (conceptual model) of the hydrogeological regime. Murray Darling Basin Commission (2000) define a conceptual model as an "*idealised summary of the current understanding of catchment conditions, and the key aspects of how the flow system works…subject to some simplifying assumptions.* This conceptual model forms the basis of the assumptions used when assessing the impact of the proposed continuation of mining at the colliery.

The data indicate the area supports the two main regional groundwater systems, being the fractured rock associated with the Hawkesbury Sandstone, and the coal seams of the Illawarra Coal Measures. Both the sandstone and the coal seams form aquifers of low to moderate, but typically not high permeability. Igneous intrusions and basalt flows form higher permeability aquifers but these are more localised and do not extend over large areas.

Recharge to the groundwater system is from direct rainfall and from up-gradient lateral groundwater flow at the eastern boundary of the study area. The recharge rate to the sandstone plateau is relatively high, and this combined with low evaporation rates in the autumn and winter months results in very fresh water in the underlying aquifers. Some recharge of groundwater from seepage through the bed of the Wingecarribee River is also a possibility, but the significance of this is not well understood.

Groundwater levels are sustained by rainfall infiltration, with the potentiometric surface controlled by ground surface topography and surface water interaction. The potentiometric surface is generally a subdued reflection of the surface topography. Groundwater mounds are present beneath the hill areas with ultimate discharge to the incised creeks and the Wingecarribee River. Groundwater discharge also occurs by evaporation, evapotranspiration through vegetation where the water table is within a few metres of the ground surface, and via extraction from water bores where they are present. In the area of the Berrima Colliery, groundwater discharge also occurs via the mined seam and from overlying strata at a rate in proportion to local permeability.

7.0 IMPACT OF PROJECT

The current impact of the mining operations and the impact of the proposed continuation of mining is discussed below.

7.1 Current Impact of Project

The primary impact of the colliery on the groundwater regime is for the groundwater ingress to the colliery to lower groundwater levels that forms a zone of depressurisation in the surrounding coal seam and overlying Hawkesbury Sandstone aquifers thereby potentially impacting the sustainable yield of any surrounding stock and domestic bores in this zone. The groundwater monitoring data around the colliery covers only a limited spatial area and there is insufficient data to determine the extent of the zone of depressurisation created by the colliery. However the available data suggests the zone of depressurisation around the colliery is relatively limited and likely to extend significantly less than 1km from the workings. This is supported by the water levels recorded in the Culpepper bores that do not appear to be impacted by the dewatering at the colliery.

The relatively limited zone of influence is expected to be related to the relatively high recharge rate to the Hawkesbury Sandstone aquifer and leakage from the Hawkesbury Sandstone into the underlying coal measures which serves to maintain water pressures in the coal seam. Seepage of surface water from the Wingecarribee River into the underlying aquifers may also serve to reduce the zone of depressurisation; however the magnitude of the seepage is not known.

The impact of the colliery on groundwater levels and surrounding bores was examined by constructing a cross section in a north-west, south-east direction through the colliery. The alignment of the cross section is shown in Drawing No. 3 and presented in Figure 7.

The cross section utilised:

- ground levels from publicly available digital elevation data (SRTM),
- structure contours for the floor of the coal seam supplied by Boral Cement,
- bore depths for the NOW groundwater database (screen lengths were assumed to be constant).

The cross section below does not suggest that any of the registered bores along the section are potentially within the zone of depressurisation created by the dewatering.

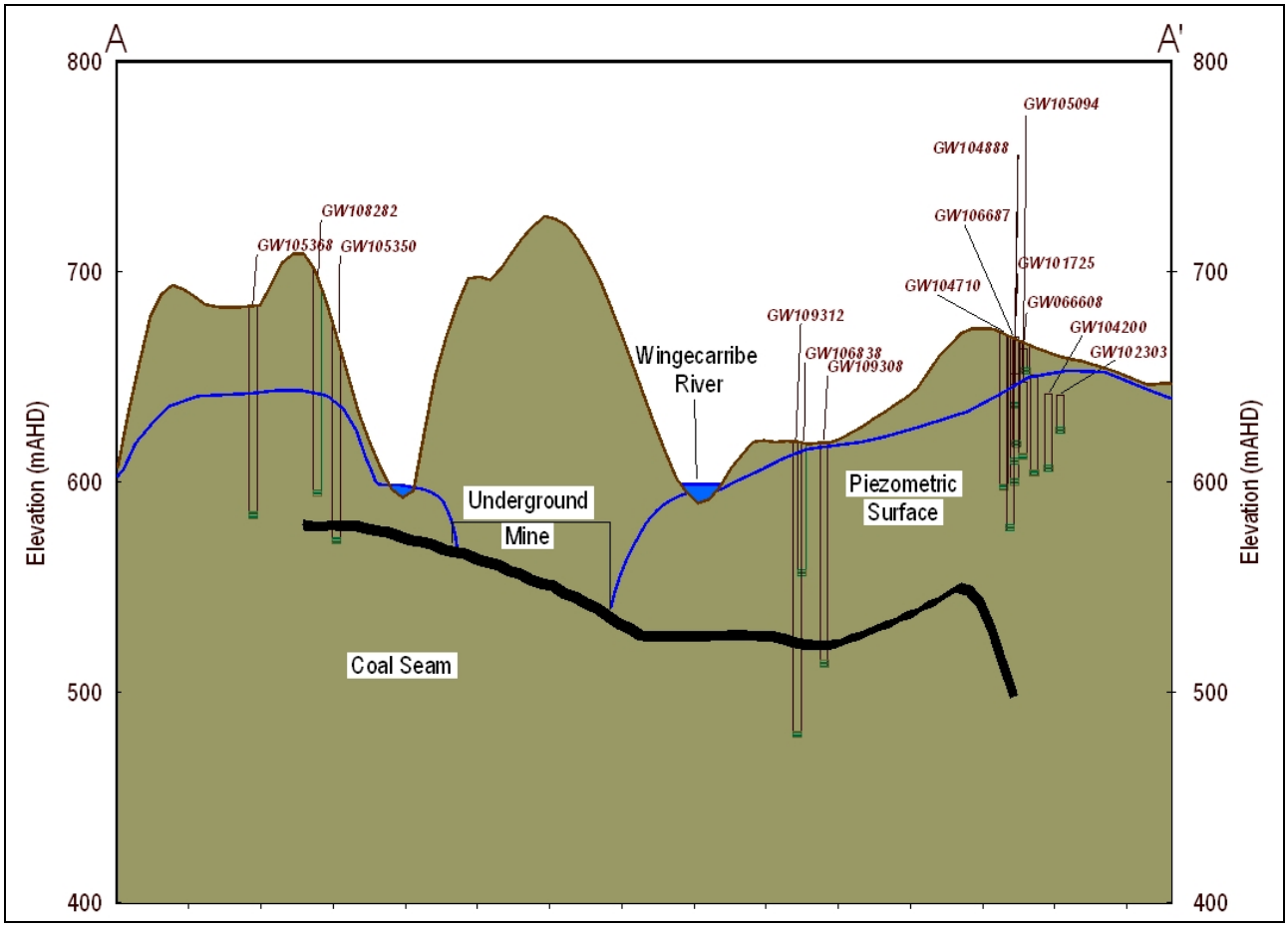


Figure 7: Cross Section - (refer Drawing No. 3)

7.2 Impact of Continuation of Mining

As the colliery has been operating continuously for over 85 years and advancing at a relatively slow rate, a quasi steady state situation is likely to have developed, whereby the zone of depressurisation has reached its maximum extent and not expanding significantly. Similarly the seepage rates to the workings are also not increasing significantly beyond the fluctuating trend identified in the monitoring data.

The inflow to the current mining operations is a combination of groundwater inflow via the coal seam face, and seepage through the roof of the coal mine via faults and dykes. The impact of the continuation of mining on groundwater seepage rates was examined using analytical equations. A more complex numerical model was not considered appropriate given the very limited monitoring data available. Analytical equations were used to assess:

- groundwater inflow through the coal seam using Darcy's Law; and
- inflow via the colliery roof assuming the seepage rate has reached steady state and is equivalent to the rate of recharge over the roof area.

The data and estimated inflows are presented in Table 4.

Table 4: GROUNDWATER INFLOW ESTIMATES

Steady inflow via coal seam		
- hydraulic conductivity	0.2 m/day	
- hydraulic gradient	0.12 (90m in 750m)	
- length of saturated coal seam face	8000m x 6m	
Calculated coal seam inflow		1.15 ML/day
Steady state inflow via roof		
- roof area	7.7 km^2	
- recharge rate	80mm/yr	
Calculated roof inflow		1.68 ML/day
TOTAL STEADY STATE INFLOW		**2.83 ML/day**

The above estimate of the total steady state inflow is within the observed range of 2ML/day to 3.5ML/day range measured at the colliery (refer Figure 5).

The continuation of operations will result in the expansion of the colliery footprint; however the length of coal seam face is not expected to increase significantly. In addition as the mine is advancing across dip not down-dip, and therefore as the mine is not getting deeper, the hydraulic gradient will not increase. Consequently the steady state inflow via the coal seam is not expected to increase; however as the roof area is increasing slightly, seepage via vertical flow will likely increase. Assuming an increase in roof area from 7.7km^2 to 8.7km^2 the total inflow is calculated to reach a steady state of 3.1 ML/day, a 7% increase in flow.

8.0 WATER LICENCING

Monitoring of volumes of water pumped from the colliery has been undertaken since June 2005. The monitoring has comprised daily measurement of the V-notch weir flow rates during the working week. The monitoring data is summarised below in Table 5.

It should be noted that the above assessment assumes the geological conditions remain similar in the SMP area to the previous workings. The mine will advance under areas of basalt cap and there is the possibility of an increase in frequency of dykes, or dykes being interconnected to overlying basalt aquifers. When these zones are intersected, higher inflows are expected. As the dykes drain the inflows would be expected to reduce, as has been observed previously in the colliery.

Table 5:SUMMARY OF GROUNDWATER INGRESS RECORDS	
Monitoring period	20 June 2005 to 7 January 2010
	4.5 years
Daily pumping rate	Average – 2.7 ML/day
	Maximum – 4.3 ML/day
	Minimum – 0.7 ML/day
Yearly pumping rate	Average – 986 ML/year

Boral Cement has submitted an application for a licence from the NOW to extract groundwater at Berrima Colliery under Part 5 of the *Water Act 1912*. This licence will allow Berrima Colliery to extract groundwater which flows into the underground workings at a maximum rate of 2,000 ML/year, averaged over 3 years, which is within the predicted increase.

9.0 GROUNDWATER MONITORING SYSTEM

This section of the report outlines the recommended groundwater monitoring program.

9.1 Discussion of Monitoring Program

A monitoring program has been developed to address the key data gaps that currently exist, and to assess the impact of the continuation of operations during mining of panel 59, south-west 1 and 406 panel. The key data gaps are:

- *Surface Water / Groundwater Interaction* - the influence of seepage from the Wingecarribee River into the underlying aquifers, and the impact of this seepage on maintaining groundwater levels around the colliery is not well understood. A program including physical measurement of flows in the river to determine if losses are occurring, and on isotopic chemistry study should be undertaken to determine if river seepage can be identified chemically in the colliery workings, and the magnitude of this seepage.

- *Zone of Depressurisation* – the groundwater monitoring bore network is not adequate enough to measure the zone of depressurisation in the coal seam, or to understand the impact of any leakage from the overlying Hawkesbury Sandstone into the depressurised seam. Installation of monitoring bores in strategic locations will enable assessment of the zone of depressurisation and also assist in assessing the surface water / groundwater interaction. It is understood abandoned coal resource holes have not been cemented and may be suitable for constructing groundwater monitoring bores. Conversion of resource exploration holes in the SMP area into groundwater monitoring bores is also currently being planned.
- *Landholder Bores* – Stock and domestic bores that surround the colliery to the east and north need to be inspected to measure water levels/quality and determine which aquifers the bores are extracting from, so that a baseline dataset is available against which to assess the impact if any of any proposed further expansion.
- *Groundwater Inflows* – the V-notch weir level is currently measured manually which is time consuming, and also means flows are not measured on the weekend when the colliery is not operational. It is recommended an electronic data logger be installed at the weir to automatically measure water level, salinity and temperature.

9.2 Installation of Additional Monitoring Bores

Two drill holes will to be drilled in the SMP area for coal resource exploration purposes. It is planned that these drill holes will be converted to groundwater bores to enable the impact of the continuing operations to be monitored. The locations of the proposed new monitoring bores are shown in Drawing No. 9. The proposed boreholes are located to north of the colliery to monitor water levels between the colliery and the existing landholder bores. These bores will serve as an early warning system should any reductions in groundwater levels be detected during the continuation of operations.

The locations of any further monitoring bores has not been determined at this stage as it will be necessary to locate the former coal exploration drill holes and determine if they are suitable to construct groundwater monitoring bores. Should coal exploration drill holes prove not to be suitable for construction of groundwater monitoring bores, then consideration should be given to drilling new bore holes.

A bore licence from NOW will be required for the new monitoring bores. All monitoring bores should be constructed by an appropriately licensed water bore driller according to the Land and Water Biodiversity Committee (2003) guidelines.

9.3 Water Level Monitoring Plan

It is recommended that electronic water level loggers are installed in the new monitoring bores and in key landholder bores identified during the bore census. The data loggers will enable water level fluctuations due to rainfall recharge and pumping to be distinguished from potential water level declines due to depressurisation of the coal seams as a result of dewatering at the colliery.

Manual water level monitoring should be undertaken on a quarterly basis.

9.4 Water Quality Monitoring Plan

It is recommended that water samples are collected from the new and existing monitoring bores on a six monthly basis. The samples should be tested for pH and EC in the field and analysed in the laboratory for pH, EC, TDS, major ions (Ca, Mg, Na, K, CO_3, HCO_3, Cl, B_2 SO_4) and trace elements As, B, F, Fe (soluble), Li, Mn, P, Se, Si, Sr, Zn.

A round of samples collected from within the colliery, from the locations along the Wingecarribee River and from the groundwater monitoring bores should also have the isotope chemistry and groundwater age assessed to further assess the significance of recharge from the river.

The seepage monitoring program should include six monthly collection of samples from:

- the active face
- dykes with significant groundwater ingress
- fault zones or significant roof leakages
- the V-notch weir

The laboratory analysis should include pH, EC, TDS, major ions (Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4) and trace elements As, B, F, Fe (soluble), Li, Mn, P, Se, Si, Sr, Zn.

9.5 Data Management and Reporting

It is recommended that data management and reporting include a formal review of the available data annually by a suitably qualified hydrogeologist. Annual reporting including all water level and water quality data should be included as part of the AEMR.

AUSTRALASIAN GROUNDWATER AND ENVIRONMENTAL CONSULTANTS PTY LTD

Reviewed by:



JAMES S. TOMLIN
Principal Hydrogeologist

ERROL H. BRIESE
Principal Hydrogeologist/Managing Director

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GLOSSARY

Alluvium - Sediment (gravel, sand, silt, clay) transported by water (i.e. deposits in a stream channel or floodplain).

Aquiclude - A low-permeability unit that forms either the upper or lower boundary of a ground-water flow system.

Aquifer - Rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Aquifer, confined - An aquifer that is overlain by a confining bed. The confining bed has a significantly lower hydraulic conductivity than the aquifer.

Aquifer, perched - A region in the unsaturated zone where the soil may be locally saturated because it overlies a low-permeability unit.

Aquifer, semi-confined - An aquifer confined by a low-permeability layer that permits water to slowly flow through it. During pumping of the aquifer, recharge to the aquifer can occur across the confining layer. Also known as a leaky artesian or leaky confined aquifer.

Aquifer, unconfined - An aquifer in which there are no confining beds between the zone of saturation and the surface. There will be a water table in an unconfined aquifer. Water-table aquifer is a synonym.

Aquitard - A low-permeability unit than can store ground water and also transmit it slowly from one aquifer to another.

Colluvium - Sediment (gravel, sand, silt, clay) transported by gravity (i.e. deposits at the base of a slope).

Cone of Depression - The depression in the water table around a well or excavation defining the area of influence of the well. Also known as cone of influence.

Drawdown - A lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused by pumping of ground water from wells or excavations.

Hydraulic Conductivity - A measure of the rate at which water moves through a soil/rock mass. It is the volume of water that moves within a unit of time under a unit hydraulic gradient through a unit cross-sectional area that is perpendicular to the direction of flow.

Hydraulic gradient - The change in total head with a change in distance in a given direction. The direction is that which yields a maximum rate of decrease in head.

Infiltration - The flow of water downward from the land surface into and through the upper soil layers.

Model calibration - The process by which the independent variables of a digital computer model are varied in order to calibrate a dependent variable such as a head against a known value such as a water-table map.

Packer test - An aquifer test performed in an open borehole; the segment of the borehole to be tested is sealed off from the rest of the borehole by inflating seals, called packers, both above and below the segment.

Piezometer - A non-pumping well, generally of small diameter, that is used to measure the elevation of the water table or potentiometric surface. A piezometer generally has a short well screen through which water can enter.

Porosity - The ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment.

Potentiometric surface - A surface that represents the level to which water will rise in tightly cased wells. If the head varies significantly with depth in the aquifer, then there may be more than one potentiometric surface. The water table is a particular potentiometric surface for an unconfined aquifer.

Pumping Test - A test made by pumping a well for a period of time and observing the response/change in hydraulic head in the aquifer.

Slug Test - A test made by the instantaneous addition, or removal, of a known volume of water to or from a well. The subsequent well recovery is measured.

Specific yield - The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Gravity drainage may take many months to occur.

Storativity - The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer, per unit change in head.

Transmissivity - A measure of the rate at which water moves through an aquifer of unit width under a unit hydraulic gradient.

Unsaturated zone - The zone between the land surface and the water table. It includes the root zone, intermediate zone, and capillary fringe. The pore spaces contain water at less than atmospheric pressure, as well as air and other gases. Saturated bodies, such as perched ground water, may exist in the unsaturated zone. Also called zone of aeration and vadose zone.

Water budget - An evaluation of all the sources of supply and the corresponding discharges with respect to an aquifer or a drainage basin.

LIMITATIONS OF REPORT

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) has prepared this report for the use of Boral Cement in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the email of 7 October 2009.

The methodology adopted and sources of information used by AGE are outlined in this report. AGE has made no independent verification of this information beyond the agreed scope of works and AGE assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to AGE was false.

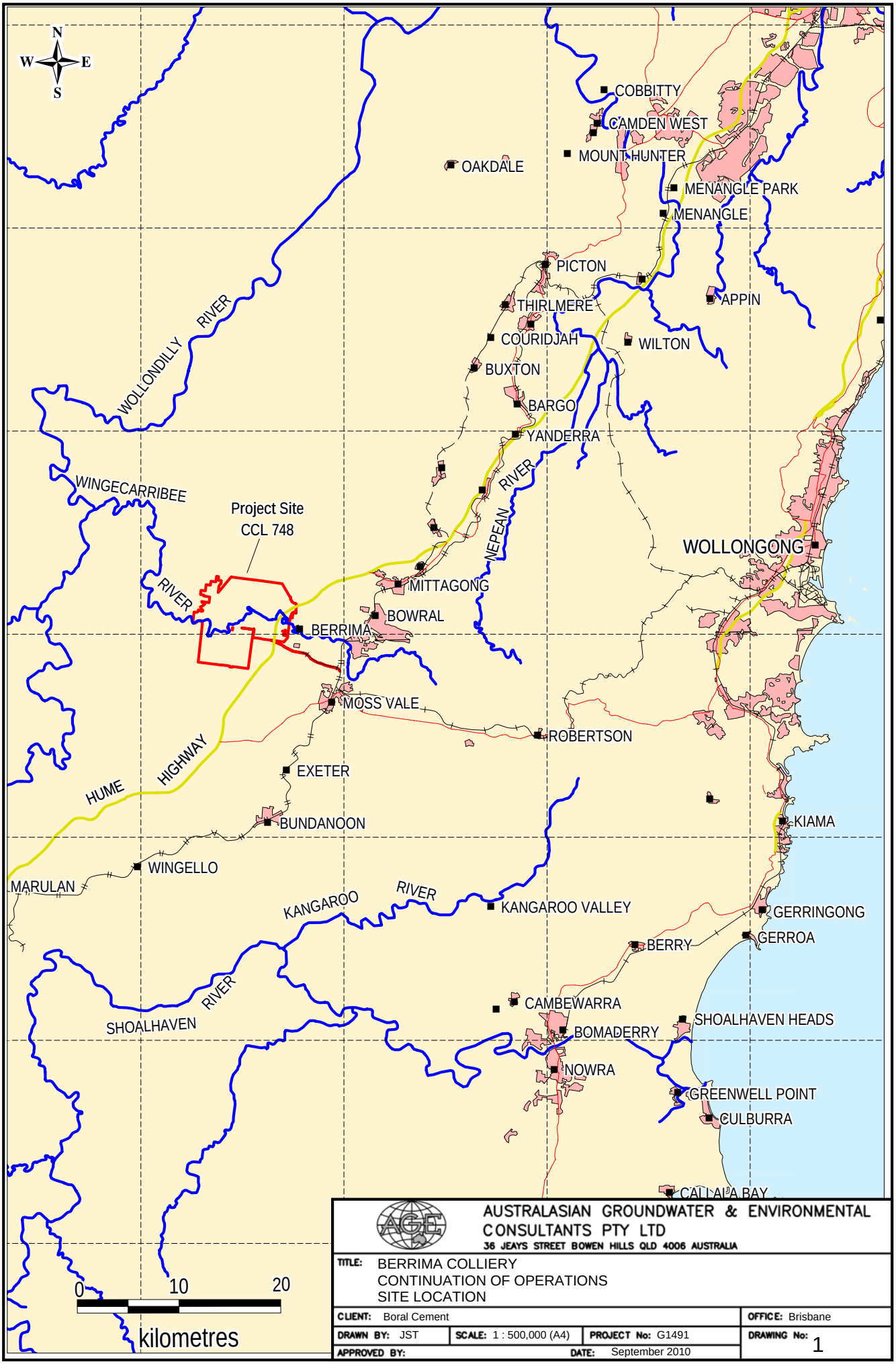
This study was undertaken between 26 November 2009 and 20 September 2010 and is based on the conditions encountered and the information available at the time of preparation of the report. AGE disclaims responsibility for any changes that may occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. It may not contain sufficient information for the purposes of other parties or other users. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

This report contains information obtained by inspection, sampling, testing and other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. Where borehole logs are provided they indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the frequency and method of sampling, and the uniformity of the site, as constrained by the project budget limitations. The behaviour of groundwater is complex. Our conclusions are based upon the analytical data presented in this report and our experience.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, AGE must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

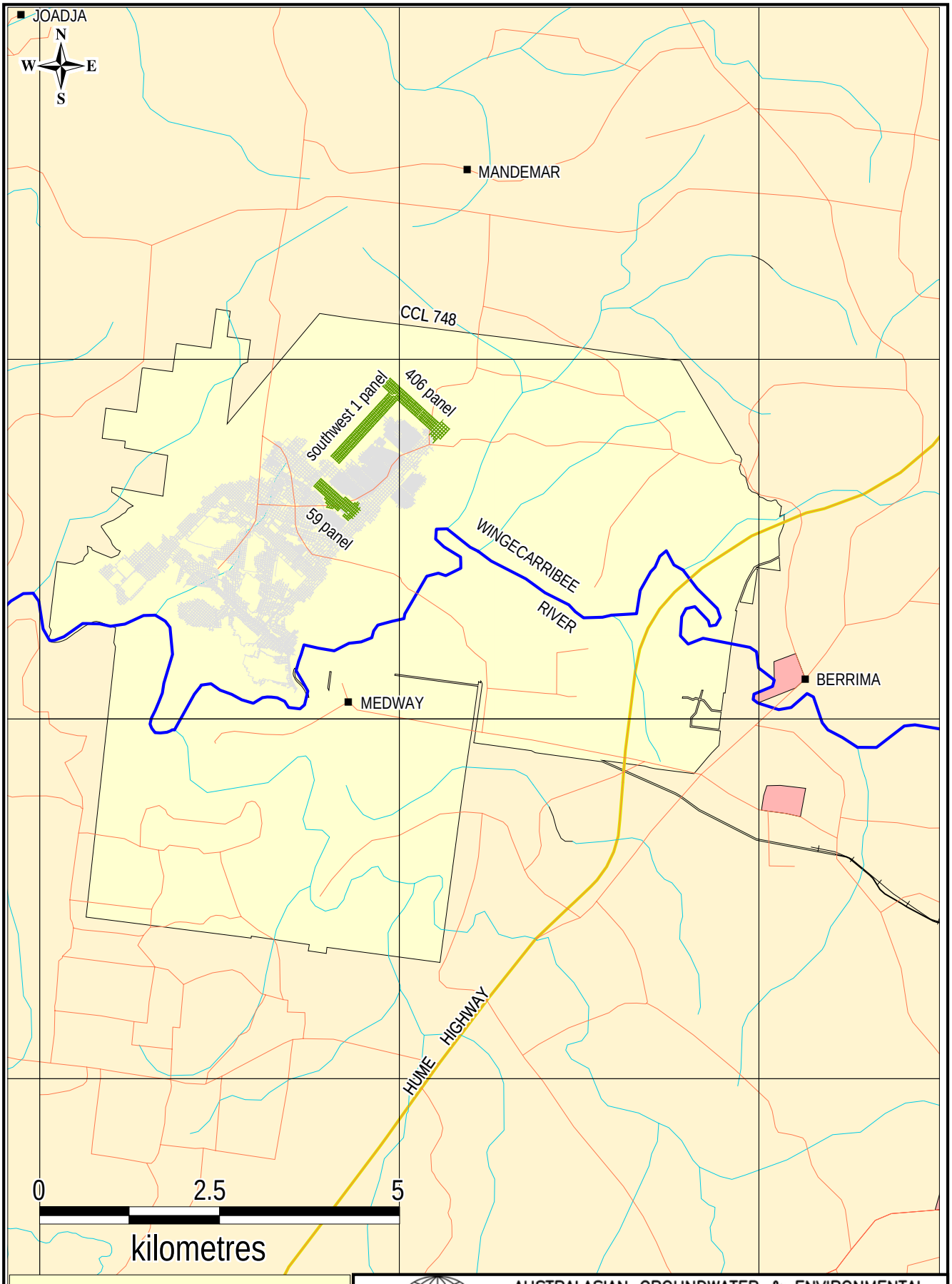
Whilst to the best of our knowledge, information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time. Therefore this document and the information contained herein should only be regarded as valid at the time of the investigation unless otherwise explicitly stated in this report.



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36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

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SITE LOCATION

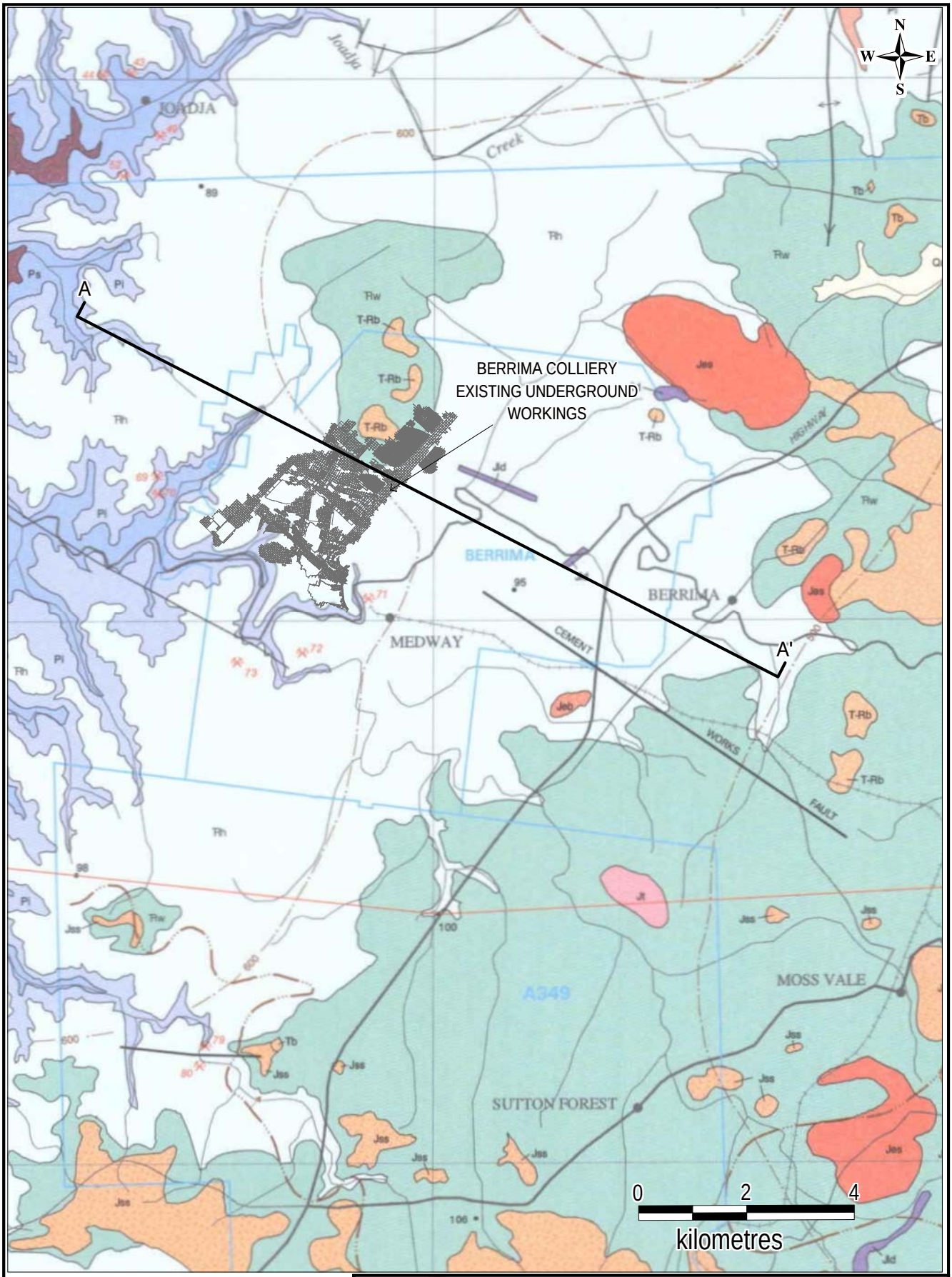
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APPROVED BY:		DATE: September 2010	



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TITLE: BERRIMA COLLIERY
CONTINUATION OF OPERATIONS
SITE LOCATION

CLIENT: Boral Cement			OFFICE: Brisbane
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APPROVED BY:		DATE: September 2010	



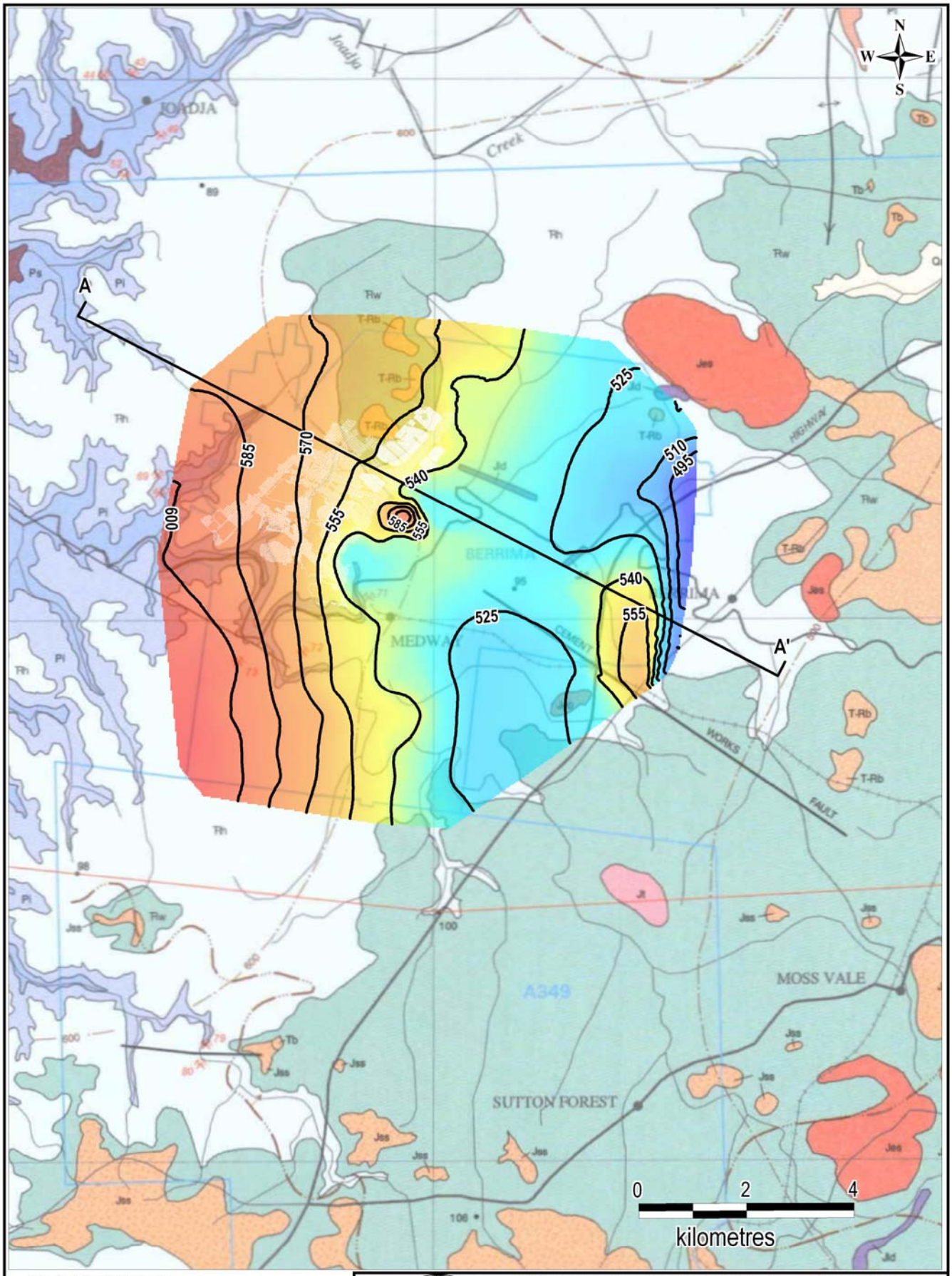
GEOLOGY SYMBOLS

Trb Robertson basalt
Jld Olivine dolerite, gabbro
Rw Wianimatta Group
Rh Hawkesbury Sandstone
Pi Illawarra Coal Measures
Ps Shoalhaven Coal Measures
Dmg Marulan Granite

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TITLE: BERRIMA COLLIERY - CONTINUATION OF MINING
GROUNDWATER ASSESSMENT
GEOLOGY

CLIENT: Boral Cement			OFFICE: Brisbane
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APPROVED BY:		DATE: September 2010	



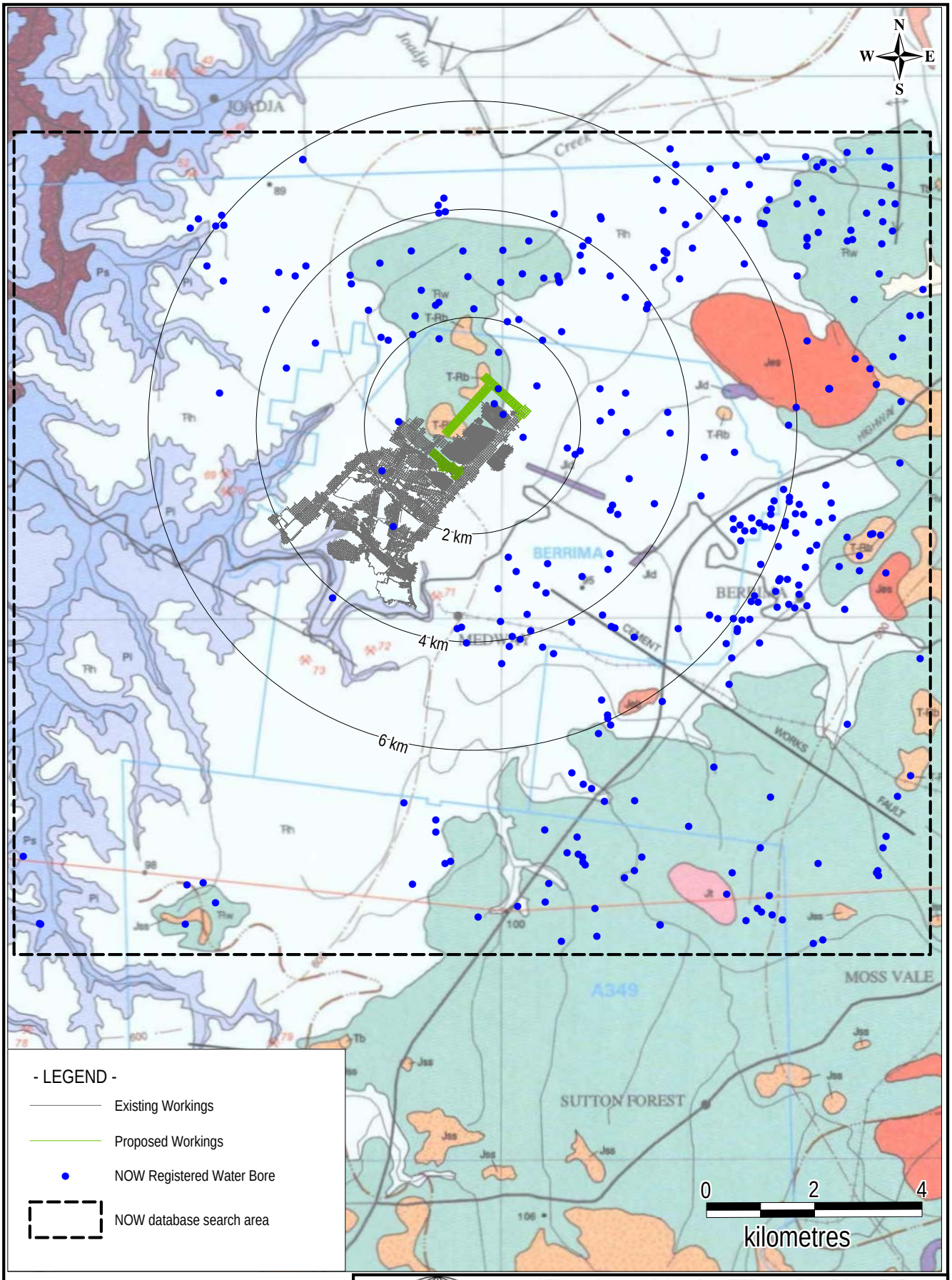
GEOLOGY SYMBOLS

Trb	Robertson basalt
Jld	Olivine dolerite, gabbro
Rw	Wianimatta Group
Rh	Hawkesbury Sandstone
Pi	Illawarra Coal Measures
Ps	Shoalhaven Coal Measures
Dmg	Marulan Granite

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TITLE: BERRIMA COLLIERY - CONTINUATION OF MINING
GROUNDWATER ASSESSMENT
WONGAWILLI COAL SEAM FLOOR STRUCTURE CONTOUR

CLIENT: Boral Cement			OFFICE: Brisbane
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APPROVED BY:		DATE: September 2010	



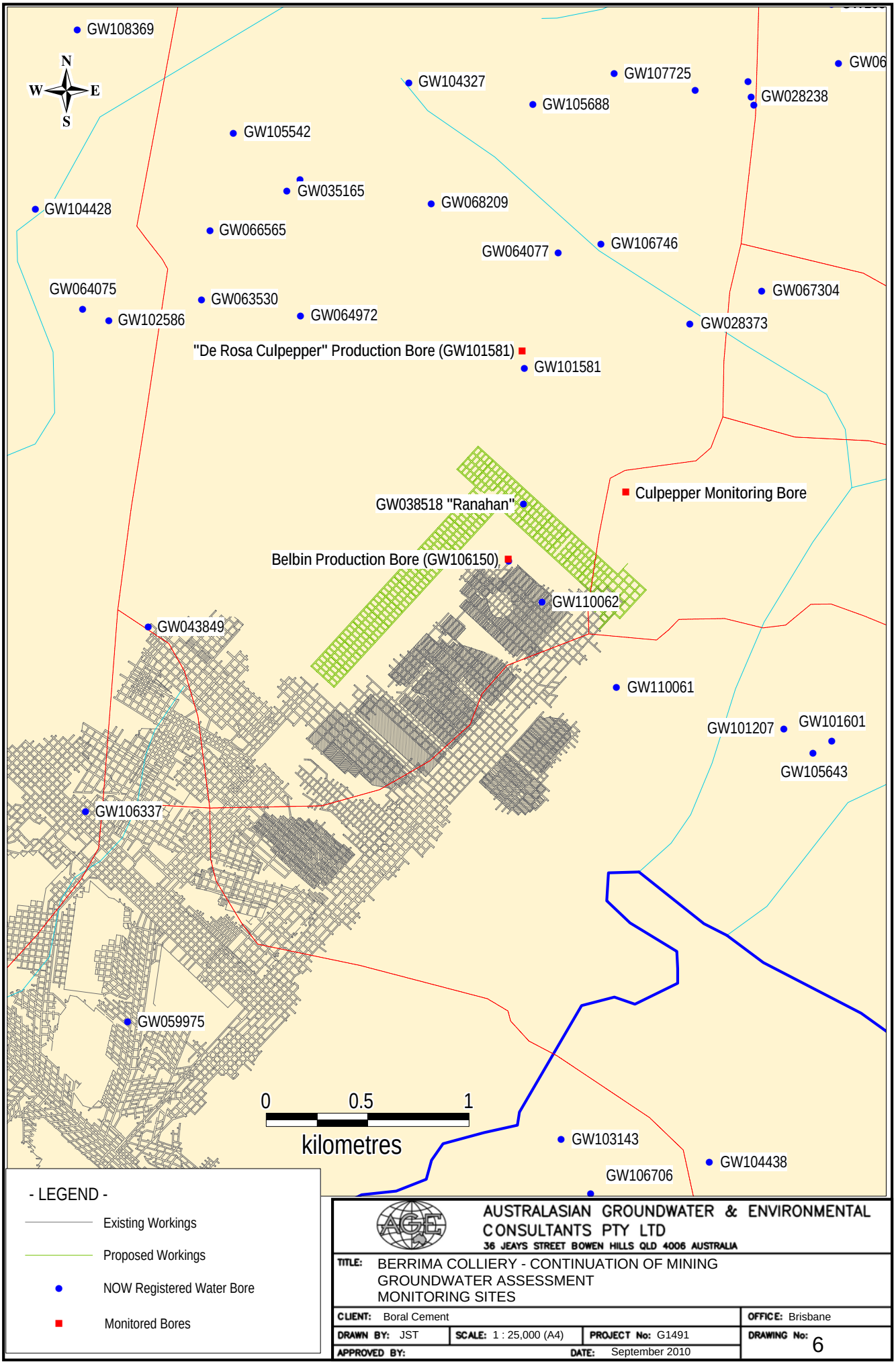
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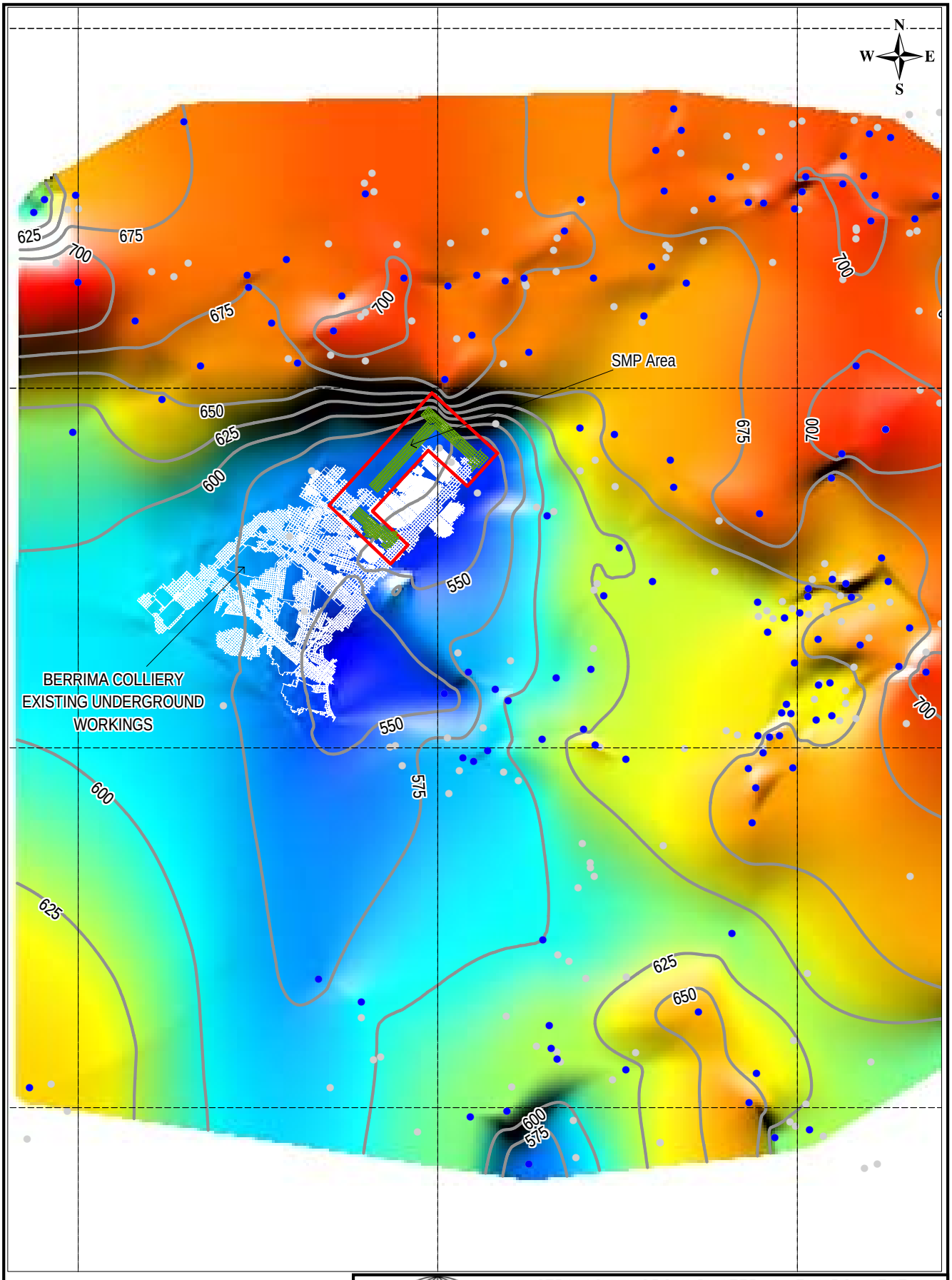
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Jld	Olivine dolerite, gabbro
Rw	Wianimatta Group
Rh	Hawkesbury Sandstone
Pi	Illawarra Coal Measures
Ps	Shoalhaven Coal Measures
Dmg	Marulan Granite

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TITLE: BERRIMA COLLIERY - CONTINUATION OF MINING GROUNDWATER ASSESSMENT
REGISTERED WATER BORES

CLIENT: Boral Cement			OFFICE: Brisbane
DRAWN BY: JST	SCALE: 1 : 100:000 (A4)	PROJECT No: G1491	DRAWING No: 5
APPROVED BY:		DATE: September 2010	


GW108369
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Culpepper Monitoring Bore
Belbin Production Bore (GW106150)
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GW105643
GW106337
GW059975
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0.5
1
kilometres
GW103143
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- LEGEND -
Existing Workings
Proposed Workings
NOW Registered Water Bore
Monitored Bores
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TITLE: BERRIMA COLLIERY - CONTINUATION OF MINING
GROUNDWATER ASSESSMENT
MONITORING SITES
CLIENT: Boral Cement
OFFICE: Brisbane
DRAWN BY: JST
SCALE: 1 : 25,000 (A4)
PROJECT No: G1491
DRAWING No: 6
APPROVED BY:
DATE: September 2010



Registered Water Bore

Approximate Groundwater Level (mAHD)

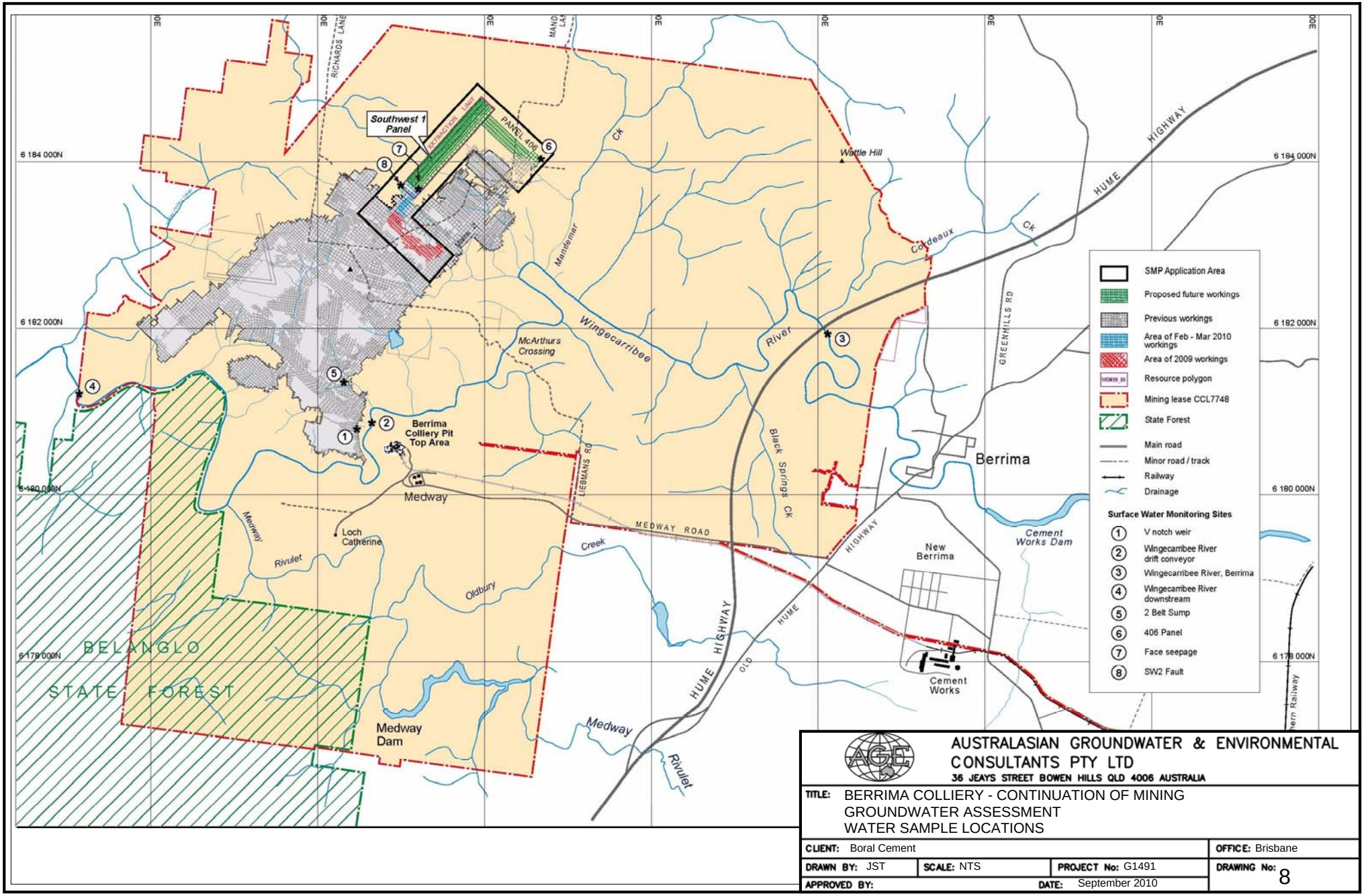
Registered Water Bores with Water Level

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TITLE: BERRIMA COLLIERY - CONTINUATION OF MINING GROUNDWATER ASSESSMENT
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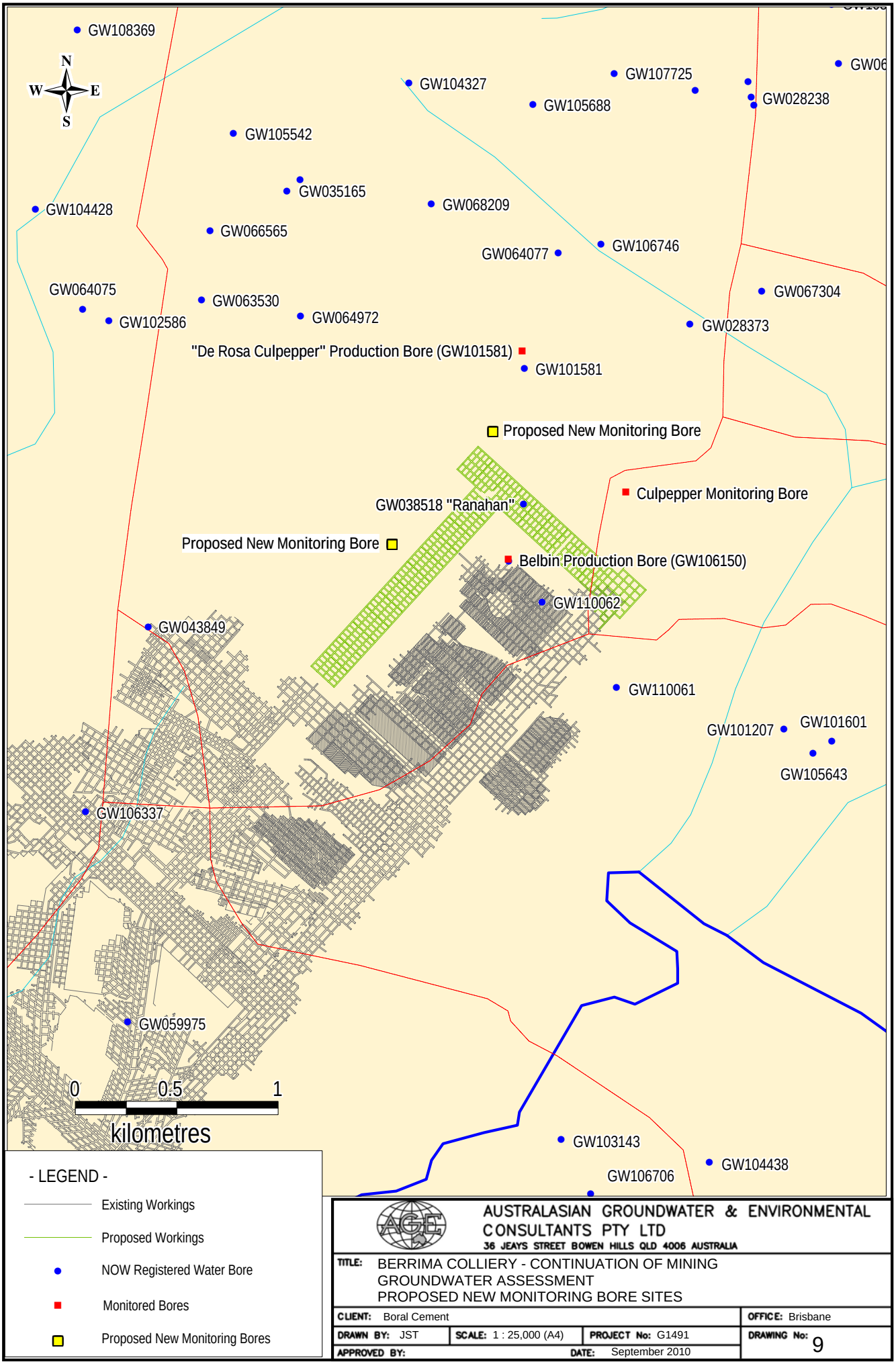
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APPROVED BY:		DATE: September 2010	



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TITLE: BERRIMA COLLIERY - CONTINUATION OF MINING GROUNDWATER ASSESSMENT
WATER SAMPLE LOCATIONS

CLIENT: Boral Cement			OFFICE: Brisbane
DRAWN BY: JST	SCALE: NTS	PROJECT No: G1491	DRAWING No: 8
APPROVED BY:		DATE: September 2010	



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TITLE: BERRIMA COLLIERY - CONTINUATION OF MINING
GROUNDWATER ASSESSMENT
PROPOSED NEW MONITORING BORE SITES

CLIENT: Boral Cement			OFFICE: Brisbane
DRAWN BY: JST	SCALE: 1 : 25,000 (A4)	PROJECT No: G1491	DRAWING No: 9
APPROVED BY:		DATE: September 2010	

APPENDIX A

SUMMARY OF WATER QUALITY ANALYSES

Table A1 - SUMMARY OF WATER QUALITY DATA - BERRIMA COLLIERY

Parameter	Units	Stock water Triggers [1]	ADWG Drinking Water Triggers	V-notch weir (1)								Face Seepage (7)			
				12 Jan 2010	18 Jan 2010	22 Jan 2010	26 Feb 2010	20 April 2010	7 May 2010	5 July 2010	7 July 2010	22 Jan 2010	20 April 2010	7 May 2010	5 July 2010
Physico-chemical															
pH Value			6.5-8.5	6.9	7.5	7.2	6.8	7.25	6.72	6.78	6.63	7.1	6.6	6.14	7.58
Electrical Conductivity	uS/cm			750	790	800	819	763	782	748	721	410	292	234	515
Total Dissolved Solids [2]	mg/L	4000	500	502.50	760	620	548.73	511.21	523.94	501.16	483.07	350	196	157	345.05
Suspended Solids	mg/L			2	6		<1	4	4	1	4		6	4	
Turbidity	mg/L				4.7										
Major Cations/Anions															
Calcium	mg/L	1000		-	53	51	55		49	47	44	21		8	48
Magnesium	mg/L			-	48	47	45		42	42	40	18		10	18
Potassium	mg/L			-	3.20	4	3.00		3.00	3	3	1		1	3
Sodium	mg/L			-	38	36	32		33	33	28	27		17	24
Bromide	mg/L			-					0.08	0.117	0.067			0.08	0.135
Chloride	mg/L		250	-		44			43.80	37.10	44.5	28		31.3	41.8
Sulphate	mg/L	1000		-		284			256	280	221	141		2.35	37.2
Bicarbonate	mg/L			-		51				36	37	8			162
Trace Metals															
Aluminium	mg/L	5	0.2	-	0.01		0.03	0.03					<0.01		
Arsenic	mg/L	0.5	0.007	-	<0.01	<0.001	<0.001	<0.001				<0.001	<0.001		
Cadmium	mg/L	0.01	0.002	-	<0.01	0.0002	0.0006	0.0006	0.0004	0.0004	0.0003	0.0013	<0.0001	<0.0001	<0.0001
Cobalt	mg/L			-	0.04		0.053	0.060	0.054	0.049	0.046		<0.001	0.00	0.001
Copper	mg/L	1	1	-	<0.01	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	mg/L			-	0.22	<0.05	0.20	0.16	0.36	0.15	0.18	4.77	5.03	9.57	0.06
Manganese	mg/L			-	2.9		2.94	3.22	3.37	2.90	2.67		0.49	0.630	0.195
Nickel	mg/L	1		-	0.14	0.125	0.213	0.208	0.181	0.161	0.152	0.32	<0.001	0.004	0.016
Zinc	mg/L	20		-	0.19	0.174	0.323	0.298	0.260	0.224	0.225	2.84	<0.005	<0.005	0.011
Nutrients															
Ammonia as N	mg/L		0.5	-						0.01	<0.01				0.04
Nitrite as N	mg/L	30		-						<0.01	<0.01				0.01
Nitrate as N	mg/L	400		-						0.03	0.03				<0.01
Nitrite + Nitrate as N	mg/L			-						0.03	0.03				0.02
Total Phophorus as P	mg/L			-						<0.01	<0.01				<0.01

1) ANZECC (2000) triggers

2) TDS calculated from EC where data not available

Table A1 - SUMMARY OF WATER QUALITY DATA - BERRIMA COLLIERY

Parameter	Units	Stock water Triggers [1]	ADWG Drinking Water Triggers	406 Panel Dyke (6)				SW2 Fault (8)				Sump below 2 Belt (5)	
				22 Jan 2010	20 April 2010	7 May 2010	5 July 2010	22 Jan 2010	20 April 2010	8 May 2010	5 July 2010	7 May 2010	5 July 2010
Physico-chemical													
pH Value			6.5-8.5	7.4	6.43	6.26	6.45	7.5	6.54	6.36	7.40	7.3	7.45
Electrical Conductivity	uS/cm			320	339	341	414	220	240	274	363	747	702
Total Dissolved Solids [2]	mg/L	4000	500	190	227	228.47	277.38	140	161	184	243.21	500.49	470.34
Suspended Solids	mg/L				4	5			<1	2.00		32	
Turbidity	mg/L												
Major Cations/Anions													
Calcium	mg/L	1000		11		12	13	5		6	18	47	46
Magnesium	mg/L			15		15	21	10		13	19	37	38
Potassium	mg/L			2		2	2	<1		<1	1	3	3
Sodium	mg/L			26		26	34	17		21	22	34	33
Bromide	mg/L					0.11	0.204			0.07	0.092	0.08	0.110
Chloride	mg/L		250	46		44.6	65.5	34		34.20	29.4	43.6	39.5
Sulphate	mg/L	1000		4		4.00	4.06	3		48.4	99.7	238	256
Bicarbonate	mg/L			81			105	47			27		39
Trace Metals													
Aluminium	mg/L	5	0.2		<0.01				<0.01				
Arsenic	mg/L	0.5	0.007	<0.001	<0.001			<0.001	<0.001				
Cadmium	mg/L	0.01	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	0.0002	0.0002	0.0008	0.0005
Cobalt	mg/L				<0.001	<0.001	0.002		0.068	0.116	0.119	0.088	0.084
Copper	mg/L	1	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	<0.001	0.005	0.002
Iron	mg/L			5.62	7.18	6.95	9.88	9.35	0.31	0.96	3.88	4.18	1.88
Manganese	mg/L				0.481	0.496	0.596		1.30	2.07	3.19	4.61	4.71
Nickel	mg/L	1		<0.001	0.001	<0.001	0.004	0.010	0.149	0.237	0.251	0.267	0.235
Zinc	mg/L	20		<0.005	<0.005	<0.005	<0.005	0.023	0.299	0.552	0.769	0.456	0.360
Nutrients													
Ammonia as N	mg/L		0.5				<0.01				<0.01		<0.01
Nitrite as N	mg/L	30					<0.01				<0.01		<0.01
Nitrate as N	mg/L	400					<0.01				<0.01		<0.01
Nitrite + Nitrate as N	mg/L						<0.01				<0.01		<0.01
Total Phophorus as P	mg/L						<0.01				0.04		0.01

1) ANZECC (2000) triggers

2) TDS calculated from EC where data not available

Table A1 - SUMMARY OF WATER QUALITY DATA - BERRIMA COLLIERY

Parameter	Units	Stock water Triggers [1]	ADWG Drinking Water Triggers	Wingecarribee River										
				Upstream (3)				Drift Conveyor Crossing (2)			Downstream (4)			
				11 March 2010	20 April 2010	10 May 2010	8 July 2010	12 Jan 2010	18 Jan 2010	10 May 2010	11 March 2010	20 April 2010	10 May 2010	8 July 2010
Physico-chemical														
pH Value			6.5-8.5	7.83	7.89	7.43	6.74	7.7	7.4		7.73	7.62	7.40	6.89
Electrical Conductivity	uS/cm			206	268	217	146	330	310		297	284	275	208
Total Dissolved Solids [2]	mg/L	4000	500	138	180	145	97.82	221.10	180		1	190	184	139.36
Suspended Solids	mg/L			14	4		12	5	5		7	4		12
Turbidity	mg/L								3.4					
Major Cations/Anions														
Calcium	mg/L	1000		12		10	6		12		17		13	11
Magnesium	mg/L			6		5	4		7.6		10		7	8
Potassium	mg/L			5		5	3		4.5		4		6	3
Sodium	mg/L			14		20	12		29		18		23	14
Bromide	mg/L					0.08	0.048						0.09	0.049
Chloride	mg/L		250			29.2	22.5						34.0	24.7
Sulphate	mg/L	1000				21.4	11.2						30.2	29.4
Bicarbonate	mg/L						22							30
Trace Metals														
Aluminium	mg/L	5	0.2	0.05	0.04				0.01		0.04	0.04		
Arsenic	mg/L	0.5	0.007	<0.001	<0.001				<0.01		<0.001	<0.001		
Cadmium	mg/L	0.01	0.002	<0.0001	<0.0001	<0.0001	<0.0001		<0.01		<0.001	<0.0001	<0.0001	<0.0001
Cobalt	mg/L			<0.001	<0.001	<0.001	<0.001		<0.01		<0.001	<0.001	<0.001	<0.001
Copper	mg/L	1	1	0.001	0.003	0.002	0.002		<0.01		0.002	0.002	0.004	0.002
Iron	mg/L			0.61	0.24	0.52	0.38		0.04		0.50	0.42	0.40	0.45
Manganese	mg/L			0.247	0.049	0.115	0.029		0.15		0.217	0.110	0.078	0.063
Nickel	mg/L	1		0.003	<0.001	<0.001	<0.001		<0.01		0.003	0.003	0.004	0.004
Zinc	mg/L	20		<0.005	<0.005	0.006	<0.005		<0.01		0.006	0.007	0.009	<0.005
Nutrients														
Ammonia as N	mg/L		0.5				<0.01							<0.01
Nitrite as N	mg/L	30					<0.01							<0.01
Nitrate as N	mg/L	400					0.025							0.016
Nitrite + Nitrate as N	mg/L						0.025							0.016
Total Phophorus as P	mg/L						0.18							0.30

1) ANZECC (2000) triggers

2) TDS calculated from EC where data not available

Appendix E

Traffic Impact Assessment

Boral Cement

Berrima Colliery

Transport Impact Assessment

TIA REPORT

ARUP

Boral Cement

Berrima Colliery

Transport Impact Assessment

September 2010

Arup
Arup Pty Ltd ABN 18 000 966 165

This report takes into account the particular instructions and requirements of our client.
It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party

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Revision	Date				
Draft 1	22/12/09	Filename	0001DraftReportBerrimaColliery.doc		
		Description	First draft		
			Prepared by	Checked by	Approved by
		Name	Tim Brooker	Tim Brooker	Colin Henson
		Signature			
Draft 2	20/01/10	Filename	0002BerrimaCollieryDraftBaselineTrafficReport.doc		
		Description	Daily Coal Truck Movement Included		
			Prepared by	Checked by	Approved by
		Name	Tim Brooker	Tim Brooker	Colin Henson
		Signature			
Draft TIA Report	28/07/10	Filename	0003DraftTIAReportBerrimaColliery.docx		
		Description	Combined (baseline & TIA) report		
			Prepared by	Checked by	Approved by
		Name	Tim Brooker	Tim Brooker	Colin Henson
		Signature			
TIA Report	07/09/10	Filename	0004BerrimaCollieryTIAReportFinalSeptember2010.docx		
		Description	Client's comment incorporated		
			Prepared by	Checked by	Approved by
		Name	Tim Brooker	Tim Brooker	Colin Henson
		Signature			

Issue Document Verification with Document ✓

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Appendices

Appendix A

Traffic Count Data

Appendix B

Sidra Intersection Results

1 Introduction

Arup has been commissioned by Boral Cement (Boral) to prepare a Transport Impact Assessment (TIA) for a Part 3A application for the continued operation of Berrima Colliery. This TIA report is a component of the Environmental Assessment (EA) to be lodged with the Department of Planning (DoP).

The TIA has been undertaken in the following two stages:

- Review of Baseline Conditions – this includes assessment of existing conditions, traffic survey, capacity of road networks, intersections etc.
- Undertake TIA – assessment of the likely traffic impact associated with the proposal

This report mainly covers the transport assessment of coal that is transported to external customers located generally north and south of the Colliery.

1.1 Project Background

Berrima Colliery has been operating since about 1890. The Colliery is an underground bord and pillar operation which mines the Wongawilli Seam. In 1926, the Colliery was purchased by the Southern Portland Cement and Coal Company (now Boral) to supply coal for the newly constructed Berrima Cement Works.

The production level of the Berrima Colliery has varied between 125,000 and 460,000 tonnes per annum (tpa) of Run of Mine (ROM) coal although the Colliery has the capacity to produce up to 500,000 tpa. While the colliery has in recent years mainly supplied the Berrima Cement Works, it has historically supplied other customers such as Berrima Power Station, Tallawarra Power Station and the Maldon Cement Works.

Coal produced at the Berrima Colliery is mostly transported by road to the Berrima Cement Works utilising two tri-axle tipper trucks. Some coal has also been transported to Port Kembla for export. While Boral Cement owns the Colliery and the mining lease, it is currently operated by Delta under contractual arrangements with Boral Cement.

The Colliery does not have any valid planning approvals but currently operates under existing use rights pursuant to the Environmental Planning and Assessment Act 1979 (EP&A Act), as mining has been occurring on the site since about 1890. However because of the changes to both the EP&A Act and Mining Act 1992 in 2005, the existing use rights of Boral Cement are due to expire in 2010. Any expansion, intensification or enlargement of the Colliery after 2010 is subject to the usual approval requirements under the EP&A Act.

Under the provisions of the EP&A Act, the ongoing operation (which includes lateral expansion) of the Colliery will also require an approval under the provisions of Part 3A. This will require the preparation of an EA which assesses the environmental, social and economic impacts that Colliery is likely to have on the surrounding environment and community.

Under Part 3A, the consent (or approval) authority is the Minister for Planning. The DoP will administer the application, assess the EA and make a recommendation to the Minister.

In the current proposal, coal would continue to be supplied to the Berrima Cement Works, as well as a range of other related industrial operations such as the Maldon Cement Works, Waurn Ponds Cement Works, and the Limestone Kilns at Marulan and Galong Limestone Mines. In accordance with recent operations, it is also proposed to supply export coal through Port Kembla. The total amount of coal produced for supply to external customers outside the Berrima local area, would vary each year but is unlikely to exceed 340,000 tpa.

The preparation of the EA report will be supported by stakeholder engagement with a variety of stakeholders, including the local community, government agencies, the local council and interest groups. Stakeholder engagement has undertaken by Boral in

accordance with a Stakeholder Engagement Plan (SEP) prepared specifically for the project.

1.2 Scope of the Project

The overall scope of this TIA report is primarily to assess the following matters:

- Assessment of existing site traffic and transport arrangements
- Review site parking provision and management
- Determine forecast traffic generation with the proposal and its impact to the surrounding road networks
- Assessment of the truck ingress, egress and circulation into the site and its impact on external road networks
- The impact of the proposal on road network traffic safety and efficiency

2 Existing Condition

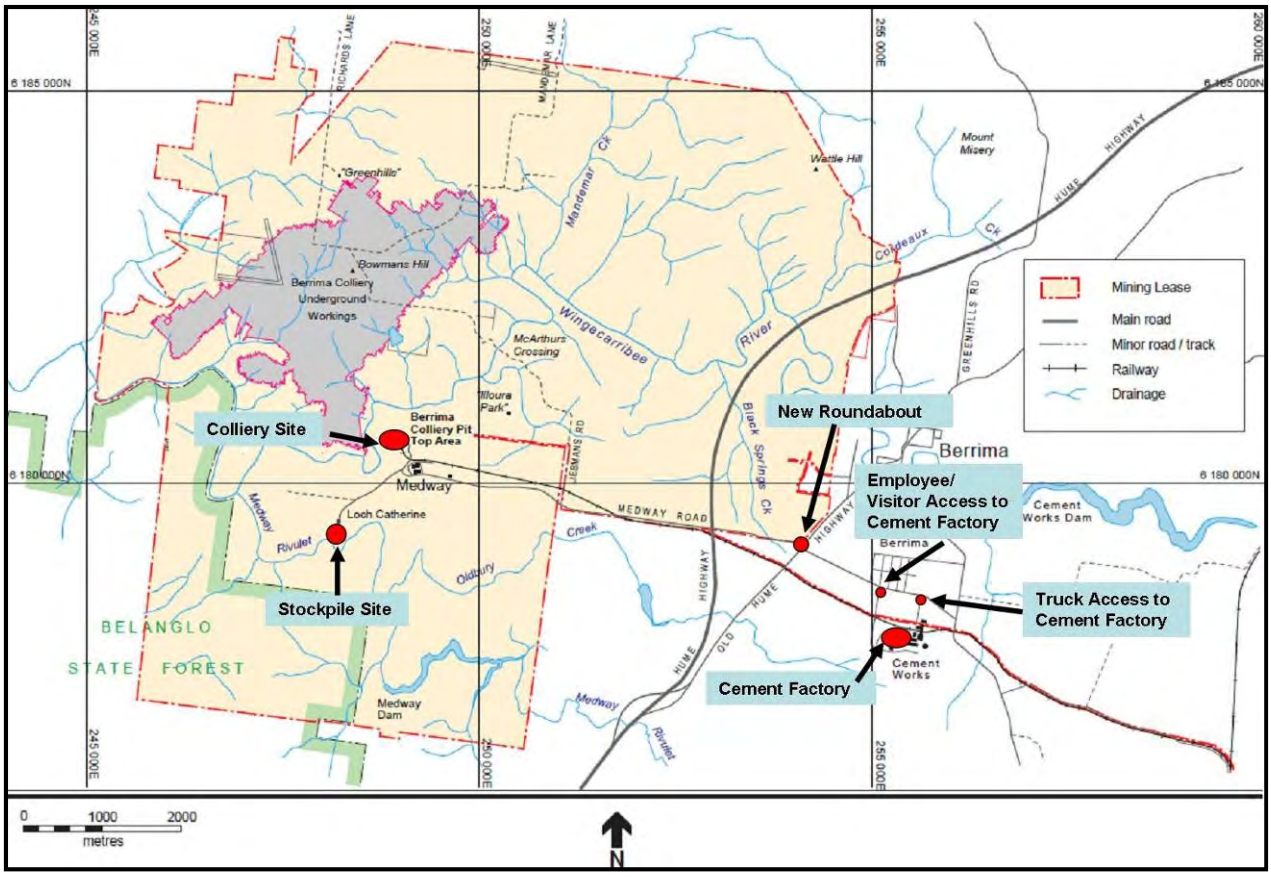
2.1 Site Location

The Berrima Colliery is located off Medway Road about 4.5 km west of Hume Highway near Berrima in the Southern Highlands of New South Wales (refer to **Figure 1**). The site includes a number of small office buildings, the inclined roadway "drift" entry to the mine and a large coal conveyor with coal loader (refer to **Photograph 1** and **Photograph 2**).

Coal is also stockpiled about 1.5 km south west of the mine at a property called "Loch Catherine" serviced via an unsealed road from Medway Road at Medway Village. The majority of coal (over 75 %) is transported directly from the colliery to the Berrima Cement Works via Medway Road.

The remainder of the coal (25%) is transported to the Loch Catherine stockpile area and then subsequently to the cement works or other external customers. Trucks collect the coal from the Loch Catherine stockpile area for despatch to the Berrima Cement Works on an as needs basis. This is generally when production levels at the colliery are low due to difficult mining conditions, breakdowns or maintenance shutdowns.

Figure 1: Site Location



Medway Village is located on the northern side of Medway Road within 300m from the Colliery site. In the early days of the mine, many employees of the Colliery used to live in this village. However, in current times none of the Colliery employees live in the village.

The Medway Village community appears to be prosperous and thriving. A number of recent new dwellings are evident, including one observed to be under construction during November 2009 (refer to **Photograph 3**).

Horse riding is an important activity in the local community. A horse riding track and horse exercising paddocks are located on the northern side of Medway Road east of the village.

Coal from the Berrima Colliery is currently despatched by Boral trucks. At present the majority of coal is transported to the cement works which is located about 7 km from the Colliery on the southern side of Taylor Avenue and about 1.5 km east of the Old Hume Highway.

A former railway line corridor still exists between the Colliery and the cement works but the railway has been non operational, since the 1960's and the tracks have been lifted. The former railway underpass beneath the Motorway (Hume Highway) remains but reinstatement elsewhere would involve railway level crossings being reopened to cross both Medway Road and The Old Hume Highway.

Photograph 1: Colliery Site Office and Coal Conveyor



Photograph 2: Boral Trucks Waiting to Load Coal at the Coal Loader



Photograph 3: New Dwelling being built in the Medway Village



2.2 Road Hierarchy

The Hume Highway (Motorway) and The Old Hume Highway are the two main arterial roads at the vicinity of the site. The Hume Highway is one of the longest highways in Australia which provides the most direct connection between Sydney and Melbourne (873km). It is generally a divided carriageway and has 2 lanes in each direction at the vicinity of Berrima (refer to **Photograph 4**).

Photograph 4: Hume Highway (Motorway) looking North



The Hume Highway speed limit is generally 110km/h but it reduces near towns or where there are sharp bends. At the vicinity of the site a southbound off - ramp and northbound on - ramp are provided to Medway Road. About 2.5 km further south, a southbound on –ramp and northbound off – ramp are provided for traffic travelling in the opposite directions.

The Old Hume Highway is now under the care and control of Wingecarribee Shire Council. It generally runs north –south but crosses Hume Highway at a number of locations by overpasses and underpasses. This is a two lane two way road with overtaking lanes at some locations (refer to **Photograph 5**). It is primarily a local access and tourist route nowadays which provides access to local towns along the length of Hume Highway. The general speed limit is 100 km/h but the speed limit is further reduced in many locations. Vehicles travelling to and from the south must travel via the Old Hume Highway to get to and from the Colliery via Medway Road.

The east – west Medway Road is also under the care and control of Wingecarribee Shire Council (refer to **Photograph 6**). This is the only access road to the Medway Village and Berrima Colliery from both Hume Highways. It is a two lane two way road with a speed limit between 50 - 100 km/h. The speed limit is restricted to 50 km/h near the Medway Village.

Photograph 5: Old Hume Highway looking South



Photograph 6: Medway Road looking East



Taylor Avenue (refer to **Photograph 7**) provides an east – west traffic connection between Old Hume Highway, the Berrima Cement Works and Moss Vale.

It also provides residential access to properties at New Berrima village via a number of local roads. It is generally a two lane two way undivided road with narrow sealed shoulders on both sides of the road. The general speed limit on Taylor Avenue is 80km/h but the speed is reduced to 50 km/h near New Berrima Village and the Berrima Cement Works.

Photograph 7: Cement Truck on Taylor Avenue looking East



The other roads associated with external coal transport routes north to destination such as the Maldon Cement Works near Picton and Port Kembla are:

- Picton Road – provides arterial connection between Hume Highway and Macarthur Road. It is generally a two lane each way road, however becomes one lane each way at the southern end.
- Mount Keira Road – provides north – south connection between Macarthur Road and Queen Elizabeth Drive on the southern end. It is a two lane two each way road. Coal haulage trucks would turn left into The Link Road on the southern end of Mount Keira Road.
- The Link Road –provides connection between Mount Keira Road and Southern Freeway (F6) via a grade separated overpass for the southbound traffic.
- Southern Freeway (F6) - The Southern Freeway forms part of the arterial route linking Sydney and Wollongong. It has generally two lanes in each direction with a central median jersey kerb along the route with standard freeway treatments including lane line, edgeline markings, pavement reflectors etc.
- Masters Road – it provides arterial connection between Southern (F6) Freeway and Springhill Road. It consists of dual carriageways with a total of six lanes with a posted speed limit of 80km/h.

- Springhill Road - Springhill Road is an arterial road connecting Masters Road and Port Kembla Coal Terminal, as well as being part of the main link from Wollongong to Port Kembla, Warrawong and Shellharbour. This State Road has a posted speed limit of 80km/h.
- Port Kembla Road - this State Road provide access to Port Kembla Coal Terminal. It functions as a local road due to it only serving a heliport, sewage treatment works, golf course and the port. Port Kembla Road is a two-lane undivided road, connecting to Springhill Road by a signalised seagull intersection.

2.3 Intersections

2.3.1 The Old Hume Highway/ Medway Road/ Taylor Avenue intersection

This intersection is controlled by a newly constructed roundabout. This relatively large roundabout was constructed with joint funding by the Australian Government and the Wingecarribee Shire Council. The $1.25m project required realignment of Medway Road and Taylor Avenue with Old Hume Highway.

There is one entry and exit lane and one circulating lane for each approach of the roundabout (refer to **Photograph 8**).

2.3.2 Springhill Road/ Masters Road Intersection

This large signalized intersection has multilane storage in all approaches. There is an existing bus lane on the south approach of the intersection.

2.3.3 Springhill Road/ Port Kembla Road Intersection

This three-legged signalised intersection has protected turn bays. Coal delivery traffic would move from west to south and vice versa.

Photograph 8: Roundabout at Old Hume Highway/ Medway Road/ Taylor Avenue

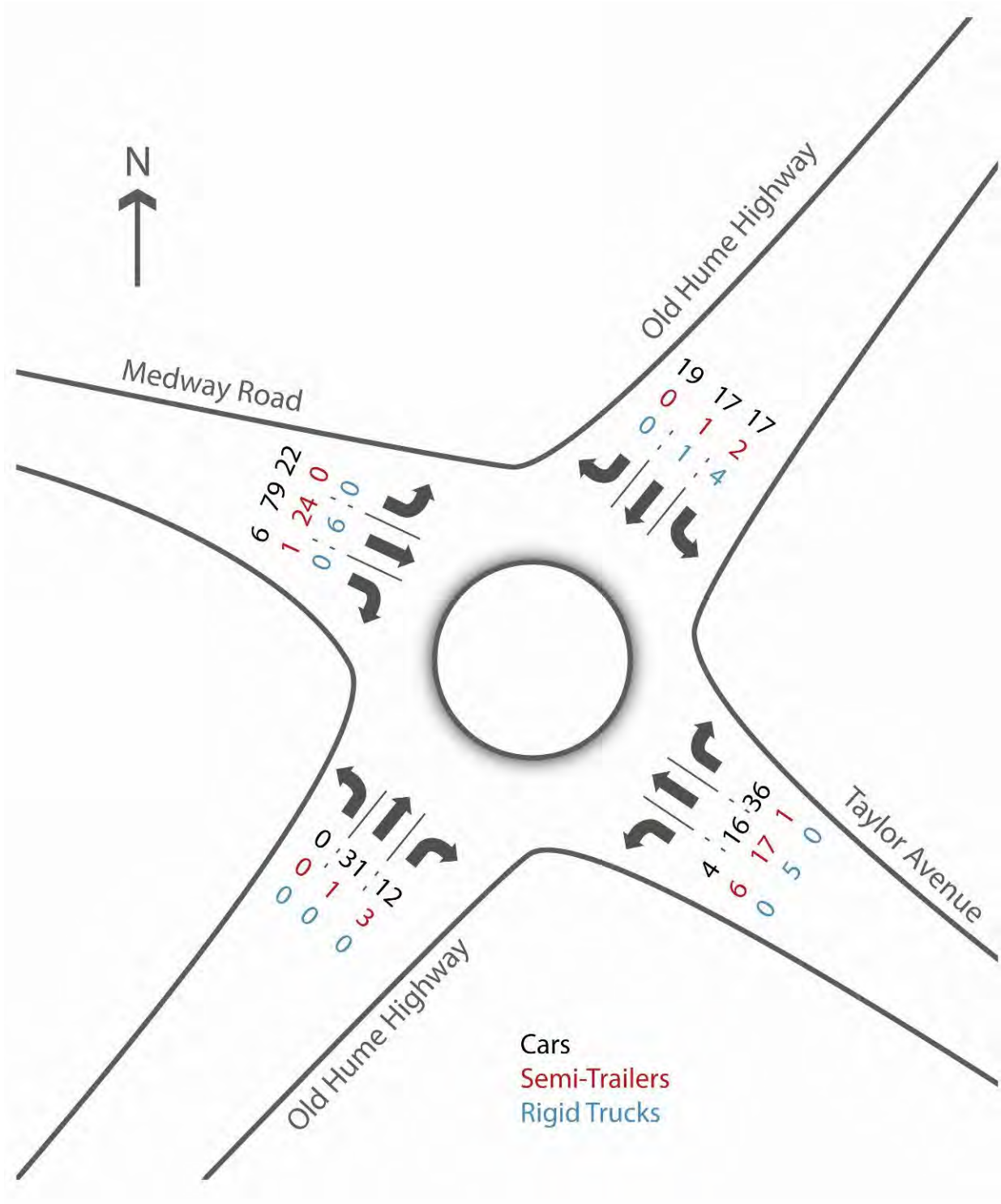


2.4 Traffic Data

2.4.1 Intersection Count

An Intersection traffic count was undertaken at the roundabout at the Old Hume Highway/ Medway Road/ Taylor Avenue on Tuesday, 20 October 2009 (non school holiday period) between 8am – 9am. It was observed that there were high volumes of heavy vehicles from all directions at the intersection (rigid truck, semi-trailer etc.). In particular, a significant amount of east – west truck traffic was observed crossing Old Hume Highway, between Medway Road and Taylor Avenue. The Intersection traffic volume data is presented in **Figure 2**.

Figure 2: AM Peak Hour Intersection Traffic Volumes



The traffic data shows a high amount of cross traffic movement of both cars and trucks between Medway Road and Taylor Avenue, which was greater than any of the Old Hume Highway traffic movements. In total 41 semi trailers crossed the Old Hume Highway during the peak hour, 24 eastbound from Medway Road and 17 westbound from Taylor Avenue. This traffic included approximately 4 semi trailer vehicle trips per hour in each direction transporting coal from the Berrima Colliery to the cement works. The other truck traffic at the roundabout was cement truck traffic to and from the BCSC cement works and other truck traffic from the Berrima and Moss Vale areas generally, which was accessing the Hume Highway (Motorway) via Medway Road. Car traffic movement at the intersection was a total of 259 cars in the peak hour which equates to 4.3 cars per minute.

2.4.2 Traffic Counts

Three seven day tube traffic counts were undertaken by an Arup appointed private contractor 'CFEIT' on October and November 2009 on Old Hume Highway, Medway Road and Taylor Avenue (refer to **Figure 3**) and a summary of the traffic data is presented in **Figure 4** . The detailed data is attached in Appendix A.

The traffic data in **Figure 4** shows that Taylor Avenue carried the highest volume of traffic including heavy vehicles. Medway Road west of the Hume Highway carried just over 500 vehicles per day.

The recorded heavy vehicles on Medway Road (124 movements per day) are mostly the Colliery associated heavy vehicles travelling to and from the Berrima Cement Works. The 50 %ile and 85%ile recorded speeds on the three roads are within or close to the posted speed limit, which indicates generally free flowing and uncongested traffic conditions on these roads at all times.

Figure 3: Traffic Tube Count Locations at Berrima

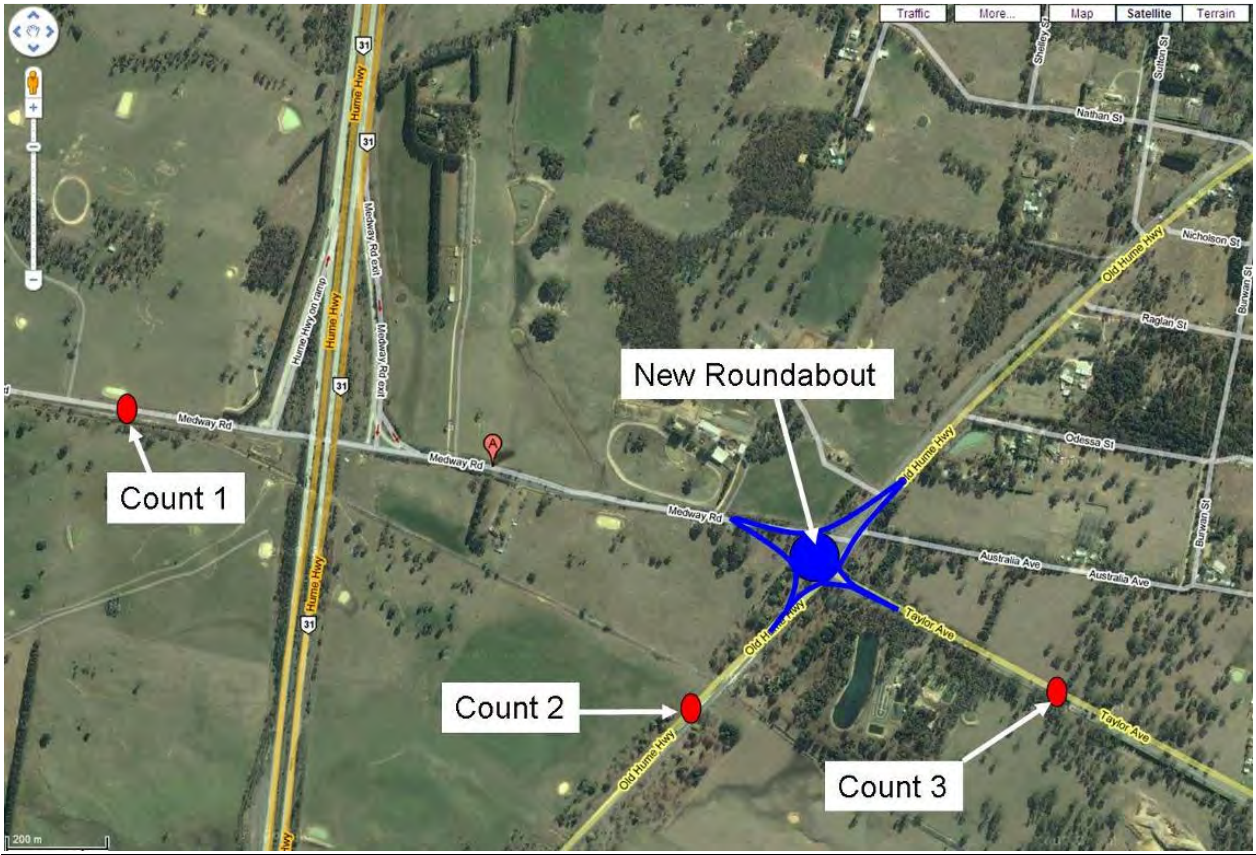
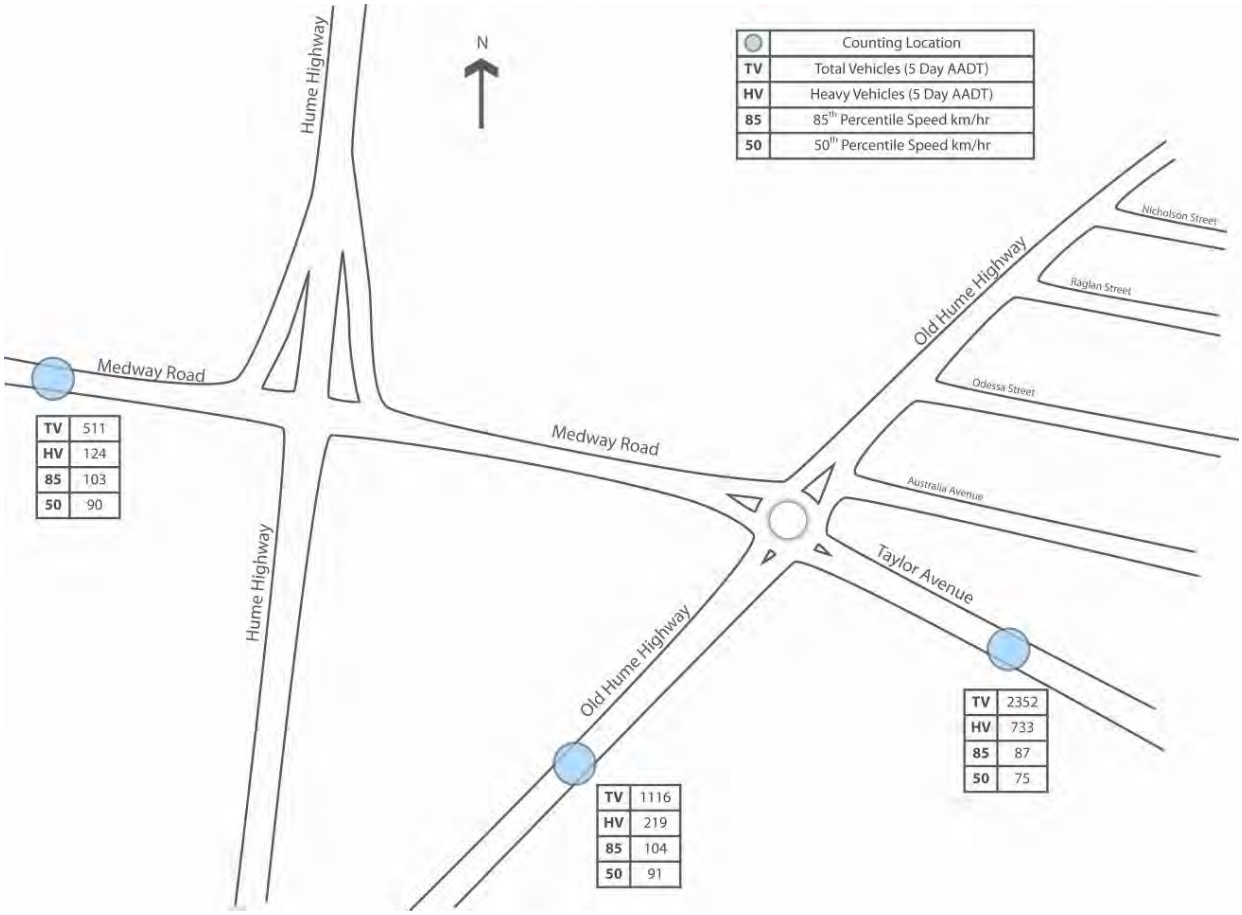


Figure 4: Bidirectional Tube Traffic Count Summary at Berrima



In addition to the above, another tube traffic count was undertaken by 'CFEIT' on Picton Road (between Macarthur Road and Almond Street) for a seven day period starting on 13 May 2010 (non – school holiday period). The bidirectional count recorded on average just over 13,000 vehicles per day, almost 50% split in each direction. The average 85 %ile speed was 107km/h for the south – east and 104 km/h for the north – west direction. Heavy vehicle movement was recorded as 24% for the south – east and 30% for the north – west direction. The detailed count results are attached in Appendix A. The RTA daily traffic count data from various locations has also been complied and summarised in **Table 1**.

Table 1: AADT Daily Traffic Count Summary for RTA Roads

Road	Count Location	Station No.	AADT	Count Year
Hume Highway	0.5km N of Old Hume Hwy	07.770	18138	2008
Hume Highway	S of Picton Rd	07.736	30592	2008
Southern Freeway (F6)	At Masters Road Overbridge	07.644	55047	2003
Southern Freeway (F6)	At Gipps Road Overbridge, Gwynneville	07.104	71643	2008
Southern Freeway (F6)	N of Northcliffe Dr, Unanderra	07.694	55493	2008
Masters Road	W of Springhill Rd, Mt St Thomas	07.700	25226	2003
Springhill Road	N of Masters Road, Mt St Thomas	07.218	35179	2005
Springhill Road	N of Keira St, Coniston	07.202	16600	2005

The data in the above table shows that the traffic volumes on the Hume Highway and Southern Freeway (F6) vary significantly on different sections of these roads. Masters Road also carries reasonably heavy amounts of traffic. The northern part of Springhill Road carries higher volume of traffic compared to the southern part, which indicates the Masters Road traffic travels predominantly to and from the north on Springhill Road.

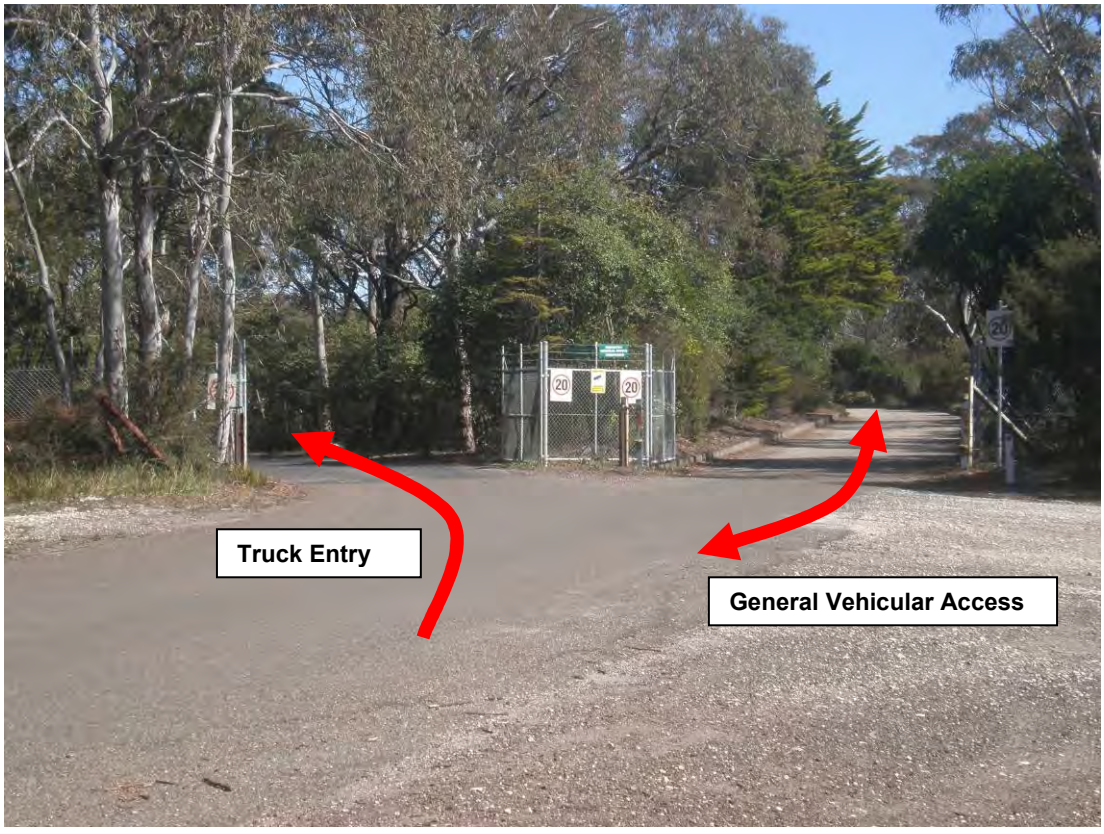
2.5 Berrima Colliery Access

The general vehicular access and truck access to the Berrima Colliery is separated at the western end of Medway Road as shown in **Photograph 9**. For general traffic, the vehicular access gate is wide enough to cater for two-way traffic movement. A roundabout is provided for vehicles to turn around within the site, directly adjacent to the main Colliery site office.

One way traffic circulation is designed for the Colliery truck access around the coal loader. Trucks come into the site via the main access road, load coal at the coal loader and then exit the site via a different gate onto Medway Road.

At the Berrima Cement Works site, two access gates are provided from Taylor Avenue. The main employee and visitor access is provided via Gate 1 at Argyle Street which is about 1.2km east of Old Hume Highway (refer to **Photograph 12**). The coal and cement truck access occurs via Gate 2 which is located further 800m east on Taylor Avenue near Perth Street (refer to **Photograph 13**).

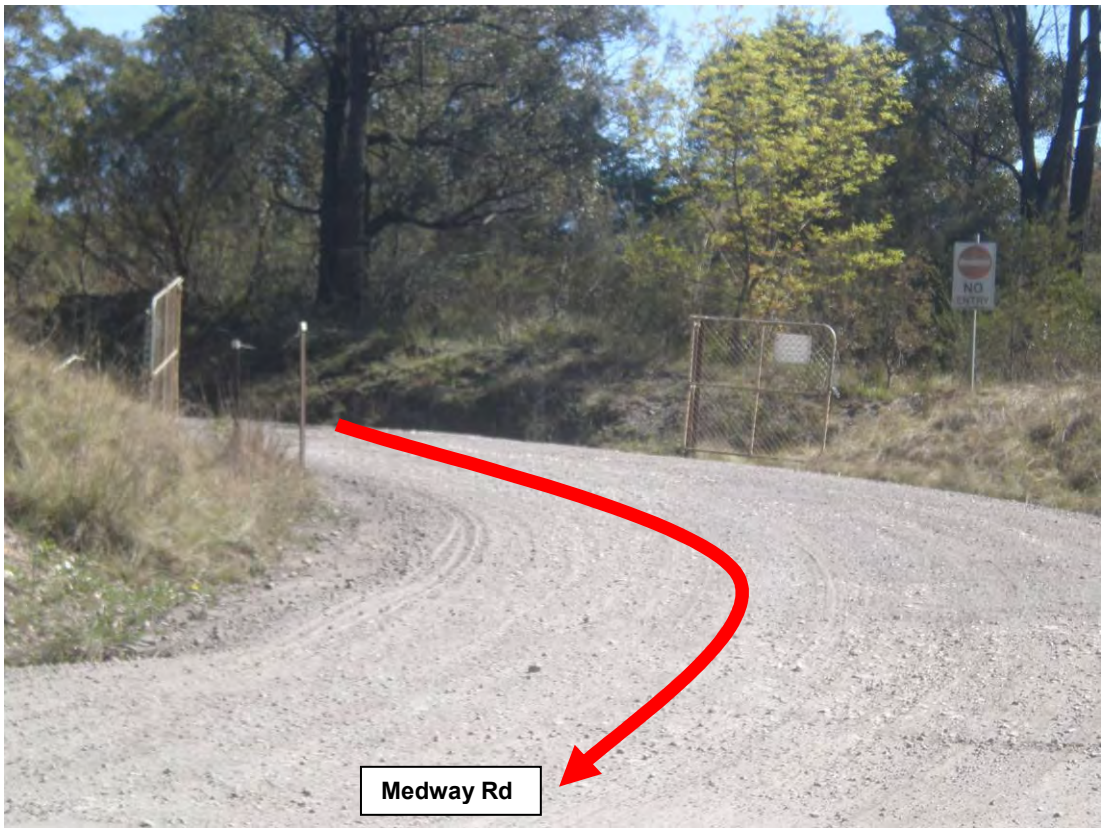
Photograph 9: Main Vehicular Accesses to the Colliery



Photograph 10: Truck Loading Coal



Photograph 11: Colliery Site Exit for Trucks



Photograph 12: Employee and Visitor Access to Boral Cement at Berrima



Photograph 13: Truck Access to Boral Berrima Cement Works



2.6 Existing Traffic Generation

2.6.1 Light Vehicles

Over 90% of the mine employees currently drive their own car to and from work as none live locally in the Medway Village and there are no public transport services in the local area.

The mine generated car traffic movements per day are currently approximately 50-60 vehicle movements per day from the mine employee traffic and a further 10-20 vehicle movements per day from mine visitors and contractors. The total daily car/other light vehicle traffic related to the mine operations is approximately 70 vehicle movements daily.

2.6.2 Heavy Vehicles

The mine related heavy vehicle traffic movement data for trucks using Medway Road west of the Hume Highway (Motorway) has been provided by Boral Cement from the Berrima Cement Works records.

The heavy vehicle movements on Medway Road are recorded separately for the two loading sites, i.e. deliveries direct from the mine and deliveries from the Loch Catherine stockpile. The total mine related heavy vehicle traffic data from these two sources has been summarised and is presented in **Table 2**.

Table 2: Summary of Coal Truck Deliveries via Medway Road July – December 2009

Month	Total Truck Deliveries	No of days of truck movements each month	Avg. Trucks/ Day	Max No. of Trucks in a day	Max no. of trucks in the peak hour*
July	177	10	18	29	3
August	510	21	24	39	4
September	442	22	20	34	3
October	625	21	30	39	4
November	409	20	20	33	3
December (data till 18 Dec)	185	7	26	42	4
Totals	2348	101	23 (Average)	42 (Maximum)	4

* - assumes peak hour traffic is about 10% of daily traffic

The data in **Table 2** shows that over a six month period, there were about 2350 coal truck deliveries on Medway Road which equates to 4700 per annum. The mine does not despatch coal haulage on Medway Road every day to and from the Cement Works. On days when coal is not transported to the cement works, the coal is stockpiled at the Loch Catherine stockpile and then transported later from there to the Cement Works on coal haulage days. These records relate to a period in 2009 when coal (220,000 tpa) was only being despatched to the Berrima Cement Works. Coal is now being despatched to the Cement Works and externally to Port Kembla.

The data also shows that coal was transported on only about 100 days in a six month period, equating to about 200 days per annum. However, Boral Cement advises that the total number of coal production days is approximately 260 days per annum.

A more detailed analysis of the data shows that deliveries normally occurred on weekdays except for a small number of weekend deliveries in November and December 2009. The average number of daily truck deliveries on the coal haulage days was 23. The maximum was 42 daily deliveries, which occurred in the month of December 2009.

Over the last few years, the Berrima Colliery has produced an average of approximately 220,000 tpa of ROM coal which is carried by approximately 5000 truck trips each year. According to this estimate the average truck carries about 40 - 45 tonnes of coal.

2.6.3 Total Mine Traffic

The total mine related traffic on Medway Road west of the Motorway (Hume Highway) is approximately 116 vehicle movements per day (70 car movements plus 46 truck movements). This represents approximately 23% of the total daily traffic on a weekday (511 vehicle movements daily).

In terms of light vehicle (car) traffic on Medway Road, the 70 movements per day of mine traffic represents about 18% of total daily car traffic (387 vehicle movements daily). The mine heavy vehicle traffic, 46 truck movements per day, represents about 37% of all heavy vehicle traffic movements on the road (124 vehicle movements daily).

The other heavy vehicle traffic which is currently using Medway Road is mostly smaller agricultural type trucks which are generally smaller trucks with only 2-3 axles rather than large semi trailers with 5-6 axles.

The overall impact of the mine truck traffic on traffic flow on Medway Road is however still relatively minor as the overall daily traffic flow on the road is low (less than 1000 vehicle movements daily) and still permits the highest level of service (Level of Service A) for traffic flow on a rural road.

The sealed road width of Medway Road is 7 metres typically which meet the AUSTROADS Rural Road design standard for any rural road with traffic of more than 1000 vehicles per day. The coal trucks are also generally able to operate at normal rural traffic speeds (100 km/hr) so do not generally inhibit the other traffic flow.

2.7 Old Hume Highway/ Medway Road/ Taylor Avenue Intersection Analysis

In urban areas, the performance of a road network is generally a function of the performance of key intersections. Performance is quantified in terms of Level of Service (LOS) and Degree of Saturation (DOS).

LOS is an index of the operational performance of traffic at an intersection and is based on the average delay per vehicle. LOS ranges from A – very good to F – highly congested conditions, as shown in **Table 3**.

Table 3: Level of Service Definitions

Description	Level of Service (RTA Definition)	Average Delay per Vehicle (s)
Very Good	A	< 14.5
Good	B	14.5 ≤ 28.5
Satisfactory	C	28.5 ≤ 42.5
Near Capacity	D	42.5 ≤ 56.5
At Capacity	E	56.5 ≤ 70.5
Over Capacity	F	≥ 70.5

Generally it is desirable to aim at achieving a LOS of C or better at all major road intersections. However, in practice, it is reasonable for some intersections to operate at LOS D at peak times. Another common measure of intersection performance is the DOS, which provides an overall measure of the capability of the intersection to accommodate the traffic levels. A DOS of 1.0 indicates that the intersection is operating at capacity; however the desirable (and practical) DOS is less than 1.0 as shown in **Table 4**.

Table 4: Practical Maximum Degree of Saturation

Intersection Type	Practical Degree of Saturation
Signals	0.90
Roundabout	0.85
Priority	0.80

The Old Hume Highway/ Medway Road/ Taylor Avenue intersection has been analysed by Sidra computer modelling (version 4). The Sidra results are included as Appendix B and show that the intersection is currently operating at LOS A in all directions.

The average delay in this intersection is only 7 seconds. The maximum DOS of any traffic approach at the intersection is only 0.123 which indicates that the intersection currently has significant spare capacity to accommodate additional traffic.

2.8 Parking Supply and Demand

Off-street parking is provided via the main colliery access road as shown in **Photograph 9**. In total about 40 - 45 parking spaces are provided on the site. The parking spaces are undesignated along the road periphery and the centre of the roundabout on the grass verge (refer to **Photograph 14**).

The Colliery has around 38 employees currently, most of who drive to work in their individual vehicles. In addition, approximately 5-10 visitors on average visit the Colliery site each day. The visitor numbers are generally spread out throughout the whole day.

During a site visit on 20 October 2009 at around 10am there were exactly 30 vehicles parked on site. There were an additional 10-15 vacant car parking spaces observed within the southern section of the site car park (refer to **Photograph 15**).

Photograph 14: Parking on the Colliery Site



Photograph 15: Vacant Parking Spaces at the southern end of the car park



2.9 Pedestrian Volumes

Pedestrian access to the Colliery site is physically restricted. The general public is not allowed to enter into the site without any valid reason. Very few pedestrians were observed either in the vicinity of the site or on roads around the Medway Village, during a site visit in October 2009.

2.10 Public Transport

Public transport is limited in Berrima. The only bus operator in the area is Berrima Buslines. It provides bus services throughout Mittagong and the Southern Highlands. It provides commuter, school bus services and day charter operations in the region.

None of the site staff or visitors normally catch public transport to access the site. Only one bus stop was noticed during the site visit which was located in New Berrima village on Taylor Avenue near the intersection of Melbourne Street (refer to **Photograph 16**).

Photograph 16: Bus Stop on Taylor Street



3 The Proposal

It is proposed to continue operations at Berrima Colliery generally in accordance with past and current operations. The Colliery has produced up to 460,000 tpa of Run of Mine coal in the past. The average production over the last ten years has been approximately 220,000 tpa. Approval is however sought to produce up to 460,000 tpa. Coal would continue to be supplied to the Berrima Cement Works, as well as other Boral industrial operations such as the Maldon Cement Works, Waurn Ponds Cement Works, and the Limestone Kilns at Marulan and Galong Limestone Mines.

In addition, coal is also proposed to be despatched to external customers including coal exported overseas through Port Kembla. Details on the current operations and proposed maximum operations are summarised in **Table 5**.

Table 5: Comparison of Current and Maximum Operation

Item	Current	Maximum
ROM coal production	220,000 tpa	460,000 tpa
Number of employee	38	63
Production day per annum	210	340
Approximate no. of coal truck deliveries per day	23 (average)	66 (50 trips to directly to external customers and 16 trips via the Loch Catherine Stockpile site)
General delivery times	6am – 9pm weekdays & 6am – 2pm Saturday	6am – 9pm weekdays & 6am – 2pm Saturday
Delivery vehicles	Tri – Axle tipper truck	Tri – Axle tipper trucks and B – Double trucks (subject to a separate approval)

The amount of coal produced for supply to external customers outside the Berrima local area would vary, but is unlikely to exceed approximately 340,000 tpa. Out of 340,000 tpa, maximum 115,000 tpa of coal is proposed to be stockpiled to Loch Catherine site before delivery to external customers and remaining 225,000 tpa is proposed to transported directly to the external customers. This means the coal deliveries to the Berrima Cement Works would reduce to approximately 120,000 tpa.

As shown in the table above, the future external coal delivery would potentially utilise B – Double vehicles. This report has not undertaken any technical assessment of the B – Double access routes. A separate feasibility study and application report is to be prepared for approval for using B – Double vehicles for coal transport to/ from the site.

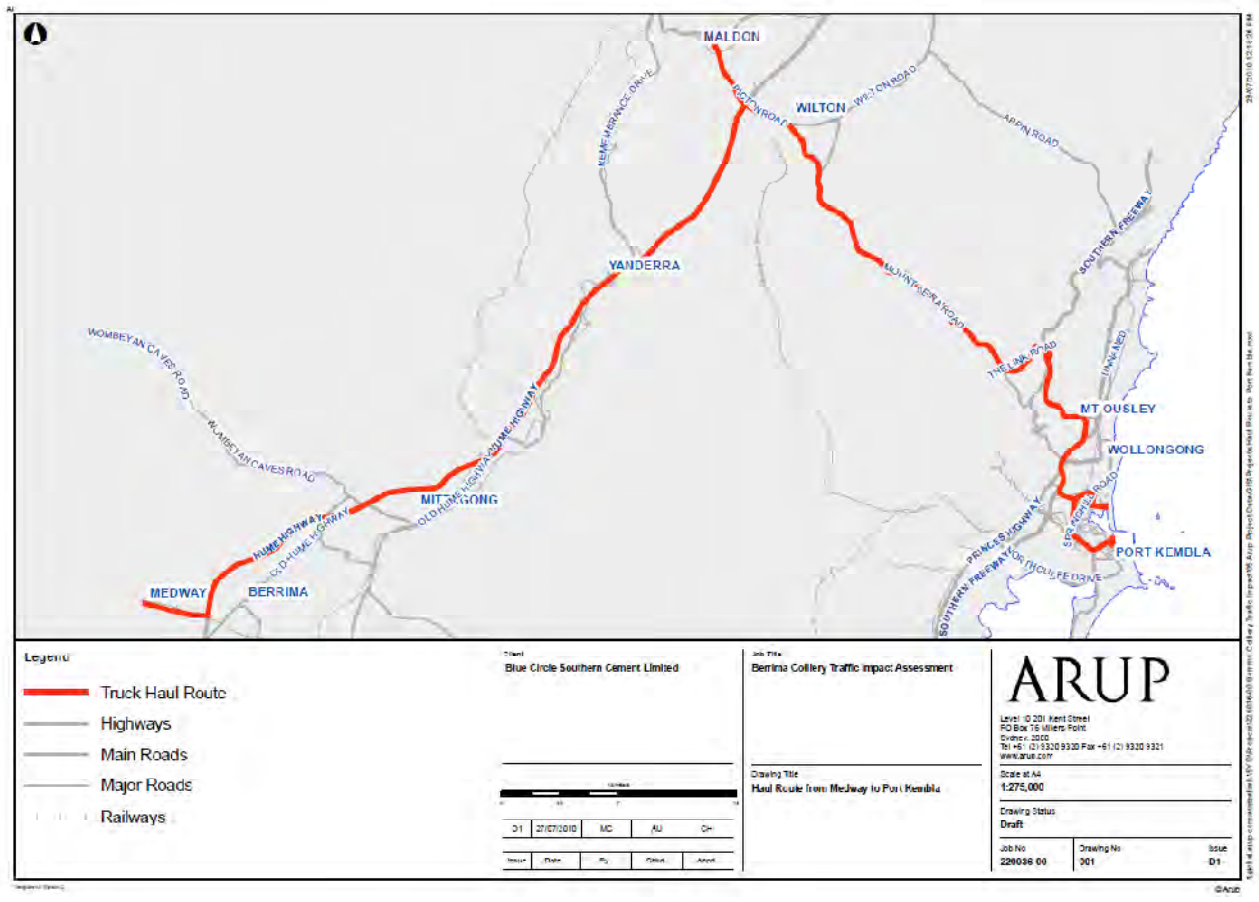
3.1 Proposed Haulage Route

The Berrima Colliery would continue to transport all coal by road, including transportation along Medway Road and Taylor Avenue to the Berrima Cement Works. Coal would also be transported both north and south along the Hume Highway to external customers. Customers supplied to the north would potentially include:

- **Maldon Cement Works:** about 60km north of the Colliery (via Medway Rd – Hume Hwy – Picton Rd).
- **Port Kembla:** about 100km east of the Colliery (via Medway Rd – Hume Hwy – Picton Rd – Mount Keira Rd – The Link Rd – Southern Freeway (F6) – Masters Rd – Springhill Rd – Port Kembla Rd). In Port Kembla coal is proposed to be transported to either the main Port Kembla Coal Terminal on the northern shore of Port Kembla or the Gateway Wharf (Port Kembla Gateway) on the southern shore. The Gateway Wharf would be accessed via turning right into Springhill Road from Masters Road and then Five Islands Road – Flinders Street – Christy Drive.
- **Sydney**: some customers in Sydney may also be supplied by the Berrima Colliery.

The main external coal transport routes to the north are illustrated in **Figure 5**.

Figure 5: Coal Transport Routes north of the Colliery



Coal to be supplied to external customers to the south would be via Medway Rd – Old Hume Hwy – Hume Hwy. The likely places to which coal would be transported include:

- **Waurn Ponds Cement Works, Victoria** – about 830km south
- **Limestone Kilns at Marulan** – about 40km south of the site
- **Galong Limestone Mines** – about 200km south – west of the site

4 Transport Impact Assessment

4.1 Potential Impact on the Road Network

As stated above, should future production levels at the Berrima Colliery be increased to 460,000 tpa, the amount of coal supplied to the external customers would increase, but would be unlikely to exceed approximately 340,000 tpa.

It is expected that on weekdays in the future, a maximum of 66 truckloads of coal would be despatched either direct from the colliery or via the Loch Catherine stockpile area, using Medway Road (refer to **Table 5**). Based on one truck carrying 40 – 45t of coal, this equates to about 2,600t – 3000t coal transported per weekday (about 675t to the Berrima cement Works and the remainder to external customers).

Of these 66 truck loads per day, it is likely that 16 truck loads per day will go directly to the Berrima Cement Works while the remaining 50 loads will go directly to other Boral industrial sites and external customers or to the Loch Catherine stockpile area. On an annual basis, it is estimated that 90% of the additional truck movements would travel to and from the north on the Hume Highway and the remaining 10% would travel to and from the south.

In addition to the external coal delivery truck movements, the colliery employee numbers are expected to increase by an additional 25 employees. Assuming all the additional employees are travelling to and from the colliery by car, there will be an additional 50 car trips per day using Medway Road. Assuming 80% of the additional employees travel to and from the north of Berrima and the remaining 20% to and from the south, the overall future colliery related car and truck traffic increases on the regional road network have been calculated and presented in **Table 6**.

Table 6: Maximum Daily Traffic Increases on Major Roads due to Increase of Coal Production

Road	Location	Existing Traffic (AADT)	Source	Traffic Increase (vehicles per day)	% Increase
Medway Rd	W of Hume Hwy	511	Arup Count	136	26.6%
Hume Hwy (Motorway)	S of Picton Rd	30592	RTA	140 (assuming all haulage to the north)	0.5%
Old Hume Hwy (south of Taylor Ave)	S of Taylor Ave	1116	Arup Count	110 (assuming all haulage to the south)	9.9%
Picton Rd	E of Hume Hwy	13138	Arup Count	100 (assuming all haulage to the port)	0.8%
Southern Freeway (F6)	At Gipps Road, Gwynneville	71643	RTA	100 (assuming all haulage to the port	0.1%
Masters Rd	W of Springhill Rd	25226	RTA	100 (assuming all haulage to the port)	0.4%
Springhill Rd	N of Masters Rd	35179	RTA	100 (assuming all haulage to the port)	0.3%
Springhill Rd	S of Masters Rd	16600	RTA	100 (assuming all haulage to the port)	0.6%

Based on the analysis in the above table, depending upon which routes are used for the external coal haulage on any specific day, the scale of the predicted future traffic increases will be very minor, except for Medway Road where the daily traffic is expected to increase by about 27%.

However, as the general coal delivery period on a typical weekday will extend between 6am – 9pm, the additional 136 vehicles on Medway Road over a 15 hour period will be an average of 9 additional vehicles per hour (one vehicle every 6 - 7 minutes) which will not generally be noticeable and will have very minimal impact on traffic flow conditions on the road.

With the exception of the Old Hume Highway, south of Taylor Avenue, the predicted traffic increase on the other roads on the arterial road network generally will be insignificant, being generally less than 1% at all locations.

On the Old Hume Highway south of Taylor Avenue, the potential 10% traffic increase with an additional 110 vehicles per day, represents 7 additional vehicles per hour on average over a 15 hour period (one vehicle every 8 - 9 minutes) This relatively minor increase of actual traffic will have only a very minimal impact on the existing traffic flow conditions on this road.

Due to the likely future reduction of coal deliveries to the Berrima Cement Works from 23 per day to 16, there will be reduction of 14 vehicle movements per day typically on Taylor Avenue, east of Old Hume Highway, which will result in a slight improvement in existing traffic conditions on this road.

4.2 Potential Impact on Intersections

The Old Hume Highway/ Medway Road/ Taylor Avenue intersection has been analysed by Sidra intersection modelling, as summarised by the intersection analysis results in **section 2.7** and Appendix B of this report.

This intersection is currently operating at LOS A, with a very low degree of saturation of 0.123. In the future, only colliery vehicles travelling to/ from the Cement Works or external customers south of Berrima will access this intersection. Therefore, this intersection will experience a maximum additional 96 vehicles per day potentially.

This corresponds to an additional 6 vehicles per hour typically travelling through this intersection during all hours of the daytime, including the peak hours, this amount of additional traffic is unlikely to have any significant impact on the existing very low degree of saturation and low traffic delays at this intersection. Hence this intersection has not been analysed for the future traffic scenario.

In August 2008, a detailed road traffic and access study was undertaken by Cardno Eppell Olsen for the Port Kembla Coal Terminal. In that study, a number of key intersections near the port were analysed. The current intersection traffic operations results have been summarised from that report and are presented in **Table 7**. The data in the table shows that all the three intersections are currently operating within acceptable LOS with some spare capacity.

Based on the predicted traffic distribution for the future Berrima Colliery coal haulage traffic to external customers in **Table 6**, the Masters Road/ Springhill Road intersection, which is the busiest intersection considered, will potentially experience an additional 100 vehicle movements per day. However, with a 15 hour operating period, there will be approximately 7 additional Berrima Colliery coal haulage vehicles travelling through this intersection each hour, including the peak hours, which will have only a very minimal traffic impact at this intersection.

Table 7: Existing Intersection Operations at Port Kembla

Intersection	Control	2008 AM Peak				2008 PM Peak			
		DS	d	Q	LoS	DS	d	Q	LoS
Masters Rd/ Springhill Rd	Signalised	0.859	33.6	277	C	0.732	42.0	172	C
Springhill Rd/ Port Kembla Rd	Signalised	0.339	5.6	28	A	0.741	12.4	63	A
Springhill Rd/ Tom Thumb Rd	Signalised	0.793	14.1	182	A	0.809	16.8	122	B

DS = Degree of Saturation
d = Delay (seconds)
% Q = % Queue Length
LoS = Level of Service

Source: Environmental Assessment; Existing Operations & Increased Road Receival Hours for Port Kembla Coal Terminal; Traffic Study; Volume 1 Main Report; Cardno Eppell Olsen; 26 August 2008

Similarly, the Springhill Road/ Tom Thumb Road and Springhill Road/ Port Kembla Road intersections, which have significantly more spare traffic capacity currently than the Masters Road/ Springhill Road intersection, are also unlikely to have any noticeable traffic impact from the Berrima Colliery traffic due to the very minor anticipated increases of traffic during either the am and pm peak traffic periods, 6 additional vehicles per hour approximately.

4.3 Parking Impact

As stated in **Table 5**, there will be net increase of 25 employees due to the proposed increase of coal production. However, all the future 63 employee of the Colliery are not expected to be present at any one time as the colliery generally runs in day and night shifts plus a maintenance shift during the night and occasional weekends.

Assuming a maximum of 60% colliery employees working at the site at any one time, the available 40 – 45 parking spaces should adequately cater for the future peak parking demand of the colliery employee and its visitors (refer to **section 2.8**).

However, should additional parking demand arise in the future, additional on - site parking capacity can be provided by more parking spaces constructed on level areas near the main site office of the colliery.

5 Summary & Conclusions

This report has assessed the anticipated transport impacts of proposed future coal production rates at Berrima Colliery, which is located off Medway Road about 4.5 km west of the Hume Highway near Berrima in the Southern Highlands of New South Wales.

The future coal production rates would not exceed historical production rates at the Colliery. With the increased coal production, additional coal would be transported to external customers located north and south of Berrima Colliery.

Depending on demand, the Berrima Cement Works may still receive up to approximately 220,000 tpa of coal. However, it is likely that it may only receive a minimum of about 120,000 tpa and if this is the case, the balance of the production (e.g. 340,000 tpa) will be dispatched to external customers. Therefore this study has primarily addressed the transport impact on the road network of additional coal transported to the external customers.

The key findings of the TIA are summarised below:

- The forecast traffic generation due to the increase of coal production of the Berrima Colliery will have only a minor impact on surrounding roads. There will be a maximum potential 136 additional vehicle movements generated per day, distributed relatively uniformly throughout a 15 hour period on a typical weekday. This will not generally be noticeable at any location on the existing road network except for Medway Road, where the level of service for all traffic will still remain at the highest Level of Service (LOS A) with generally free flowing traffic conditions for all traffic. Due to the likely reduction in future coal deliveries to the Berrima Cement Works, there will be slight reduction in truck movements on Taylor Avenue.
- The major intersections at Berrima (Old Hume Highway/ Medway Road/ Taylor Avenue) and Port Kembla (Springhill Road/ Tom Thumb Road and Springhill Road/ Port Kembla Road) are all currently operating at satisfactory LOS and DOS. The very minor predicted peak hour increases of traffic at these intersections are unlikely to have any noticeable future traffic impact at either of these locations.
- The Berrima Colliery has sufficient on – site parking to accommodate the additional staff. However should demand arise, additional car parking capacity can be provided by a new car parking area constructed near the site office in the future.
- All coal deliveries from the Berrima Colliery are currently undertaken by Tri-Axle semi trailer vehicles. However the additional coal deliveries to the external customers (outside the Berrima local area) may be undertaken by B – Double vehicles in the future. Should this be required, a separate technical assessment, under a separate approval process, will be undertaken to verify the traffic safety and amenity impacts of using B – Double vehicles for this longer distance coal transport.

Appendix A

Traffic Count Data

CfeIT bob.white@cfeit.com (02) 9740 8600

Traffic Count Summary Report

Count Number	**5116**	Ref : **ARUP**	**Lat/Long : S34 29 49.2 / E150 18 24.1** **LOCAL MAP**
Street	**MEDWAY ROAD, BERRIMA : Between RAILWAY PARADE & OLD HUME HIGHWAY (bidirectional) :**		
Location	West of Hume Highway, east of first local road on north, ELP		*Carriageway*

TOTAL COUNT MATRIX

Start Date	24-OCT-09
Start Time	100
Duration	7 DAYS
Interval	1 HOUR

Weekly 50th Percentile Speed	90
Weekly 85th Percentile Speed	103
Five Day AADT	511
Seven Day AADT	474

	MON *26TH*	TUE *27TH*	WED *28TH*	THU *29TH*	FRI *30TH*	SAT *24TH*	SUN *25TH*	5 Day Total	5 Day Average	7 Day Total	7 Day Average
Midnight - 1am	0	7	3	7	12	3	5	**29**	**6**	**37**	**5**
1am - 2am	0	3	10	3	1	1	0	**17**	**3**	**18**	**3**
2am - 3am	0	0	0	0	0	1	0	**0**	**0**	**1**	**0**
3am - 4am	0	0	3	0	1	0	1	**4**	**1**	**5**	**1**
4am - 5am	9	4	4	4	4	0	0	**25**	**5**	**25**	**4**
5am - 6am	19	24	24	24	19	4	0	**110**	**22**	**114**	**16**
6am - 7am	20	19	21	16	25	17	7	**101**	**20**	**125**	**18**
7am - 8am	30	27	44	20	30	17	6	**151**	**30**	**174**	**25**
8am - 9am	**45**	**37**	**45**	**59**	**55**	27	19	**241**	**48**	**287**	**41**
9am - 10am	37	34	31	33	21	28	31	**156**	**31**	**215**	**31**
10am - 11am	24	32	20	38	41	43	29	**155**	**31**	**227**	**32**
11am - Midday	29	28	30	23	41	**49**	**49**	**151**	**30**	**249**	**36**
Midday - 1pm	26	29	38	23	42	30	31	**158**	**32**	**219**	**31**
1pm - 2pm	28	35	33	31	34	**32**	**53**	**161**	**32**	**246**	**35**
2pm - 3pm	39	37	**48**	40	43	28	25	**207**	**41**	**260**	**37**
3pm - 4pm	34	36	36	31	29	28	30	**166**	**33**	**224**	**32**
4pm - 5pm	**53**	**57**	42	**53**	**56**	21	14	**261**	**52**	**296**	**42**
5pm - 6pm	30	43	37	35	39	19	25	**184**	**37**	**228**	**33**
6pm - 7pm	21	23	20	25	16	18	20	**105**	**21**	**143**	**20**
7pm - 8pm	20	10	7	18	18	13	11	**73**	**15**	**97**	**14**
8pm - 9pm	10	6	4	7	18	5	5	**45**	**9**	**55**	**8**
9pm - 10pm	5	3	3	5	10	5	1	**26**	**5**	**32**	**5**
10pm - 11pm	7	4	0	5	5	1	1	**21**	**4**	**23**	**3**
11pm - Midnight	4	3	1	0	1	6	0	**9**	**2**	**15**	**2**
Total	**490**	**501**	**504**	**500**	**561**	**396**	**363**	**2556**	**511**	**3315**	**473**

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Data displayed has been compiled from pneumatic traffic count processes and is subject to the documented limitations

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Hourly Classification Summary

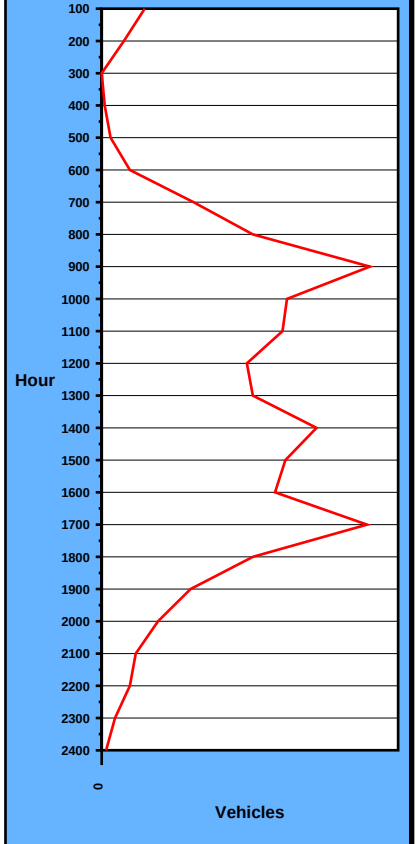
Count Number	**5116**	Ref : **ARUP**	**Lat/Long : S34 29 49.2 / E150 18 24.1** **LOCAL MAP**
Street	**MEDWAY ROAD, BERRIMA : From RAILWAY PARADE to OLD HUME HIGHWAY : EAST BOUND**		
Location	West of Hume Highway, east of first local road on north, ELP		*Carriageway*

Start Date	24-OCT-09
Start Time	100
Duration	7 DAYS
Interval	1 HOUR

Weekly 50th Percentile Speed	**90**
Weekly 85th Percentile Speed	**104**
Five Day AADT	**261**
Seven Day AADT	**240**

THE BODY OF THIS REPORT SHOWS : SEVENDAY TRAFFIC

Time	00	01	02	03	04	05	06	07	08	09	10	11	12	13	Total	Avg
Midnight - 1am	0	29	0	0	0	0	0	0	0	0	0	0	0	0	**29**	**4**
1am - 2am	0	15	0	0	0	0	0	0	0	0	0	0	0	0	**15**	**2**
2am - 3am	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
3am - 4am	0	0	0	2	0	0	0	0	0	0	0	0	0	0	**2**	
4am - 5am	0	5	0	1	0	0	0	0	0	0	0	0	0	0	**6**	**1**
5am - 6am	0	13	0	2	1	0	0	0	0	1	2	0	0	0	**19**	**3**
6am - 7am	1	49	2	7	1	0	0	0	0	2	0	0	0	0	**62**	**9**
7am - 8am	0	63	3	31	1	0	0	2	1	1	0	0	0	0	**102**	**15**
8am - 9am	1	141	2	24	6	0	1	2	2	2	0	0	0	0	**181**	**26**
9am - 10am	1	90	2	23	7	0	0	0	0	2	0	0	0	0	**125**	**18**
10am - 11am	0	86	2	19	7	0	2	0	0	6	0	0	0	0	**122**	**17**
11am - Midday	0	69	0	16	3	0	0	1	2	7	0	0	0	0	**98**	**14**
Midday - 1pm	0	75	2	13	4	0	0	1	2	5	0	0	0	0	**102**	**15**
1pm - 2pm	0	114	3	11	7	0	1	3	3	3	0	0	0	0	**145**	**21**
2pm - 3pm	0	99	0	15	1	1	0	0	2	6	0	0	0	0	**124**	**18**
3pm - 4pm	0	87	1	19	2	0	0	1	2	5	0	0	0	0	**117**	**17**
4pm - 5pm	2	147	1	22	3	0	0	1	0	3	0	0	0	0	**179**	**26**
5pm - 6pm	0	82	0	11	6	0	0	0	2	1	0	0	0	0	**102**	**15**
6pm - 7pm	0	47	1	7	1	0	0	1	1	2	0	0	0	0	**60**	**9**
7pm - 8pm	0	29	1	5	2	0	0	1	0	0	0	0	0	0	**38**	**5**
8pm - 9pm	0	21	0	1	1	0	0	0	0	0	0	0	0	0	**23**	**3**
9pm - 10pm	0	19	0	0	0	0	0	0	0	0	0	0	0	0	**19**	**3**
10pm - 11pm	0	9	0	0	0	0	0	0	0	0	0	0	0	0	**9**	**1**
11pm - Midnigh	0	3	0	0	0	0	0	0	0	0	0	0	0	0	**3**	
Total	5	1292	20	229	53	1	4	13	17	46	2	0	0	0	**1682**	**240**
% of Total		77	1	14	3			1	1	3						



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Hourly Classification Summary

Count Number	**5116**	Ref : **ARUP**	**Lat/Long : S34 29 49.2 / E150 18 24.1** **LOCAL MAP**
Street	**MEDWAY ROAD, BERRIMA : From OLD HUME HIGHWAY to RAILWAY PARADE : WEST BOUND**		
Location	West of Hume Highway, east of first local road on north, ELP		*Carriageway*

Start Date	24-OCT-09
Start Time	100
Duration	7 DAYS
Interval	1 HOUR

Weekly 50th Percentile Speed	**90**
Weekly 85th Percentile Speed	**102**
Five Day AADT	**250**
Seven Day AADT	**233**

THE BODY OF THIS REPORT SHOWS : SEVENDAY TRAFFIC

Time	00	01	02	03	04	05	06	07	08	09	10	11	12	13	Total	Avg
Midnight - 1am	0	8	0	0	0	0	0	0	0	0	0	0	0	0	**8**	**1**
1am - 2am	0	3	0	0	0	0	0	0	0	0	0	0	0	0	**3**	
2am - 3am	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**	
3am - 4am	0	2	0	1	0	0	0	0	0	0	0	0	0	0	**3**	
4am - 5am	0	19	0	0	0	0	0	0	0	0	0	0	0	0	**19**	**3**
5am - 6am	0	91	0	4	0	0	0	0	0	0	0	0	0	0	**95**	**14**
6am - 7am	0	60	1	1	1	0	0	0	0	0	0	0	0	0	**63**	**9**
7am - 8am	0	48	0	12	3	0	0	1	1	7	0	0	0	0	**72**	**10**
8am - 9am	0	76	0	10	5	0	0	1	7	7	0	0	0	0	**106**	**15**
9am - 10am	0	71	1	11	2	0	0	0	3	2	0	0	0	0	**90**	**13**
10am - 11am	0	70	3	14	7	0	0	1	5	5	0	0	0	0	**105**	**15**
11am - Midday	0	123	2	10	5	0	1	0	4	6	0	0	0	0	**151**	**22**
Midday - 1pm	0	95	3	5	4	0	0	0	5	5	0	0	0	0	**117**	**17**
1pm - 2pm	0	74	2	5	8	0	0	0	9	3	0	0	0	0	**101**	**14**
2pm - 3pm	0	105	4	15	6	1	1	0	1	3	0	0	0	0	**136**	**19**
3pm - 4pm	0	79	4	12	3	0	1	1	6	1	0	0	0	0	**107**	**15**
4pm - 5pm	2	92	2	8	4	0	0	0	5	4	0	0	0	0	**117**	**17**
5pm - 6pm	2	105	3	4	4	0	1	1	3	3	0	0	0	0	**126**	**18**
6pm - 7pm	1	72	0	3	0	0	0	1	3	2	1	0	0	0	**83**	**12**
7pm - 8pm	1	52	0	3	0	0	0	0	1	2	0	0	0	0	**59**	**8**
8pm - 9pm	0	28	0	0	0	0	1	0	1	1	1	0	0	0	**32**	**5**
9pm - 10pm	0	12	0	0	0	0	0	0	1	0	0	0	0	0	**13**	**2**
10pm - 11pm	0	14	0	0	0	0	0	0	0	0	0	0	0	0	**14**	**2**
11pm - Midnigh	0	12	0	0	0	0	0	0	0	0	0	0	0	0	**12**	**2**
Total	6	1312	25	118	52	1	5	6	55	51	2	0	0	0	**1633**	**233**
% of Total		80	2	7	3				3	3						



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Traffic Count Summary Report

Count Number	**5117**	Ref : **ARUP**	**Lat/Long : S34 30 13.3 / E150 19 02.6**	**LOCAL MAP**
Street	**OLD HUME HIGHWAY, BERRIMA : Between MARULAN TOWNSHIP & OXLEY HILL ROAD (bidirectional) :**			
Location	South of Roundabout, 80km sign			*Carriageway*

TOTAL COUNT MATRIX

Start Date	24-OCT-09
Start Time	100
Duration	7 DAYS
Interval	1 HOUR

Weekly 50th Percentile Speed	91
Weekly 85th Percentile Speed	104
Five Day AADT	1116
Seven Day AADT	1077

	MON *26TH*	TUE *27TH*	WED *28TH*	THU *29TH*	FRI *30TH*	SAT *24TH*	SUN *25TH*	5 Day Total	5 Day Average	7 Day Total	7 Day Average
Midnight - 1am	4	2	2	2	5	11	6	**15**	**3**	**32**	**5**
1am - 2am	2	3	2	5	2	6	2	**14**	**3**	**22**	**3**
2am - 3am	3	2	0	0	2	6	6	**7**	**1**	**19**	**3**
3am - 4am	2	6	8	14	6	3	0	**36**	**7**	**39**	**6**
4am - 5am	9	13	10	9	9	3	5	**50**	**10**	**58**	**8**
5am - 6am	20	28	21	20	25	10	6	**114**	**23**	**130**	**19**
6am - 7am	34	28	39	34	38	23	11	**173**	**35**	**207**	**30**
7am - 8am	71	78	84	74	77	32	19	**384**	**77**	**435**	**62**
8am - 9am	71	81	**97**	**89**	81	56	31	**419**	**84**	**506**	**72**
9am - 10am	73	58	73	58	87	75	60	**349**	**70**	**484**	**69**
10am - 11am	60	56	85	83	74	**95**	68	**358**	**72**	**521**	**74**
11am - Midday	**100**	**85**	83	78	**101**	93	**87**	**447**	**89**	**627**	**90**
Midday - 1pm	71	74	88	80	110	**98**	92	**423**	**85**	**613**	**88**
1pm - 2pm	76	61	86	70	100	79	89	**393**	**79**	**561**	**80**
2pm - 3pm	72	79	**105**	77	**113**	86	**112**	**446**	**89**	**644**	**92**
3pm - 4pm	**81**	95	78	93	101	68	111	**448**	**90**	**627**	**90**
4pm - 5pm	79	95	76	92	86	78	83	**428**	**86**	**589**	**84**
5pm - 6pm	**81**	**97**	92	**100**	84	46	75	**454**	**91**	**575**	**82**
6pm - 7pm	30	42	45	38	59	45	36	**214**	**43**	**295**	**42**
7pm - 8pm	21	11	29	27	36	33	25	**124**	**25**	**182**	**26**
8pm - 9pm	5	19	17	22	26	20	9	**89**	**18**	**118**	**17**
9pm - 10pm	10	12	17	15	25	8	11	**79**	**16**	**98**	**14**
10pm - 11pm	16	9	12	20	19	17	8	**76**	**15**	**101**	**14**
11pm - Midnight	6	9	6	10	9	12	4	**40**	**8**	**56**	**8**
Total	**997**	**1043**	**1155**	**1110**	**1275**	**1003**	**956**	**5580**	**1116**	**7539**	**1077**

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Hourly Classification Summary

Count Number	**5117**	Ref : **ARUP**	**Lat/Long : S34 30 13.3 / E150 19 02.6**
Street	**OLD HUME HIGHWAY, BERRIMA : From MARULAN TOWNSHIP to OXLEY HILL ROAD : NORTH BOUND**		
Location	South of Roundabout, 80km sign		*Carriageway*

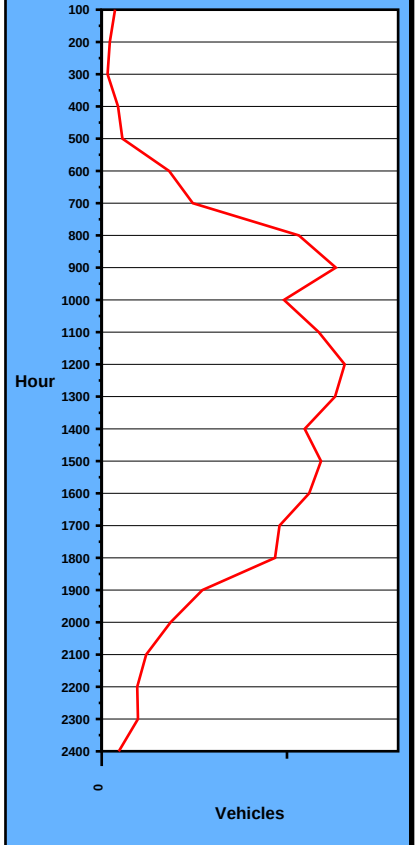
LOCAL MAP

Start Date	24-OCT-09
Start Time	100
Duration	7 DAYS
Interval	1 HOUR

Weekly 50th Percentile Speed	**92**
Weekly 85th Percentile Speed	**104**
Five Day AADT	**565**
Seven Day AADT	**543**

THE BODY OF THIS REPORT SHOWS : SEVENDAY TRAFFIC

Time	00	01	02	03	04	05	06	07	08	09	10	11	12	13	Total	Avg
Midnight - 1am	0	14	0	0	0	0	0	0	1	2	1	0	0	0	**18**	**3**
1am - 2am	0	4	0	1	1	0	0	0	1	2	2	0	0	0	**11**	**2**
2am - 3am	0	4	0	1	2	0	0	0	0	0	1	0	0	0	**8**	**1**
3am - 4am	2	9	1	4	2	0	0	0	0	2	2	0	0	0	**22**	**3**
4am - 5am	1	15	0	6	0	0	0	0	0	3	3	0	0	0	**28**	**4**
5am - 6am	2	74	2	4	3	0	0	1	1	3	1	0	0	0	**91**	**13**
6am - 7am	0	107	1	7	1	0	0	0	2	5	0	0	0	0	**123**	**18**
7am - 8am	0	218	10	18	1	0	2	0	6	9	2	0	0	0	**266**	**38**
8am - 9am	1	262	5	17	11	0	0	2	9	8	1	0	0	0	**316**	**45**
9am - 10am	1	209	3	9	7	0	0	2	6	9	0	0	0	0	**246**	**35**
10am - 11am	0	235	8	29	5	0	1	1	3	10	1	0	0	0	**293**	**42**
11am - Midday	3	280	7	17	6	0	1	0	3	10	1	0	0	0	**328**	**47**
Midday - 1pm	0	268	4	19	8	1	0	1	6	8	0	0	0	0	**315**	**45**
1pm - 2pm	0	215	9	15	7	0	2	2	6	17	1	0	0	0	**274**	**39**
2pm - 3pm	2	252	12	15	1	0	0	0	3	8	3	0	0	0	**296**	**42**
3pm - 4pm	1	227	12	24	5	0	2	2	1	5	1	0	0	0	**280**	**40**
4pm - 5pm	0	206	4	18	2	0	1	0	1	7	1	0	0	0	**240**	**34**
5pm - 6pm	3	202	4	16	4	0	0	0	1	4	0	0	0	0	**234**	**33**
6pm - 7pm	0	123	3	5	0	0	0	0	0	5	0	0	0	0	**136**	**19**
7pm - 8pm	1	76	2	7	1	0	1	0	0	5	0	0	0	0	**93**	**13**
8pm - 9pm	0	48	2	5	1	0	0	0	0	3	1	0	0	0	**60**	**9**
9pm - 10pm	0	30	2	5	1	1	0	0	1	4	4	0	0	0	**48**	**7**
10pm - 11pm	1	34	1	6	0	0	0	1	1	4	1	0	0	0	**49**	**7**
11pm - Midnigh	0	13	0	2	0	0	0	1	0	3	4	0	0	0	**23**	**3**
Total	18	3125	92	250	69	2	10	13	52	136	31	0	0	0	**3798**	**543**
% of Total		82	2	7	2				1	4	1					



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Hourly Classification Summary

Count Number	**5117**	Ref : **ARUP**	**Lat/Long : S34 30 13.3 / E150 19 02.6**
Street	**OLD HUME HIGHWAY, BERRIMA : From OXLEY HILL ROAD to MARULAN TOWNSHIP : SOUTH BOUND**		
Location	South of Roundabout, 80km sign		*Carriageway*

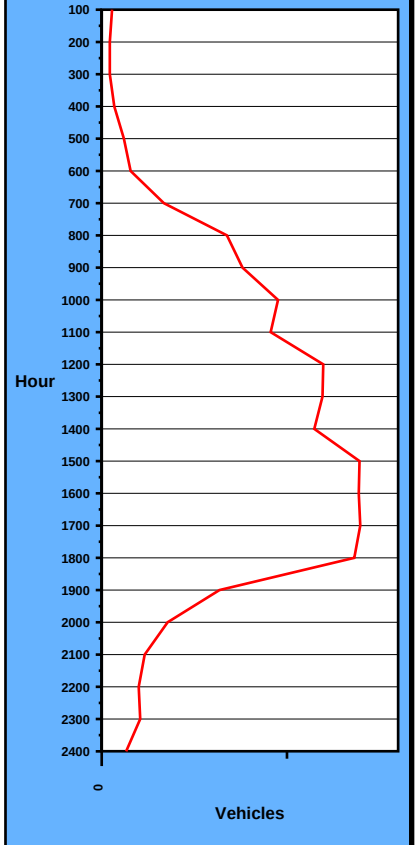
LOCAL MAP

Start Date	24-OCT-09
Start Time	100
Duration	7 DAYS
Interval	1 HOUR

Weekly 50th Percentile Speed	**90**
Weekly 85th Percentile Speed	**104**
Five Day AADT	**551**
Seven Day AADT	**534**

THE BODY OF THIS REPORT SHOWS : SEVENDAY TRAFFIC

Time	00	01	02	03	04	05	06	07	08	09	10	11	12	13	Total	Avg
Midnight - 1am	0	12	0	1	0	0	0	0	0	1	0	0	0	0	**14**	**2**
1am - 2am	0	9	0	2	0	0	0	0	0	0	0	0	0	0	**11**	**2**
2am - 3am	0	3	0	4	0	0	0	0	1	3	0	0	0	0	**11**	**2**
3am - 4am	0	2	0	9	0	0	0	1	1	3	1	0	0	0	**17**	**2**
4am - 5am	0	15	0	3	1	0	0	2	1	5	3	0	0	0	**30**	**4**
5am - 6am	0	21	2	2	1	0	0	0	2	7	4	0	0	0	**39**	**6**
6am - 7am	1	50	4	12	1	0	0	1	3	10	2	0	0	0	**84**	**12**
7am - 8am	1	123	4	22	6	0	2	4	1	5	1	0	0	0	**169**	**24**
8am - 9am	1	132	4	28	3	1	1	7	4	7	2	0	0	0	**190**	**27**
9am - 10am	3	167	12	39	3	0	1	6	0	7	0	0	0	0	**238**	**34**
10am - 11am	0	179	8	23	5	0	1	1	2	8	1	0	0	0	**228**	**33**
11am - Midday	0	241	5	30	4	2	0	3	1	9	4	0	0	0	**299**	**43**
Midday - 1pm	4	246	6	23	3	1	3	1	3	6	2	0	0	0	**298**	**43**
1pm - 2pm	1	230	17	23	5	0	1	4	0	6	0	0	0	0	**287**	**41**
2pm - 3pm	0	302	7	20	2	0	1	2	3	10	1	0	0	0	**348**	**50**
3pm - 4pm	2	296	4	23	2	0	2	0	1	12	5	0	0	0	**347**	**50**
4pm - 5pm	2	292	12	22	7	1	1	4	0	6	2	0	0	0	**349**	**50**
5pm - 6pm	2	282	3	24	11	2	1	3	1	11	1	0	0	0	**341**	**49**
6pm - 7pm	2	137	2	11	0	0	0	1	0	6	0	0	0	0	**159**	**23**
7pm - 8pm	0	77	1	3	3	0	0	1	0	2	2	0	0	0	**89**	**13**
8pm - 9pm	0	47	1	4	2	0	0	1	0	3	0	0	0	0	**58**	**8**
9pm - 10pm	1	41	0	2	1	0	0	0	2	2	1	0	0	0	**50**	**7**
10pm - 11pm	0	41	1	4	0	0	0	0	1	3	2	0	0	0	**52**	**7**
11pm - Midnigh	0	26	0	3	2	0	0	0	0	1	1	0	0	0	**33**	**5**
Total	20	2971	93	337	62	7	14	42	27	133	35	0	0	0	**3741**	**534**
% of Total	1	79	2	9	2			1	1	4	1					



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Traffic Count Summary Report

Count Number	**5115**	Ref : **ARUP**	**Lat/Long : S34 30 05.3 / E150 19 33.8** **LOCAL MAP**
Street	**TAYLOR AVENUE, BERRIMA : Between OLD HUME HIGHWAY & BERRIMA ROAD (bidirectional) :**		
Location	East of new roundabout, about mid way to residential streets in New Berrima, ELP 313643		*Carriageway*

TOTAL COUNT MATRIX

Start Date	03-NOV-09
Start Time	1400
Duration	7 DAYS
Interval	1 HOUR

Weekly 50th Percentile Speed	75
Weekly 85th Percentile Speed	87
Five Day AADT	2622
Seven Day AADT	2310

	MON *9TH*	TUE *10TH / 3RD*	WED *4TH*	THU *5TH*	FRI *6TH*	SAT *7TH*	SUN *8TH*	5 Day Total	5 Day Average	7 Day Total	7 Day Average
Midnight - 1am	4	11	9	18	17	19	15	**59**	**12**	**93**	**13**
1am - 2am	11	13	7	12	17	10	7	**60**	**12**	**77**	**11**
2am - 3am	13	13	16	9	6	7	6	**57**	**11**	**70**	**10**
3am - 4am	20	23	29	27	19	10	10	**118**	**24**	**138**	**20**
4am - 5am	18	40	53	45	49	17	8	**205**	**41**	**230**	**33**
5am - 6am	90	100	99	100	114	35	17	**503**	**101**	**555**	**79**
6am - 7am	117	114	136	111	105	48	23	**583**	**117**	**654**	**93**
7am - 8am	176	193	184	186	180	72	36	**919**	**184**	**1027**	**147**
8am - 9am	**211**	**197**	**212**	**203**	**211**	117	63	**1034**	**207**	**1214**	**173**
9am - 10am	155	184	187	164	173	127	91	**863**	**173**	**1081**	**154**
10am - 11am	147	152	177	152	182	131	123	**810**	**162**	**1064**	**152**
11am - Midday	142	159	164	158	175	**152**	**133**	**798**	**160**	**1083**	**155**
Midday - 1pm	151	150	169	164	**212**	**155**	109	**846**	**169**	**1110**	**159**
1pm - 2pm	123	133	165	155	208	140	112	**784**	**157**	**1036**	**148**
2pm - 3pm	159	178	163	177	207	139	94	**884**	**177**	**1117**	**160**
3pm - 4pm	187	178	220	209	184	99	**129**	**978**	**196**	**1206**	**172**
4pm - 5pm	**202**	**209**	**221**	**220**	206	101	102	**1058**	**212**	**1261**	**180**
5pm - 6pm	180	202	208	193	189	100	88	**972**	**194**	**1160**	**166**
6pm - 7pm	109	119	111	116	104	90	60	**559**	**112**	**709**	**101**
7pm - 8pm	73	49	53	77	72	48	46	**324**	**65**	**418**	**60**
8pm - 9pm	44	51	45	57	50	30	30	**247**	**49**	**307**	**44**
9pm - 10pm	40	48	44	26	25	21	17	**183**	**37**	**221**	**32**
10pm - 11pm	32	25	36	37	33	28	19	**163**	**33**	**210**	**30**
11pm - Midnight	28	23	25	13	13	14	14	**102**	**20**	**130**	**19**
Total	**2432**	**2564**	**2733**	**2629**	**2751**	**1710**	**1352**	**13109**	**2621**	**16171**	**2310**

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Hourly Classification Summary

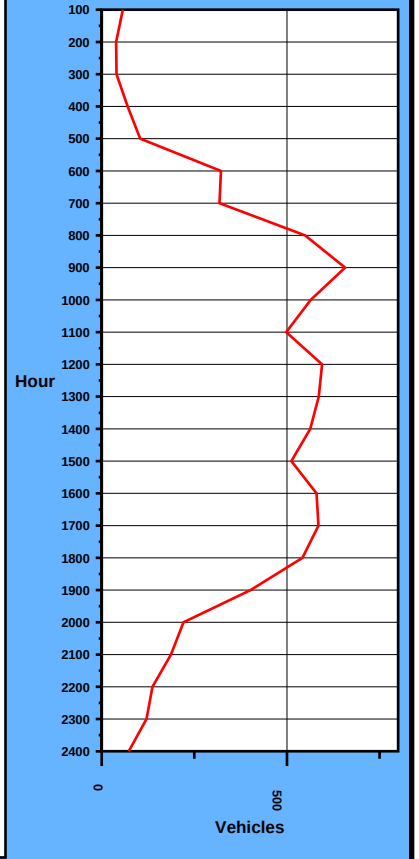
Count Number	**5115**	Ref : **ARUP**	**Lat/Long : S34 30 05.3 / E150 19 33.8** **LOCAL MAP**
Street	**TAYLOR AVENUE, BERRIMA : From OLD HUME HIGHWAY to BERRIMA ROAD : EAST BOUND**		
Location	East of new roundabout, about mid way to residential streets in New Berrima, ELP 313643		*Carriageway*

Start Date	03-NOV-09
Start Time	1400
Duration	7 DAYS
Interval	1 HOUR

Weekly 50th Percentile Speed	**74**
Weekly 85th Percentile Speed	**86**
Five Day AADT	**1340**
Seven Day AADT	**1189**

THE BODY OF THIS REPORT SHOWS : SEVENDAY TRAFFIC

Time	00	01	02	03	04	05	06	07	08	09	10	11	12	13	Total	Avg
Midnight - 1am	0	37	0	4	0	0	0	0	1	12	3	0	0	0	**57**	**8**
1am - 2am	0	16	0	5	1	0	0	0	1	11	5	0	0	0	**39**	**6**
2am - 3am	0	20	0	8	1	0	0	0	4	5	2	0	0	0	**40**	**6**
3am - 4am	0	27	0	4	0	0	0	0	9	12	18	0	0	0	**70**	**10**
4am - 5am	1	43	0	26	0	0	0	1	6	16	11	0	0	0	**104**	**15**
5am - 6am	1	221	1	19	4	0	0	2	12	51	11	0	0	0	**322**	**46**
6am - 7am	0	198	3	38	11	0	0	2	7	42	17	0	0	0	**318**	**45**
7am - 8am	5	378	7	53	6	1	3	3	11	62	20	0	0	0	**549**	**78**
8am - 9am	1	479	14	39	22	4	1	2	17	58	20	0	0	0	**657**	**94**
9am - 10am	3	337	10	59	26	5	2	1	15	86	20	0	0	0	**564**	**81**
10am - 11am	2	310	15	38	21	2	2	1	7	80	20	0	0	0	**498**	**71**
11am - Midday	2	390	7	56	14	1	1	2	21	62	39	0	0	0	**595**	**85**
Midday - 1pm	1	369	17	43	23	4	6	2	17	72	32	0	0	0	**586**	**84**
1pm - 2pm	0	381	19	41	15	5	2	0	20	63	17	0	0	0	**563**	**80**
2pm - 3pm	1	353	10	38	13	3	3	3	10	62	16	0	0	0	**512**	**73**
3pm - 4pm	1	451	10	41	11	1	0	2	7	42	14	0	0	0	**580**	**83**
4pm - 5pm	1	461	16	33	7	0	1	2	8	40	16	0	0	0	**585**	**84**
5pm - 6pm	3	449	12	32	9	0	1	1	1	29	5	0	0	0	**542**	**77**
6pm - 7pm	1	336	10	16	6	0	0	0	5	22	6	0	0	0	**402**	**57**
7pm - 8pm	0	182	6	9	4	0	1	1	3	13	2	0	0	0	**221**	**32**
8pm - 9pm	0	155	8	6	0	0	0	0	1	13	4	0	0	0	**187**	**27**
9pm - 10pm	0	100	2	10	0	0	0	0	0	13	12	0	0	0	**137**	**20**
10pm - 11pm	1	85	2	5	1	0	0	0	3	19	5	0	0	0	**121**	**17**
11pm - Midnigh	0	56	0	6	2	0	0	0	1	8	0	0	0	0	**73**	**10**
Total	24	5834	169	629	197	26	23	25	187	893	315	0	0	0	**8322**	**1189**
% of Total		70	2	8	2				2	11	4					



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Hourly Classification Summary

Count Number	**5115**	Ref : **ARUP**	**Lat/Long : S34 30 05.3 / E150 19 33.8**
Street	**TAYLOR AVENUE, BERRIMA : From BERRIMA ROAD to OLD HUME HIGHWAY : WEST BOUND**		
Location	East of new roundabout, about mid way to residential streets in New Berrima, ELP 313643		*Carriageway*

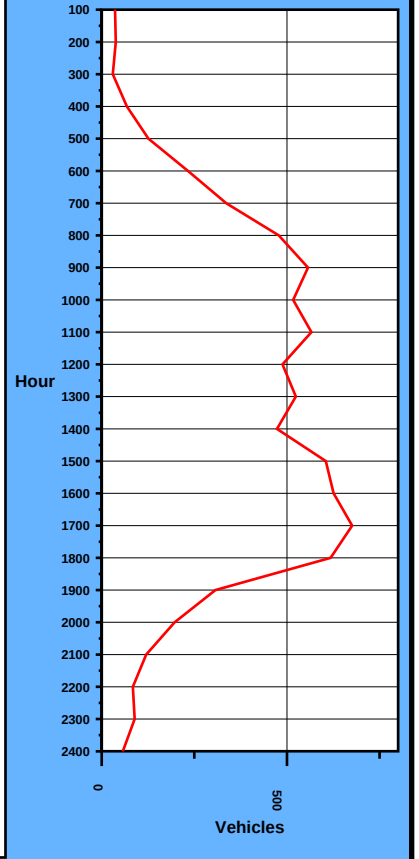
LOCAL MAP

Start Date	03-NOV-09
Start Time	1400
Duration	7 DAYS
Interval	1 HOUR

Weekly 50th Percentile Speed	**76**
Weekly 85th Percentile Speed	**87**
Five Day AADT	**1282**
Seven Day AADT	**1121**

THE BODY OF THIS REPORT SHOWS : SEVENDAY TRAFFIC

Time	00	01	02	03	04	05	06	07	08	09	10	11	12	13	Total	Avg
Midnight - 1am	0	23	0	1	1	0	0	0	0	7	4	0	0	0	**36**	**5**
1am - 2am	0	16	0	5	3	0	0	1	4	6	3	0	0	0	**38**	**5**
2am - 3am	0	12	0	3	4	1	0	0	0	6	4	0	0	0	**30**	**4**
3am - 4am	0	29	1	17	4	0	0	1	3	8	5	0	0	0	**68**	**10**
4am - 5am	1	49	0	18	10	0	0	7	9	20	12	0	0	0	**126**	**18**
5am - 6am	2	136	4	19	6	0	0	6	9	37	14	0	0	0	**233**	**33**
6am - 7am	1	217	6	28	20	3	1	5	7	37	11	0	0	0	**336**	**48**
7am - 8am	5	327	7	33	21	3	1	3	9	52	17	0	0	0	**478**	**68**
8am - 9am	4	393	6	49	25	1	2	4	11	49	13	0	0	0	**557**	**80**
9am - 10am	2	337	19	46	14	6	2	5	10	58	18	0	0	0	**517**	**74**
10am - 11am	1	339	13	65	24	0	1	5	13	88	17	0	0	0	**566**	**81**
11am - Midday	0	319	11	53	17	1	0	3	12	51	21	0	0	0	**488**	**70**
Midday - 1pm	0	335	8	57	13	4	2	1	21	57	26	0	0	0	**524**	**75**
1pm - 2pm	3	301	11	38	19	1	0	4	13	59	24	0	0	0	**473**	**68**
2pm - 3pm	0	443	12	37	18	8	1	4	10	57	15	0	0	0	**605**	**86**
3pm - 4pm	3	496	8	44	10	0	0	3	15	38	9	0	0	0	**626**	**89**
4pm - 5pm	0	564	11	50	7	0	2	0	9	24	9	0	0	0	**676**	**97**
5pm - 6pm	1	501	5	34	7	2	1	4	12	28	23	0	0	0	**618**	**88**
6pm - 7pm	0	262	4	11	5	1	0	1	1	16	6	0	0	0	**307**	**44**
7pm - 8pm	1	150	3	6	6	0	0	2	3	22	4	0	0	0	**197**	**28**
8pm - 9pm	0	95	0	5	5	0	0	0	2	13	0	0	0	0	**120**	**17**
9pm - 10pm	0	57	2	10	1	0	0	1	1	9	3	0	0	0	**84**	**12**
10pm - 11pm	0	70	0	3	1	0	0	0	2	6	7	0	0	0	**89**	**13**
11pm - Midnigh	1	36	2	3	1	0	0	1	3	7	3	0	0	0	**57**	**8**
Total	25	5507	133	635	242	31	13	61	179	755	268	0	0	0	**7849**	**1121**
% of Total		70	2	8	3			1	2	10	3					



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Traffic Count Summary Report

Count Number	**5838**	Ref : **ARUP**	**Lat/Long : S34 14 45.6 / E150 42 00.1**	**UBD 444 A-6**
Street	**PICTON ROAD, WILTON : Between SOUTH WESTERN FREEWAY & MOUNT KEIRA ROAD (bidirectional) :**			
Location	Between Arnold (Wilton Rd) and Macarthur Rd			*Carriageway*

TOTAL COUNT MATRIX

Start Date	13-MAY-10
Start Time	100
Duration	7 DAYS
Interval	1 HOUR

Weekly 50th Percentile Speed	95
Weekly 85th Percentile Speed	104
Five Day AADT	13138
Seven Day AADT	12509

	MON *17TH*	TUE *18TH*	WED *19TH*	THU *13TH*	FRI *14TH*	SAT *15TH*	SUN *16TH*	5 Dav Total	5 Dav Average	7 Dav Total	7 Dav Average
Midnight - 1am	38	72	67	77	80	100	113	**334**	**67**	**547**	**78**
1am - 2am	32	62	50	77	68	78	56	**289**	**58**	**423**	**60**
2am - 3am	32	48	53	55	67	62	31	**255**	**51**	**348**	**50**
3am - 4am	82	77	77	85	94	59	40	**415**	**83**	**514**	**73**
4am - 5am	218	210	211	196	193	114	71	**1028**	**206**	**1213**	**173**
5am - 6am	488	433	512	437	450	199	94	**2320**	**464**	**2613**	**373**
6am - 7am	924	902	900	892	882	390	173	**4500**	**900**	**5063**	**723**
7am - 8am	**1139**	**1030**	**1158**	**1005**	**985**	490	264	**5317**	**1063**	**6071**	**867**
8am - 9am	993	980	1049	951	982	588	415	**4955**	**991**	**5958**	**851**
9am - 10am	800	745	793	845	850	775	660	**4033**	**807**	**5468**	**781**
10am - 11am	816	713	701	752	860	887	815	**3842**	**768**	**5544**	**792**
11am - Midday	735	651	691	724	793	**931**	**900**	**3594**	**719**	**5425**	**775**
Midday - 1pm	654	585	657	654	820	794	859	**3370**	**674**	**5023**	**718**
1pm - 2pm	773	722	726	421	916	756	841	**3558**	**712**	**5155**	**736**
2pm - 3pm	804	801	859	864	1079	700	944	**4407**	**881**	**6051**	**864**
3pm - 4pm	**985**	**970**	992	989	1132	723	1046	**5068**	**1014**	**6837**	**977**
4pm - 5pm	966	916	**1048**	**1053**	**1255**	**811**	**1152**	**5238**	**1048**	**7201**	**1029**
5pm - 6pm	944	887	964	945	1113	788	1026	**4853**	**971**	**6667**	**952**
6pm - 7pm	549	573	578	552	779	493	632	**3031**	**606**	**4156**	**594**
7pm - 8pm	285	301	302	313	461	254	421	**1662**	**332**	**2337**	**334**
8pm - 9pm	206	200	250	245	331	190	276	**1232**	**246**	**1698**	**243**
9pm - 10pm	168	189	206	203	213	201	171	**979**	**196**	**1351**	**193**
10pm - 11pm	147	135	177	214	171	173	116	**844**	**169**	**1133**	**162**
11pm - Midnight	94	89	103	124	156	122	81	**566**	**113**	**769**	**110**
Total	**12872**	**12291**	**13124**	**12673**	**14730**	**10678**	**11197**	**65690**	**13138**	**87565**	**12509**

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Hourly Classification Summary

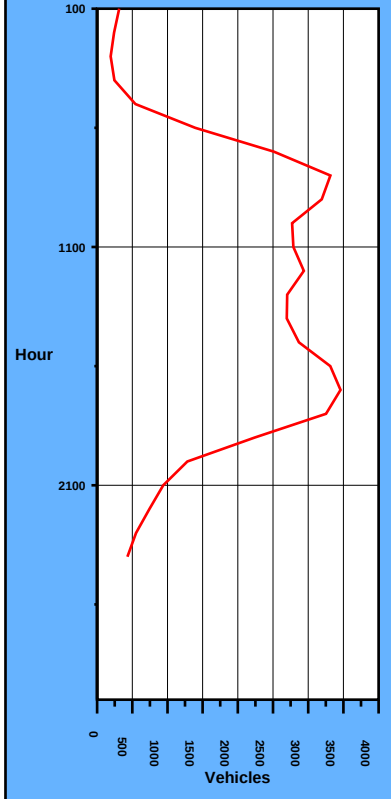
Count Number	**5838**	Ref : **ARUP**	**Lat/Long : S34 14 45.6 / E150 42 00.1**	**UBD 444 A-6**
Street	**PICTON ROAD, WILTON : From SOUTH WESTERN FREEWAY to MOUNT KEIRA ROAD : SOUTH EAST**			
Location	Between Arnold (Wilton Rd) and Macarthur Rd			*Carriageway*

Start Date	13-MAY-10
Start Time	100
Duration	7 DAYS
Interval	1 HOUR

Weekly 50th Percentile Speed	**98**
Weekly 85th Percentile Speed	**107**
Five Day AADT	**6759**
Seven Day AADT	**6418**

THE BODY OF THIS REPORT SHOWS : SEVENDAY TRAFFIC

Time	00	01	02	03	04	05	06	07	08	09	10	11	12	13	Total	Avg
Midnight - 1am	3	195	1	27	17	0	0	3	27	27	14	0	0	0	**314**	**45**
1am - 2am	2	97	1	32	22	1	5	6	29	38	8	0	0	0	**241**	**34**
2am - 3am	0	74	2	28	23	1	9	8	17	24	6	0	0	0	**192**	**27**
3am - 4am	1	88	3	19	28	1	13	14	25	42	12	0	0	0	**246**	**35**
4am - 5am	3	189	5	79	69	8	20	15	58	85	13	0	0	0	**544**	**78**
5am - 6am	6	708	18	170	127	6	16	27	102	167	48	0	0	0	**1395**	**199**
6am - 7am	11	1719	35	284	123	11	14	28	81	176	28	0	0	0	**2510**	**359**
7am - 8am	6	2544	34	233	135	14	14	35	79	183	38	0	0	0	**3315**	**474**
8am - 9am	12	2527	45	206	83	11	14	23	67	171	34	0	0	0	**3193**	**456**
9am - 10am	6	2086	67	204	85	7	18	16	66	168	48	0	0	0	**2771**	**396**
10am - 11am	8	2043	71	215	91	10	8	21	81	183	59	0	0	0	**2790**	**399**
11am - Midday	7	2184	92	194	97	7	12	24	89	185	46	0	0	0	**2937**	**420**
Midday - 1pm	13	1980	68	194	104	6	17	22	77	183	38	0	0	0	**2702**	**386**
1pm - 2pm	21	1964	70	199	77	8	12	23	84	186	51	0	0	0	**2695**	**385**
2pm - 3pm	10	2157	79	212	73	9	12	26	87	160	43	0	0	0	**2868**	**410**
3pm - 4pm	7	2688	74	200	88	3	10	17	53	136	38	0	0	0	**3314**	**473**
4pm - 5pm	6	2998	61	167	54	3	8	15	37	88	22	0	0	0	**3459**	**494**
5pm - 6pm	8	2845	59	150	40	1	8	8	36	78	20	0	0	0	**3253**	**465**
6pm - 7pm	0	1950	42	105	33	2	3	4	27	61	10	0	0	0	**2237**	**320**
7pm - 8pm	2	1058	27	71	26	3	6	5	13	50	22	0	0	0	**1283**	**183**
8pm - 9pm	1	747	18	49	21	1	3	18	20	52	10	0	0	0	**940**	**134**
9pm - 10pm	2	546	13	46	31	2	4	12	28	51	7	0	0	0	**742**	**106**
10pm - 11pm	2	391	8	28	19	0	3	9	31	58	5	0	0	0	**554**	**79**
11pm - Midnigh	2	307	3	25	13	0	3	5	20	44	9	0	0	0	**431**	**62**
Total	139	34085	896	3137	1479	115	232	384	1234	2596	629	0	0	0	**44926**	**6418**
% of Total		76	2	7	3		1	1	3	6	1					



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Hourly Classification Summary

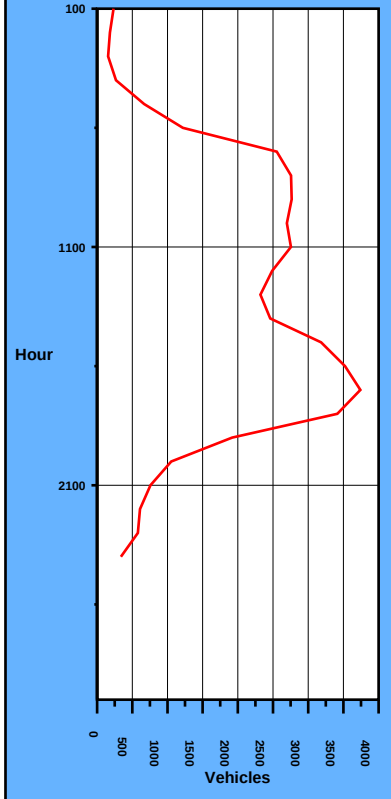
Count Number	**5838**	Ref : **ARUP**	**Lat/Long : S34 14 45.6 / E150 42 00.1**	**UBD 444 A-6**
Street	**PICTON ROAD, WILTON : From MOUNT KEIRA ROAD to SOUTH WESTERN FREEWAY : NORTH WEST**			
Location	Between Arnold (Wilton Rd) and Macarthur Rd			*Carriageway*

Start Date	13-MAY-10
Start Time	100
Duration	7 DAYS
Interval	1 HOUR

Weekly 50th Percentile Speed	**95**
Weekly 85th Percentile Speed	**104**
Five Day AADT	**6379**
Seven Day AADT	**6091**

THE BODY OF THIS REPORT SHOWS : SEVENDAY TRAFFIC

Time	00	01	02	03	04	05	06	07	08	09	10	11	12	13	Total	Avg
Midnight - 1am	13	129	2	28	21	5	0	2	5	26	2	0	0	0	**233**	**33**
1am - 2am	5	79	3	34	20	6	2	8	5	17	3	0	0	0	**182**	**26**
2am - 3am	4	63	1	31	21	4	3	5	3	20	1	0	0	0	**156**	**22**
3am - 4am	7	103	4	43	41	5	6	14	12	27	6	0	0	0	**268**	**38**
4am - 5am	23	315	7	89	88	23	7	28	23	54	12	0	0	0	**669**	**96**
5am - 6am	38	682	11	142	162	30	10	19	32	80	12	0	0	0	**1218**	**174**
6am - 7am	74	1739	11	328	205	24	14	28	45	76	9	0	0	0	**2553**	**365**
7am - 8am	96	1782	16	430	250	22	10	32	32	81	5	0	0	0	**2756**	**394**
8am - 9am	77	1802	27	388	221	32	25	29	33	118	13	0	0	0	**2765**	**395**
9am - 10am	56	1677	35	389	218	29	24	50	46	157	16	0	0	0	**2697**	**385**
10am - 11am	69	1731	64	328	230	28	27	61	41	154	21	0	0	0	**2754**	**393**
11am - Midday	32	1618	67	298	165	16	24	51	55	142	20	0	0	0	**2488**	**355**
Midday - 1pm	35	1545	43	285	166	14	18	34	45	125	11	0	0	0	**2321**	**332**
1pm - 2pm	42	1724	52	240	164	15	14	30	52	116	11	0	0	0	**2460**	**351**
2pm - 3pm	48	2256	52	326	225	17	14	33	46	144	22	0	0	0	**3183**	**455**
3pm - 4pm	50	2653	52	349	183	20	17	39	36	106	18	0	0	0	**3523**	**503**
4pm - 5pm	60	2821	72	347	212	14	9	56	45	90	16	0	0	0	**3742**	**535**
5pm - 6pm	50	2732	36	297	157	22	6	22	21	60	11	0	0	0	**3414**	**488**
6pm - 7pm	40	1471	18	191	107	11	9	24	15	28	5	0	0	0	**1919**	**274**
7pm - 8pm	22	755	13	104	70	8	5	16	21	37	3	0	0	0	**1054**	**151**
8pm - 9pm	28	516	9	81	59	5	2	10	12	34	2	0	0	0	**758**	**108**
9pm - 10pm	19	368	7	81	66	14	6	8	8	28	4	0	0	0	**609**	**87**
10pm - 11pm	24	372	4	61	54	12	2	8	8	32	2	0	0	0	**579**	**83**
11pm - Midnigh	11	208	3	36	27	6	1	7	9	25	5	0	0	0	**338**	**48**
Total	923	29141	609	4926	3132	382	255	614	650	1777	230	0	0	0	**42639**	**6091**
% of Total	2	68	1	12	7	1	1	1	2	4	1					



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Appendix B

Sidra Intersection Results

Taylor Ave (east)
Old Hume Hwy (north)
Old Hume Hwy (south)
Medway Rd (west)

MOVEMENT SUMMARY

Site: ExistingAMPeak

Old Hume Hwy/ Medway Rd/ Taylor Ave Intersection, Berrima
Existing Am Peak
Roundabout

Movement Performance - Vehicles

Mov ID	Turn	Demand Flow veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South	Old Hume Hwy (south)										
1	L	1	0.0	0.039	6.0	LOS A	0.2	1.4	0.21	0.49	50.7
2	T	34	3.1	0.039	4.7	LOS A	0.2	1.4	0.21	0.37	51.8
3	R	16	20.0	0.039	12.1	LOS A	0.2	1.4	0.21	0.79	46.5
Approach		51	8.3	0.039	7.0	LOS A	0.2	1.4	0.21	0.50	49.9
East	Taylor Ave (east)										
4	L	11	60.0	0.080	7.6	LOS A	0.4	3.5	0.15	0.44	51.2
5	T	40	57.9	0.080	5.5	LOS A	0.4	3.5	0.15	0.31	52.2
6	R	39	2.7	0.080	11.5	LOS A	0.4	3.5	0.15	0.77	46.4
Approach		89	34.1	0.080	8.3	LOS A	0.4	3.5	0.15	0.53	49.3
North	Old Hume Hwy (north)										
7	L	24	26.1	0.053	6.8	LOS A	0.3	2.0	0.26	0.48	50.4
8	T	20	10.5	0.053	5.0	LOS A	0.3	2.0	0.26	0.38	51.1
9	R	20	0.0	0.053	11.7	LOS A	0.3	2.0	0.26	0.76	46.3
Approach		64	13.1	0.053	7.8	LOS A	0.3	2.0	0.26	0.54	49.1
West	Medway Rd (west)										
10	L	23	0.0	0.122	6.3	LOS A	0.6	5.1	0.20	0.53	50.6
11	T	115	27.5	0.122	5.3	LOS A	0.6	5.1	0.20	0.38	52.0
12	R	7	14.3	0.123	12.1	LOS A	0.6	5.1	0.20	0.86	46.7
Approach		145	22.5	0.122	5.8	LOS A	0.6	5.1	0.20	0.43	51.4
All Vehicles		349	21.7	0.123	7.0	LOS A	0.6	5.1	0.20	0.49	50.2

Level of Service (Aver. Int. Delay): LOS A. Based on average delay for all vehicle movements. LOS Method: Delay (RTA NSW).
Level of Service (Worst Movement): LOS A. LOS Method for individual vehicle movements: Delay (RTA NSW).
Approach LOS values are based on the worst delay for any vehicle movement.
Roundabout Capacity Model: SIDRA Standard.

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Appendix F

Truck Driver Code of Conduct

Boral Cement Medway Mine – Driver's Code of Conduct

Driver's Code of Conduct

Medway Mine/ Loch Catherine Stockpile



(**August 2010 Version 1)**

10/05/2011

Boral Cement Medway Mine – Driver's Code of Conduct

1. Introduction

As part of Boral Cement's environmental assessments of the operations around Medway Coal Mine and Stockpile at Loch Catherine a commitment has been made to prepare and implement a Driver's Code of Conduct for the haulage of coal on a day to day basis to Berrima Cement Works and any additional movement during the extraction of Coal from the Mine or Stockpile.
The Code utilises industry best practice to minimise and manage the traffic impact associated with the movement of heavy vehicles to and from the Sites.

The Code has been developed in conjunction with Boral Cement's Operational Lease and the respect towards local Residents in the area and the environmental impacts. Transport Contractors, Roads and Traffic Authority (RTA), Wingecarribee Shire Council (WSC), and Residents of Medway have been involved in the development of the Code.

2. Scope

The Driver's Code of Conduct requires that specific measures are developed in consultation with the RTA and WSCto focus on opportunities to minimise, mitigate and manage traffic volume, traffic safety and acoustic impact.

The following documents have been reviewed in the formulation of the Driver's Code of Conduct:
- Boral Logistics Truck Driver's Procedures.
- Boral Logistics/Cement Traffic Management Plan.
- Boral Logistics Driver's Handbook.
- Boral Logistics CoR Accreditation.
- NSW Road Rules.
- RTA Heavy Vehicle Management Procedures & Permits.

3. Objectives

The Objectives are:
- Ensure compliance with the conditions of the Medway Mine operating lease and respect for the Medway residents, Road users and the Environment.
- Encourage the application of the Driver's Code of Conduct for all users of Medway Road.
- An Environmentally safe operation of all tasks.
- Maximise public safety at all times.

4. Cartage Routes

All trucks travelling to and from Medway Mine/ Loch Catherine & Berrima Works or alternative destinations will do so by using major arterial roads as outlined:
- Medway Road
- Taylor Avenue
- Hume Highway
- Old Hume Highway

Haulage hazards and specific procedures are as follows:

Hume Highway
The Hume Highway is a divided road with a speed limit of 100km/hr for heavy vehicles. Care at all times should be taken with faster moving vehicles.



Hume Highway / Berrima Exit

Berrima Exit
On exiting the Hume Highway with care the speed limit reduces to 60 km/hr leading into Medway Road allowing for traffic to turn right towards Medway Mine and left towards Berrima Works. Medway Road speed limit is 80km/hr at the intersection.



Berrima Exit / Medway Road

Medway Road
Turn right into Medway Road and head west towards the Medway Mine. Prior to reaching the Mine site you will pass through the village of Medway and speed limit is to be reduced to 30km/hr before passing the turn off to the left for Loch Catherine and the entry to the Mine site. All speed limits and signage to be obeyed at all times and maintain respect for local traffic and residents.

Obeying a speed limit of 30km/hr through the Medway village will ensure compliance of dust standards applicable to operation of the mine.



Medway Road (West to Medway Mine)



Medway village, 50km/hr limit

Medway Mine
On the Mine site follow the directions and the 40km/hr speed limit. Operations on site will provided to all drivers by a separate induction process.


Loch Catherine turn off on left



Medway Mine, 40km/hr limit

5. Noise Minimisation Controls & Standards

This section designates the specific noise mitigation measures which must be adhered to at all times. This includes rules on compression braking, tipping practices and speed limits for the approach and departure from the Mine site.

Due to the close proximity of local residents drivers are requested to limit the noise that may created with their operations and respect at all times the needs of the local traffic and residents.

Compression brakes must not be used in this vicinity.

Tailgates must be secure and locked to avoid noise or spillage, clean draw bars.

Approach Mine site speed humps at low speed.

Avoid queuing or parking in Medway Road.

Always observe the posted speed on site and on the road with the exception of Medway village where speed is to be kept at or below 30km/hr.
No tailgating will be permitted.

Loads must be covered and compliant.

Equipment to be used must be fit for task.

Driver must have a HV Licence and compliance to all authorities.

6. Incident Management and Reporting

To ensure that, in the event of an incident the affect is minimised, a rapid response from the haulage company is required. Drivers are to contact their supervisors immediately and in turn their supervisors are to take action and advise Boral Cement of the issue.

If there is product spillage while loading or en route the driver must immediately inform and warn persons in the area that maybe at risk. The driver must then inform Mine staff or his supervisor of the spillage. All spills must be cleaned up and waste disposed of in an acceptable and environmental manner. Place warning signs where it is fit to do so.

7. Compliance Monitoring

This Code of Conduct will be reviewed every twelve months and compliance audits carried out on all haulage contractors under the Safety Act 2008 and the Chain of Responsibility and Fatigue Management.

In addition daily operations will be monitored for any breaches of required compliance and the haulage contractors are to explain, investigate and demonstrate corrective actions when a compliance breach occurs.

8. Operating Times

Although the Medway Mine lease allows for 24/7 operations in respect of the environment and the residents we only allow operations between 6.00am and 9.00pm Monday to Friday with the occasional need to operate on a Saturday.

Drivers are to comply with these operating hours at all times, unless authorised in the case of specific campaign movements. In this case the residents will be notified in advance.

Incident Reporting numbers:

Boral Cement: Nick Wyatt 0401 895 624
Boral Logistics: Rick Towers 0401 895 704
