


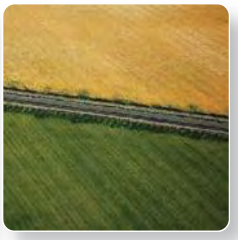


Russell Vale Colliery

UNDERGROUND EXPANSION PROJECT
RESIDUAL MATTERS REPORT

for

Wollongong Coal Limited

June 2014

Hansen Bailey
ENVIRONMENTAL CONSULTANTS

RUSSELL VALE COLLIERY
UNDERGROUND EXPANSION PROJECT

PREFERRED PROJECT
RESIDUAL MATTERS
REPORT

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20 June 2014

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RUSSELL VALE COLLIERY UNDERGROUND EXPANSION PROJECT

RESIDUAL MATTERS REPORT

for

Wollongong Coal Limited

1 OVERVIEW

1.1 INTRODUCTION

Wollongong Coal Limited (WCL) owns and operates the Russell Vale Colliery (formerly known as NRE No. 1 Colliery). In October 2013, WCL submitted a Preferred Project Report (PPR) to modify the application for the Underground Expansion Project (UEP). Submissions on the PPR were made by a number of regulatory authorities.

This Residual Matters Report has been prepared by Hansen Bailey Environmental Consultants (Hansen Bailey) on behalf of WCL to provide a response to the submissions from regulatory authorities.

A Noise Impact Assessment and Flood Study will be provided separately in the near future. All other issues are responded to in this Report.

1.2 BACKGROUND

A Project Application (PA 09_0013) for the UEP was made on 12 August 2009 which sought approval for longwall mining operations in the Wongawilli Seam. The Project Application proposed the extraction of 11 longwalls in the Wonga East area and 7 longwalls in the Wonga West area. The Project Application was supported by the "*NRE No.1 Colliery Project Application (09_0013) Environmental Assessment*" (ERM, 2009) (UEP EA). The UEP EA was placed on public exhibition from 18 February 2013 to 5 April 2013. A total of 840 submissions were received including 12 regulators, two special interest groups and 826 individuals (446 of which were in support of the Project and 380 were objections).

The proponent's Response to Submissions report (RTS) was included in the PPR submitted to the Department of Planning & Infrastructure (P&I) in October 2013. The PPR proposed significant changes to the mine plan to reduce environmental impacts in response to stakeholder comments.

The PPR proposed the following changes to the mine plan for the UEP:

- Removal of the Wonga West area from the proposed mine plan;
- Removal of LW8 in the Wonga East area; and
- Amendments to the alignments and dimensions of the other longwalls in the Wonga East area.

The mine plan that is currently proposed comprises eight longwall panels (LW1-3, LW6-7 and LW9-11).

The UEP PPR was provided by P&I to various regulators for comment. Submissions were received from 10 regulators and three independent peer reviewers engaged by P&I. This Residual Matters Report responds to these submissions. **Table 1** indicates the regulators and reviewers to which the RTS was provided, the date each responded and whether a response from the proponent is required.

Since the submission of the PPR and RTS, Gujarat NRE Coking Coal Limited has changed its name to Wollongong Coal Limited and the name of the mine has been changed from NRE No.1 Colliery to Russell Vale Colliery. P&I has also changed its name to the Department of Planning & Environment (DP&E).

Table 1
RTS List of Regulator Responses

Ref	Regulator	Date of Response	Response Required
1.	P&I – Peer Review Coffey	26 November 2013	Yes
2.	P&I – Peer Review Hebblewhite	17 November 2013	Yes
3.	P&I – Peer Review Evans & Peck	28 January 2014	Yes
4.	NSW Office of Water (NOW)	30 October 2013	Yes
5.	Wollongong City Council (WCC)	13 November 2013	Yes
6.	Department of Trade & Investment Resources & Energy (DRE)	26 November 2013	Yes
7.	Dams Safety Committee (DSC)	25 October 2013	Yes
8.	Environment Protection Authority (EPA)	25 October 2013	No outstanding issues
9.	Heritage Council of NSW (Heritage)	22 October 2013	Yes
10.	Office of Environment & Heritage (OEH)	15 November 2013	Yes
11.	Roads & Maritime Services (RMS)	22 October 2013	Yes
12.	Sydney Catchment Authority (SCA)	6 November 2013	Yes
13.	NSW Fisheries	29 October 2013	No outstanding issues

The PPR included impact assessments for subsidence (SCT, 2013), biodiversity (Biosis, 2013a) and heritage (Biosis, 2013b). These assessments have been revised in response to the regulatory submissions on the PPR. In addition, new studies have been undertaken to assess the impacts of the Preferred Project on groundwater, surface water and traffic. The purpose of each specialists' impact assessment is summarised in **Table 2**.

Table 2
Specialists' Impact Assessments

Appendix	Study	Purpose
B	Subsidence Assessment	Revised version of the subsidence assessment (SCT, 2013) included in the PPR. This document supersedes the earlier assessment.
C	Groundwater Assessment*	New assessment. This fully assesses the groundwater impacts of the Preferred Project.
E	Surface Water and Groundwater Addendum	Addresses the miscellaneous issues raised in submissions that are not addressed in Appendices C or F.
F	Surface Water Modelling*	New assessment. This assesses the potential impacts on surface water resources resulting from cracking induced by the Preferred Project.
G	Biodiversity Assessment	Revised version of the biodiversity assessment (Biosis, 2013a) included in the PPR. This document supersedes the earlier assessment.
H	Heritage Assessment	Responses to the submissions on the Heritage Assessment (Biosis, 2013b) included in the PPR.
I	Traffic & Transport Impact Assessment*	New assessment. This fully assesses the traffic impacts of the Preferred Project.
K	Geological Report	Revised version of the Geological Report included in the PPR (Gujarat NRE Coking Coal, 2013). This report was revised to include geological investigations undertaken since the PPR. This report supersedes the 2013 report.

** Assessments for these disciplines were included in the UEP EA. These are the only studies undertaken for the Preferred Project with respect to these disciplines.*

1.3 REPORT STRUCTURE

The majority of responses to regulatory issues are provided in individual reports from technical specialists in **Appendix B** to **Appendix L**. Miscellaneous issues are discussed in **Section 2**.

A Noise Impact Assessment and Flood Impact Assessment will be forwarded separately in the near future. All other issues are addressed in this Report. To assist the reader, the table in **Appendix A** lists each issue raised by each regulator (or peer reviewer) and indicates where it is addressed in this Report.

2 ENVIRONMENTAL AND SOCIO-ECONOMIC ISSUES

This section provides residual regulatory issues in italics; with WCL's response in normal type. The regulatory submissions are included in tabular format in ***Appendix A****.*

2.1 DEPARTMENT OF PLANNING AND INFRASTRUCTURE

2.1.1 Issue – Mine Plan Figure

P&I noted that no scale is shown on the mine plan figure of the UEP PPR and also that it is not geo-referenced. P&I requires confirmation of the positioning of Cataract Creek with respect to LW7 of the PPR mine plan.

Figure 1 illustrates the mine plan for the UEP (to scale and with geo-referencing) to show the location of LW7 relative to Cataract Creek.

2.1.2 Issue – Environmental Monitoring Program

P&I make a number of recommendations regarding the site monitoring program, specifically in relation to the integrated surface water, groundwater and ecological monitoring programs.

WCL will comply with any conditions of Project Approval in this regard and is currently re-designing an Environmental Monitoring Program (EMP) to integrate surface water, groundwater and ecological monitoring programs to ensure an ongoing comprehensive assessment of the ecosystem function of the potentially affected upland swamps.

This EMP will include monitoring of:

- Subsidence impacts on creeks;
- Height of depressurisation;
- Water quality and quantity;
- An expansion of the existing network of shallow swamp piezometers, and regular review to assess any abnormal behaviour that cannot be attributed to evapotranspiration or drainage to a watercourse;
- Data from the establishment of a meteorological station within the Wonga East area to measure rainfall and potential evapotranspiration;
- Piezometers to be established at the upslope end and downslope end of a minimum of two swamps in order to understand the down-slope movement of shallow groundwater;
- Two additional flow monitoring points to swamps in which pairs of piezometers (upslope and downslope) are to be installed;
- The water balance of each monitored swamp on a monthly basis using recorded rainfall, estimated evapotranspiration and recorded water levels and outflow measurement; and
- Characterisation of soils within the swamps to determine:
    - o Porosity - in order to provide a basis for relating piezometer water levels to rainfall and evapotranspiration; and

- o Presence (or absence) of clay materials at the interface with the underlying sandstone which could mitigate water loss from the swamp to the underlying sandstone in the event that subsidence induced cracking of the sandstone occurs under a swamp.

2.1.3 Issue – Impacts on Bellambi Gully

P&I noted that discharges of stormwater and treated mine water into Bellambi Gully have resulted in impacts on the flow regime and water quality of the stream.

WCL currently holds an Environmental Protection Licence (EPL) for its operations at Russell Vale Colliery. Discharges of treated stormwater and mine water will continue to be undertaken in accordance with EPL 12040.

2.1.4 Issue – Flood Management

P&I suggested that additional flood controls are required to prevent flooding of the Russell Vale Site, as occurred in August 1998.

A Flood Study is being undertaken for the Bellambi Creek catchment to understand existing flood conditions and to determine the necessary flood mitigation measures. This Flood Study will be provided in the near future.

2.1.5 Other issues

Issues raised by P&I relating to subsidence, groundwater, surface water and ecology are addressed in **Appendix B**, **Appendix C**, **Appendix E**, **Appendix F** and **Appendix G**.

A Subsidence Assessment (SCT, 2013) for the Preferred Project was submitted as part of the PPR in October 2013. This Subsidence Assessment has been updated in light of the following developments since October 2013:

- Completion of mining for Longwall 5;
- Additional subsidence monitoring, particularly valley closure measurements;
- Identification of a sandstone formation; and
- Completion of a peer review of this assessment.

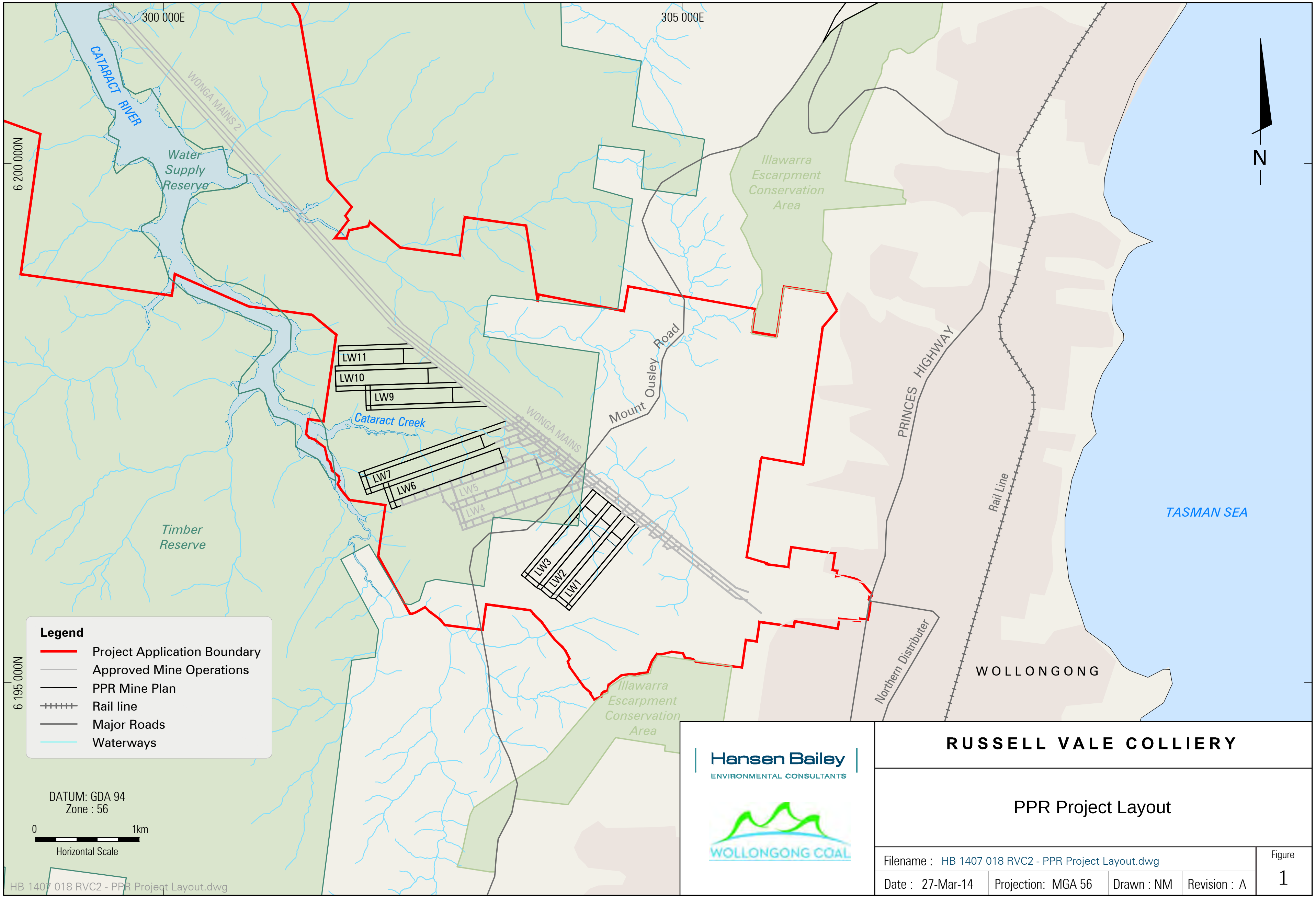
The updated Subsidence Assessment is provided in **Appendix B**. Responses to the submissions on the PPR are addressed in Appendix 2 of **Appendix B**.

Numerical groundwater modelling has been undertaken to determine the impacts of the Preferred Project on groundwater systems, streams and Cataract Reservoir. This assessment is provided in full in **Appendix C**.

A peer review of the groundwater assessment was conducted by Associate Professor Noel Merrick of HydroSimulations (refer to **Appendix D**).

2.2 NSW OFFICE OF WATER

Issues raised by NOW in response to the PPR generally relate to subsidence, groundwater, surface water and upland swamps. These issues are addressed in **Appendix B**, **Appendix C, Appendix E**, **Appendix F** and **Appendix G**.


300 000E
305 000E
6 200 000N
6 195 000N
CATARACT RIVER
WONGA MAINS 2
Water Supply Reserve
Illawarra Escarpment Conservation Area
Mount Ousley Road
PRINCES HIGHWAY
Rail Line
TASMAN SEA
LW11
LW10
LW9
Cataract Creek
WONGA MAINS
LW7
LW6
LW5
LW4
LW3
LW2
LW1
Timber Reserve
Northern Distributer
WOLLONGONG
Illawarra Escarpment Conservation Area
N
Legend
Project Application Boundary
Approved Mine Operations
PPR Mine Plan
Rail line
Major Roads
Waterways
DATUM: GDA 94
Zone : 56
0
1km
Horizontal Scale
HB 1407 018 RVC2 - PPR Project Layout.dwg
Hansen Bailey
ENVIRONMENTAL CONSULTANTS
WOLLONGONG COAL
RUSSELL VALE COLLIERY
PPR Project Layout
Filename : HB 1407 018 RVC2 - PPR Project Layout.dwg
Date : 27-Mar-14
Projection: MGA 56
Drawn : NM
Revision : A
Figure
1

2.3 WOLLONGONG CITY COUNCIL

2.3.1 Issue - Noise Barriers

WCC cites the EA noise impact assessment (ERM, 2012) and notes that the noise modelling incorporated the following noise attenuation / mitigation measures:

(i) "A 3 metre high acoustic barrier to the south of Broker Street;
(ii) A 3.6 metre high roadside type barrier to the north of the internal access road from the weighbridge to the Princes Highway; and
(iii) Noise mitigation of certain equipment such as mine ventilation fans and dozers."

WCC's concern relates to the need to construct the barriers to protect surrounding residential areas from noise emanating from the mine's pit top operations.

Further, WCC also notes that the recent noise audit report (i.e. referred to in the Preferred Project Report) does not properly consider how certain weather conditions (i.e. wind speed and direction, cloud cover, etc.) influence noise emanating from the pit top activities.

WCC also notes that the PPR fails to provide conclusive advice as to what noise mitigation measures will be introduced in order to address potential noise impacts from the Pit Top area activities, especially truck loading activities and dozers working upon the stockpile areas. Noise impacts along Bellambi Lane also remain unresolved. The construction of the new screening and sizing station should be a condition of consent if the application is ultimately approved.

It is noted that the EPA submission to the UEP PPR dated 25 October 2013 did not list any issues relating to noise.

The Director-General's Environmental Assessment Report for the Preliminary Works Project (P&I, 2011) identifies that the predicted noise levels at Receivers 1-4 (R1 – R4) will increase by a maximum of 3 dB as a result of the removal of the acoustic barriers included in the noise model. As these receivers are predicted to receive exceedances of the Project Specific Noise Criteria (PSNC) both with and without the barriers, P&I considers that the barriers are "*of limited beneficial effect*" and that the "*proposed barriers would be visually intrusive*".

As such P&I (2011) states that WCL should "*first implement all reasonable and feasible source controls (through the proposed replacement of various surface facilities and any other appropriate measures) and then conduct a comprehensive noise audit, to ensure that any additional migratory measures are well designed and placed in order to achieve maximum community benefit.*"

Pacific Environment (2012) conducted a noise audit, as recommended by P&I, and noted that:

> "*A statistical analysis of the data taken from the Bureau of Meteorology Wollongong weather station (Station Number 068241) provided in NRE No.1 Colliery Preliminary Works assessment, indicate that winds blowing from the site to receivers are not a feature of the area (i.e. >= 3 m/s winds occurring more than 30% of the time).*
>
> *In addition, the assessment found that the frequency of occurrence of F and G atmospheric stability categories is less than 30% of the winter evening and night periods. Therefore, in accordance with the INP, wind effects and temperature inversions have not been considered in this analysis. An average temperature of 20 degrees Celsius and a relative humidity of 70% were implemented in the model.*"

However, a revised Noise Impact Assessment is currently being undertaken for the Preferred Project. The results of this modelling will be provided separately in the near future.

2.3.2 Issue – Air Quality

WCC requires that appropriate conditions of consent should also be required which satisfactorily address the air quality (PM10 particulate and total suspended particulate) issues.

Based on the outcomes of consultation with regulators and P&I during the development of conditions, WCL will comply with the conditions of Project Approval that relate to air quality.

2.3.3 Issue – Employee's Carpark

WCC requests that appropriate conditions of consent be imposed requiring the sealing and line marking of the employee's carpark.

WCL does not believe that this action will make any significant contribution to improving water quality on site. However, based on the outcomes of consultation with regulators and P&I during the development of conditions, WCL will comply with any conditions of Project Approval in this regard.

2.3.4 Other Issues

Other issues raised by WCC in response to the UEP PPR generally relate to subsidence and groundwater, which are addressed in **Appendix B** and **Appendix C**.

2.4 DEPARTMENT OF TRADE & INVESTMENT, DIVISION OF RESOURCES & ENERGY

2.4.1 Issue – Rehabilitation Plan

Rehabilitation Plan

1. *The Proponent must prepare and implement a Rehabilitation Plan to the satisfaction of the Director General of Department of Trade & Investment, Regional Infrastructure and Services.*

2. Rehabilitation Plan must:

a. Be submitted and approved by the Director General of Department of Trade and Investment, Regional Infrastructure and Services prior to carrying out any surface disturbing activities of the development, unless otherwise agreed by the Minister;

b. Be prepared in accordance with DRE guidelines and in consultation with the department, Office of Environment and Heritage, Environmental Protection Authority, Office of Water, Council and the mine Community Consultative Committee;

c. Incorporate and be consistent with the rehabilitation objectives in the EIS, the statement of commitments and table 1;

d. Integrate and build on, to the maximum extent practicable, the other management plans required under this approval; and

e. Address all aspects of mine closure and rehabilitation, including post mining land use domains, rehabilitation objectives, completion criteria and rehabilitation monitoring and management.

It is the intention of DRE that the Rehabilitation Plan fulfil the requirements of the Mining Operation Plan (which will become the Rehabilitation and Environmental Management Plan (REMP) once the Mining Act amendments have commenced).

Based on the outcomes of consultation with regulators and P&I during the development of conditions, WCL will comply with any conditions of Project Approval requiring the development of a Rehabilitation Plan. The Rehabilitation Plan will be prepared in accordance with all relevant policies and guidelines and in consultation with the relevant regulators.

2.4.2 Issue – Extraction Plan

DRE requires the inclusion of the preparation of an Extraction Plan that must take into consideration likely impacts that activities may have on Old Bulli Pillar Workings within the area and on key natural features and public infrastructures; such as angled voltage transmission towers, Mount Ousley Road, the Illawarra Escarpment and Cataract Creek / Cataract Reservoir.

1. The proponent must undertake Geotechnical Investigations prior to the submission of an extraction plan.

2. The extraction plan must:

a. Give consideration to impacts of old workings and include a detailed investigation of overlying old Bulli Pillar workings in consultation with DRE, which:

- *Assess the stability of remnant coal pillars in the former Bulli Seam workings;*
- *Includes revised subsidence predictions for the second working areas*
- *Recommends final design of the second workings panels and any necessary adaptive management measures;*

b. *Includes a Built features Management Plan prepared in consultation with DRE, which:*
   - *Address in appropriate detail all items of key public infrastructure, other public infrastructure and all other built features;*
   - *Has been prepared following appropriate consultation with the owner/s of potentially affected features;*
   - *Recommends appropriate remedial measures and includes commitments to mitigate, repair, replace or compensate all predicted impacts on potentially affected built features in a timely manner;*

c. *Includes a Public Safety Management Plan, which has been prepared in consultation with DRE; and*

d. *Includes a Subsidence Monitoring Program, which has been prepared in consultation with DRE.*

Based on the outcomes of consultation with regulators and P&I during the development of conditions, WCL will comply with any conditions of Project Approval requiring the development of an Extraction Plan. The Extraction Plan will be prepared in accordance with all relevant policies and guidelines and in consultation with the relevant regulators.

2.4.3 Issue – First Workings

DRE notes that "First workings on site, other than in accordance with an approved Extraction Plan, may be carried out provided DRE is satisfied that the first workings are designed to remain long term stable and non-subsiding, except insofar as they may be impacted by an approved second working."

WCL will ensure that first workings are developed in accordance with the relevant geotechnical and engineering standards sufficient to ensure long term stability, with negligible subsidence.

2.4.4 Other Issues

Other issues raised by DRE in response to the UEP PPR relate generally to subsidence and are addressed in **Appendix B**.

2.5 DAM SAFETY COMMITTEE

The Dam Safety Committee's residual issues relate to the development of a numerical groundwater model.

The groundwater modelling undertaken for the Preferred Project is presented in **Appendix C**. The independent peer review is presented in **Appendix D**.

2.6 ENVIRONMENT PROTECTION AUTHORITY

No additional issues have been raised by the EPA and as such no response is required.

It should be noted that a revised Noise Impact Assessment will be provided in the near future.

2.7 HERITAGE COUNCIL

Issues raised by the Heritage Council in response to the UEP PPR are addressed in **Appendix H**.

2.8 NSW OFFICE OF ENVIRONMENT AND HERITAGE

2.8.1 Issue – Further Modifications to Mine Plan

"OEH does not consider that the PPR fully addresses the issues previously identified and therefore recommends the mining plan should be modified further to avoid impacts to these significant natural features."

Significant changes to the mine plan were made for the UEP PPR to minimise the impacts on significant surface features whilst still recovering a commercially viable percentage of the available coal resource. The approach is focused on balancing the predicted environmental impacts on natural and manmade surface features against the legacy of the existing underground workings and the economics of the reserve within current mining operations.

Further reductions to the mine plan would result in the loss of economic viability of the proposed operations and subsequent sterilisation of the coal resource.

2.8.2 Issue – Fish Monitoring

OEH recommends that a monitoring and management program be developed with Fisheries NSW in regard to Macquarie Perch, Trout Cod and Murray Cod in Cataract Creek.

WCL will comply with any conditions of Project Approval with respect to this issue.

2.8.3 Other issues

Issues raised by OEH relating to subsidence, groundwater, surface water, ecology and heritage impacts are addressed in **Appendix B**, **Appendix C**, **Appendix E**, **Appendix F**, **Appendix G** and **Appendix H**.

2.9 ROADS AND MARITIME SERVICE

Additional traffic modelling using the SIDRA model has been undertaken.

The Traffic & Transport Impact Assessment is included in full in **Appendix I**. The assessment was provided to Roads and Maritime Services (RMS) for consideration on 11 April 2014.

On 28 May 2014, RMS advised that the increase in traffic due to the UEP would not have a significant impact on the main road network (see **Appendix J**).

2.10 SYDNEY CATCHMENT MANAGEMENT AUTHORITY

2.10.1 Issue – Exclusion of mining from Notification Area

The SCA recommended that longwall mining should be excluded from the Notification Area for Cataract Reservoir.

2.10.2 Response

Section 89 of the *Mining Act 1992* provides that the DSC must be notified prior to the granting of a mining lease within a notification area for a prescribed dam. The ability to grant a mining lease within a notification area implies that mining is permitted in notification areas. To exclude mining within the Notification Area, as suggested by SCA, would be contrary to the Mining Act.

WCL looks forward to working closely with the SCA and other key stakeholders to ensure that underground mining within the Notification Area for the Cataract Reservoir is conducted without incident.

2.10.3 Other Issues

Issues raised by the SCA relate generally to subsidence, groundwater and surface water and are addressed in **Appendix B**, **Appendix C**, **Appendix E** and **Appendix F**.

2.11 NSW FISHERIES

No additional issues have been raised by NSW Fisheries in relation to the UEP PPR.

* * *

for
HANSEN BAILEY

Andrew Wu
Environmental Engineer

Dianne Munro
Principal

3 REFERENCES

- Biosis (2013a), *NRE No. 1 Colliery – Underground Expansion Project: Preferred Project Report – Biodiversity*
- Biosis (2013b), *NRE No. 1 Colliery – Underground Expansion Project: Preferred Project Report – Heritage*
- Department of Environment, Climate Change and Water (2009), *Waste Classification Guidelines*
- Department of Planning and Infrastructure (2011), *Major Project Assessment NRE No. 1 Colliery Preliminary Works Project (MP 10_0046)*
- ERM (2013), *NRE No.1 Colliery Project Application (09_0013) Environmental Assessment*
- Gujarat NRE Coking Coal Pty Ltd (2013), U*nderground Expansion Project Preferred Project Report including Response to Submissions*
- Pacific Environment Limited (2012), *Report – Gujarat NRE No. 1 Colliery Noise Audit*.
- SCT (2013), *Subsidence Assessment for Gujarat NRE Preferred Project Russell Vale No 1 Colliery*
- Standards Australia (1995), *Australian Standard AS4282 (INT) 1995 – Control of Obtrusive Effects of Outdoor Lighting*

Appendix A

TABLE OF REGULATORY SUBMISSIONS ON THE PPR

Table 1 – Regulatory Submissions on the PPR and where each is Addressed

Ref	Regulator	Issue	Where Addressed
1.	DP&E	**2.1 Changes to the Mine Plan** The new mine plan is presented in Figure 4 of the PPR however no scale is shown and it is not georeferenced. This mine plan was positioned with respect to the MGA by overlaying the EA and PPR mine plans of Figure 4 of the PPR onto a georeferenced drawing of the EA mine plan, and scaling it until a visual match was obtained between the two versions of the EA mine plan. The result is shown in Figure 1. This process allowed positioning of Cataract Creek (not shown in Figure 4 of the PPR) with respect to LW7 of the PPR mine plan. However, the positioning error from this process is unknown.	Figure 1
2.	DP&E	The mined thickness will vary between 2.5m and 3.0m (depending mainly on coal quality). The mined height for LW4 was previously reported as 3.1m (Geoterra, 2012a). SG (2012) reported a mined height of 3.2m for this panel.	No response required
3.	DP&E	Based on the new mine plan, the PPR states that there is an interpreted risk of significant secondary impact to swamps BCUS4 and CCUS4.	No response required
4.	DP&E	**2.2 Longwall LW7** <u>2.2.1 Surface Subsidence Monitoring at Other Panels and Implications for the Height of the Collapsed Zone</u> Subsidence measurements over existing total extraction workings in the Wongawilli East area are presented in detail in the PPR. These measurements are important as an indicator for the subsidence behaviour in a multiple seam mining environment. Subsidence monitoring of Balgownie and Wongawilli Seam panels in Wonga East indicates that incremental Balgownie panel subsidence ranged between 0.9m and 1.2m where overlying Bulli goaf (room and pillar panels with pillar extraction) was present, approaching 80% of the mined height (implying a mined height of about 1.5m for the Balgownie panels). In unusual areas (latent subsidence, goaf edge), the incremental subsidence reached 1.4m, approaching 100% of the mined height. Figure 2a (after Figure 49 of the PPR) shows these results.	Subsidence discussion provided in Appendix B
5.	DP&E	Maximum incremental subsidence at Wongawilli LW4 was 1.4m. For the mining geometry of LW4, and assuming single seam mining, surface subsidence would be expected to range between 0.1m and 0.3m, about 14% of the observed subsidence where Balgownie and Bulli goafs are present. The PPR states that cross panel subsidence profiles indicate that the maximum subsidence in the centre of the Wongawilli panels is controlled by overburden bridging capacity rather than strata recompression. The presence of overlying goafs reduces the bridging capacity of overlying strata, having a significant effect on maximum incremental subsidence for the Wongawilli panels. It was also observed that the additional subsidence was confined to the panel footprint. Figure 2b (after Figure 58 of the PPR) shows these results.	Subsidence discussion provided in Appendix B

Ref	Regulator	Issue	Where Addressed
6.	DP&E	Surface subsidence results presented in the PPR indicate that the accrued surface subsidence from multiple seam operations is more than an addition of estimated single seam subsidences. Although a relationship between surface subsidence and the height of desaturation (H) is unavailable (due to the significantly greater dependence of surface subsidence on overburden depth compared to H), the surface subsidence results would suggest that the accrued height of the collapsed zone for multiple seam operations also may be more than an addition of estimated single-seam H values (Tammetta, 2012). If this is the case, the consequence is that, where a Wongawilli panel underlies existing full extraction workings, the height of H for the Wongawilli panel will be larger than that calculated using the relationship for single seam mining (Tammetta, 2012).	Groundwater discussion provided in Appendix C
7.	DP&E	<u>2.2.2 Surface Impacts outside the Panel Footprint</u> Information relating to changes in hydraulic conductivity just off the panel footprint is particularly sparse, however several authors have estimated the extent of an impact zone from observations of dewatering in water supply wells off the panel footprint. This zone is just off-panel, and adjacent to the panel. It is where a relatively fast response is observed in hydraulic heads following caving, usually because of an immediate change in void ratio from fracturing. Long-term effects on hydraulic heads extend further, but are caused by laminar flow induced by drainage. In the off-panel impact zone, deformation is generally less than, and of a different character to, deformation within the collapsed zone.	Groundwater discussion provided in Appendix C
8.	DP&E	Ouyang and Elsworth (1993) estimated a probable angle of influence (defined as the angle whose tangent is the lateral distance to an impact at the surface, divided by the overburden thickness) of 42° from 39 off-panel wells (Figure 3). Cifelli and Rauch (1986) estimated an average angle of influence of about 20°, with several observations of impact outside this angle. The Australian Federal Government (2013) estimated a maximum angle of influence for impacts to peat swamps of approximately 45°. These impacts were characterised by deformation of the rock underneath the swamp.	Groundwater discussion provided in Appendix C
9.	DP&E	Where there may be a small lateral distance between the surface impact zone and the potential collapsed zone of the panel, there is a risk of direct connection between the fracturing of the surface impact zone and the collapsed zone, through deformed media having enhanced hydraulic conductivity in the impact zone. High-relief topography may exacerbate this connection through enhanced lateral movement. Where the top of a collapsed zone is some distance below the surface, the surface disturbance may not be strongly hydraulically linked to the collapsed zone.	Groundwater discussion provided in Appendix C

Ref	Regulator	Issue	Where Addressed
10.	DP&E	2.2.3 New Proposed Position of LW7 The new layout of LW7 is shown in detail in Figure 4. Subject to the accuracy of the positioning of the panels (the positioning of the new mine plan is approximate (see above) and the channel centreline was digitised from information in Geoterra 2012a, 2012b, and ERM, 2013, see also Coffey, 2013), it appears that the last 40m of the new LW7 position ceases to be overlain by any part of the adjacent Bulli room and pillar panel. The localised northern corner of LW7 is now positioned under a small, about 50m wide, devoid of existing full extraction workings.	No response required
11.	DP&E	While the method of Tammetta (2012) is useful for estimating H for a single seam operation, and was useful in identifying areas of concern for the EA longwall layout, it cannot be used over such a small area of observation for multiple seam mining.	Groundwater discussion provided in Appendix C
12.	DP&E	The minimum separation distance between the northern corner of LW7 and the Cataract Creek channel centreline is approximately 45m (see Figure 4). Despite the absence of existing full extraction workings over a small strip of about 50m width, there may still be a risk to the capacity of the channel of Cataract Creek to transmit surface water. There may also still be a risk of direct hydraulic connection between the creek channel and goaf, through the collapsed zone, where the channel comes to close to the panel edge. The significance of these risks cannot be quantified, but warrants consideration.	Groundwater discussion provided in Appendix C
13.	DP&E	**2.3 Numerical Simulation Strategy** In the PPR, the proponent presents a strategy for groundwater numerical simulation which largely satisfies the recommendations made in Coffey (2013). However, this strategy discusses potential or perceived limitations with the recommended probability analysis and the database available for calibration. Further clarification is provided below on these facets. The strategy also makes assumptions which are stated as being based on recommendations in Coffey (2013). The relevant recommendations in Coffey (2013) are clarified in relation to the assumptions made in the proponent's strategy. These clarifications are also provided below.	No response required
14.	DP&E	2.3.1 Probabilistic Analysis The probabilistic analysis of induced seepage from Lake Cataract does not need to be undertaken using the Monte Carlo process. This was not stipulated in Coffey (2013). It is considered that manual running of around 30 to 40 cases, with hydraulic conductivity arrays varied for each, would be sufficient to guide the assessment of uncertainty. Required output would comprise the change in baseflow to, or direct seepage from, the lake and other associated drainages (such as Cataract Creek).	Groundwater discussion provided in Appendix C

Ref	Regulator	Issue	Where Addressed
15.	DP&E	<u>2.3.2 Calibration Database</u> The EA identified a large number of data sources which were considered sufficient (subject to acquisition of near-field drawdown data) to undertake a transient calibration as requested. These are sufficient to undertake a calibration as requested, and develop a useful and robust model. These data are listed in the following sections, and are of sufficient size to allow the development of a reasonable transiently calibrated model. *Hydraulic Heads* The hydraulic head monitoring network comprises 40 measuring devices (8 standpipe piezometers and 32 vibrating wire piezometers) distributed throughout the depth profile at 11 locations. Project specific monitoring locations include a number where frequent monitoring has been undertaken since mid 2012. Hydraulic head monitoring data from the vibrating wire piezometer (VWP) nest at GW1 (see Coffey, 2013) were selected by the proponent for collection of near-field drawdown from longwall advance, for the purpose of model calibration. The monitoring data were not presented in the PPR but were supplied by Gujarat by email on 19 November 2013, at the request of the reviewer. Figure 4 shows the supplied data. The key in Figure 4 shows the depth below ground for each VWP, and the lithology at that depth (HBSS, BACS, BGSS, and SPCS denote the Hawkesbury Sandstone, Bald Hill Claystone, Bulgo Sandstone, and Stanwell Park Claystone respectively). The hydrographs for Bulgo Sandstone VWPs capture the effect of depressurisation from LW5 in late 2012. The measured drawdown is considered useful for model calibration of near-field disturbance. Monitoring locations P501 and P502 in Wonga West (monitoring locations WB17 and WB18 respectively, from Singh and Jakeman, 2001) have detailed monitoring data from 1993. These overlie historical Bulli seam longwalls LW501 and LW502 in the Wonga West area, but are still useful for calibration since they are located in the model domain and contain important information regarding vertical hydraulic head gradients. *Groundwater Fluxes* The following data were identified in Coffey (2013) for use in model calibration. • Regular flow monitoring data for Lizard Creek for the period October 2009 to August 2012 for monitoring location LC3 (WRM, 2012). Data from February 2011 onward appear well suited to a baseflow analysis. • Publicly available stream flow monitoring data for two gauges located within the area of interest (Bellambi Creek and Loddon River), simultaneously covering the period 1991 to 1995 (WRM,2012). • Flow monitoring at locations CC3 and CC4 on Cataract Creek (see Figure 11 and Table 16 of Geoterra, 2012b), reported to have been commenced using either temporary box notch weirs, or the flow velocity / cross section method, both of which provide direct flow measurements.	Groundwater discussion provided in Appendix C Water monitoring is discussed in Appendix E

Ref	Regulator	Issue	Where Addressed
		• Pool depth monitoring at four locations in Cataract Creek since 2010, and at three locations since April 2012. Pool heights are also measured at several monitoring points in Lizard and Wallandoola Creeks. Geoterra (2012b) states that pool depth measurements will be converted to flow rates once rating tables are developed for the monitoring sites. • Detailed monitoring of water extracted from the Wonga East workings (27 Cut Through) from 2010. • Water being pumped out of previous mine workings to the west of Cataract Reservoir. Should pumping rates be available, they would be most useful. *Hydraulic Conductivity* The site-specific hydraulic conductivity database accrued by the proponent comprises six short duration pump tests at six locations, and 65 packer tests at eight locations. This is considered reasonable. Coffey (2013) presented other published data for the Southern Coalfield for the purpose of providing (if needed) a basis for constraints in the hydraulic conductivity field for model calibration, and a basis for probabilistic numerical analysis of potential leakage from Lake Cataract. Large databases of pre and post-mining hydraulic conductivity over centre panel were provided to the proponent in Coffey (2013), for the purpose of being considered during model calibration. Of these, Reid (1996) contains useful data for strata impacted by mining, and for undisturbed strata, for the Southern Coalfield.	

Ref	Regulator	Issue	Where Addressed
16.	DP&E	2.3.3 Other Clarifications *Model Class* The PPR states that a Class 3 model, as defined in Barnett et al (2012), will be required. No class of model was stipulated in Coffey (2013) for the recommended simulation. This is because a strict application of the criteria in Barnett et al (2012) (for example, that predictive stresses should not be more than double the calibration stresses) could rule out an otherwise useful model and leave no tool available for impact prediction. Regardless of model class, any model will have some level of uncertainty which is directly dependent on (amongst other things) the calibration data base and the performance of calibration. Such a model may not meet predictive criteria in Barnett et al (2012) however this is not considered detrimental, particularly if the uncertainty is explored with a probabilistic analysis taking account of observed variations in hydraulic properties. The available calibration data base for the subject area (see above) is considered very large in relation to many other areas in the world, and is considered sufficient to support the development of a numerical model that can provide results that will be useful for decision making. Provided that calibration is conducted as requested, and the uncertainty of the model is addressed as recommended, non-compliance with some criteria in Barnett et al (2012) may be tolerable. Any non-compliances can be raised with an external reviewer, during the modelling effort, for consultation and consideration. The recommendations in Coffey (2013), combined with the available calibration data, might translate to a Class 2 / Class 3 hybrid model, according to the criteria in Barnett (2012). *General Calibration* The questioning of the model calibration in ERM (2013) was completely independent of the criteria in Barnett (2012). That calibration was undertaken for steady state conditions and is considered substandard for the purpose of the model. The modelling strategy in the PPR discusses proposed transient calibration using hydraulic heads and fluxes. Calibration to measured hydraulic conductivities is not explicitly stated but these observations would need to be incorporated into the calibration. *Clarification of Severe Deformation* Coffey (2013) indicated that laminar flow models are inappropriate for simulation of media where severe deformation has occurred. Severe deformation is defined as the case where strains are exceptionally large and laminar flow no longer occurs. The collapsed zone is a typical example. Strains are typically greater than 6mm/m and flow occurs in unsaturated conditions. The model will need to use approximations for the collapsed zone. Severe strains at the surface (the tensile cracking zone) create hydraulic conductivity fields with extremely high uncertainty ranges. Outside these zones, the laminar flow formulation is appropriate.	Groundwater discussion provided in Appendix C. A probabilistic analysis was undertaken using 30 stochastic model runs.

Ref	Regulator	Issue	Where Addressed
17.	DP&E	**2.4 Swamps** The PPR states that swamps have undergone subsidence due to previous mining, and that despite this, they are reported as thriving. The height of the collapsed zone from previous mining is calculated to not have reached the surface tensile cracking zone, therefore permanent drainage from the swamp to a goaf is unlikely to have occurred. If H intersects the ground surface, permanent drainage will occur. Where H does not reach to surface, filling of only a finite surface storage (increased void ratio from surface tensile fracturing) occurs, frequently resulting in temporary water loss.	Groundwater discussion provided in Appendix C
18.	DP&E	**3.1 LW7** By corollary, surface subsidence results presented in the PPR suggest that the accrued height of the collapsed zone for multiple seam operations may be more than an addition of estimated single-seam H values. If this is the case, the consequence is that, where a Wongawilli panel underlies existing full extraction workings, the height of H for the Wongawilli panel will be larger than that calculated using the relationship for single seam mining (Tammetta, 2012). The new layout of LW7 places its northern corner under a small localised strip, of about 50m width, devoid of existing full-extraction workings. Despite the absence of existing full extraction workings over this strip, there may still be a risk to the capacity of the channel of Cataract Creek to transmit surface water. Where the top of a collapsed zone is some distance below the surface, the surface disturbance at a channel bed may not link to the collapsed zone. Where the collapsed zone intersects ground surface, there is considered to be a risk of direct hydraulic connection between the creek channel and goaf, through the collapsed zone, for small separation distances between a channel and the panel edge. The level of risk is difficult to quantify but warrants consideration. No groundwater tools or theory are known that could provide a quantification of this risk, however the risk warrants consideration, and deferral is made on this issue to subsidence engineers.	Subsidence discussion provided in Appendix B Groundwater discussion provided in Appendix C
19.	DP&E	**3.2 Numerical Simulation Strategy** The strategy presented by the proponent for groundwater numerical simulation largely satisfies the recommendations made in Coffey (2013). However, this strategy discusses potential or perceived limitations, and several assumptions (see above), which are not necessarily real. Recommendations in Coffey (2013) are further clarified in relation to the assumptions made by the proponent, and discussion is provided to ameliorate the limitations perceived by the proponent.	No Response Required

Ref	Regulator	Issue	Where Addressed
20.	DP&E	**3.3 Recommendations** Since the potential risk to Cataract Creek revolves around H for LW7, it is recommended that the height of the collapsed zone be measured at LW4 or LW5, at a location where all three coal seams have been mined. At least one borehole should be installed for this purpose, however two would be preferable. Since this survey would benefit all parties, and the cost is not small, perhaps some of the cost can be borne by government. Should this be possible, the government should retain rights to the data.	Groundwater discussion provided in Appendix C
21.	DP&E	Appropriate monitoring of groundwater response and ground deformation should be undertaken for LW7, from LW7 startup or earlier, whereby sufficient warning is available to allow termination of LW7 before connection of the creek channel to the goaf occurs. Deferral is made to ground movement experts on the appropriate type of ground movement monitoring and instrumentation (and its location) to fulfil this purpose.	Groundwater discussion provided in Appendix C
22.	DP&E	**A. Summary Section** 1) Summary, p(i) – SCT notes correctly that the presence of the old workings in the other mined overlying (Balgownie and Bulli) Seams, whilst providing some challenges, does present an advantage in the ability to project the location of known geological structures between the seams into the proposed Wongawilli workings.	Subsidence discussion provided in Appendix B
23.	DP&E	2) Summary, p(ii) – SCT notes that previous Bulli Seam longwall experience will assist in understanding the subsidence mechanisms involved (for this geology), and the prediction of actual subsidence values. It is also noted that incremental subsidence and the approach of Holla and Barclay will be used for predicting tilts and strains; and that the ACARP Method (Waddington Kay & Associates (now MSEC)) will be used for predicting maximum closure. These approaches are considered valid and appropriate; furthermore, they now address the shortcomings in the previous Seedsman work which was lacking with respect to predictions in non-conventional subsidence effects such as valley closure due to surface topographic variations.	Subsidence discussion provided in Appendix B

Ref	Regulator	Issue	Where Addressed
24.	DP&E	3) Summary, p(ii) – It is noted that *"subsidence behaviour is essentially predictable albeit with somewhat different characteristics to subsidence over single seam mining operations".* The term "essentially predictable" is rather vague or imprecise in meaning, presumably due to the complexity of the issue under discussion. As previously noted, it is due to the effect of multiseam mining on subsidence behaviour. It is simply not possible to provide accurate, absolute subsidence predictions, based on such a limited database of current multi-seam experience. SCT identifies the reason for subsidence differences in a multi-seam environment as being due to *"overburden stiffness characteristics and therefore the bridging capacity across individual panels, but is otherwise essentially similar to the subsidence behaviour above single seam operations".* Whilst I agree with this statement to a point, it perhaps over-simplifies the issue of exactly how the assessment of the changed overburden stiffness characteristics can be carried out in order to predict multi-seam subsidence with any degree of certainty. It also makes no reference to the important issue of time-dependency, when previous goaf areas (particularly old partial or first workings panels) are remobilised.	Subsidence discussion provided in Appendix B
25.	DP&E	4) Summary, p(ii) – SCT notes that there is potential for some localised pillar instability in the overlying Bulli Seam workings in the vicinity of Longwall 1 when mining in the Wongawilli Seam takes place.	Subsidence discussion provided in Appendix B
26.	DP&E	5) Summary, pp(iii-iv) – SCT has undertaken an assessment of previous subsidence effects due to the mining of both the Bulli and Balgownie Seams. The Bulli Seam subsidence is estimated (see later in body of report for explanation of basis for estimation technique); this has then been combined with measured data from longwall mining in the Balgownie Seam. An interesting (and considered reasonable) statement is that in the multi-seam environment *"the goaf edge subsidence profile is expected to be softer than elsewhere".*	No response required

Ref	Regulator	Issue	Where Addressed
27.	DP&E	6) Summary, p(iv) – It is noted that the PPR includes an adaptive management strategy *"based on closure monitoring and cessation of mining if there is a likelihood of significant perceptible impacts becoming apparent".* This is discussed in relation to Cataract Creek in particular, and the possible impacts of valley closure effects. Whilst this principle of adaptive management is considered reasonable, it is reliant on several factors which have not as yet been clearly defined, but which are essential to the success of such a strategy. These were identified in my initial report and include: a. What amount of lead time will be available in the relevant monitoring data locations, to provide meaningful data on which decisions can be made prior to the impacts occurring at Cataract Creek? b. What certainty will there be, that the observed surface subsidence effects and related impacts will cease immediately if mining is ceased in the area? c. What is the proposed management structure whereby such decisions will be made – both with regard to the interpretation of the monitoring data; and also with respect to deciding to stop the longwall, and how quickly can such a process take place?	Subsidence discussion provided in Appendix B
28.	DP&E	7) Summary, p(iv) – SCT makes a significant comment and recommendations, with respect to the potential impact of mining on the identified 33 upland swamps identified by Biosis. Firstly, it is stated that mining is not expected to cause significantly different impacts to those already experienced due to earlier mining – however, such previous experience has not been well documented, to date (this is partly due to the simple lack of previous data available). It is therefore difficult to agree with, or endorse this statement, in the absence of any supporting data. Consistent with a lack of real quality data on swamp impacts, SCT then rightly argues for *"more work is required to determine the relationship between mining subsidence and the long term health of swamps".* It is stated that there is a rare opportunity within this lease area where base data, or at least experience exists over many decades, to undertake a more thorough review. SCT further recommends the formation of an ongoing monitoring and review strategy with respect to subsidence impacts on swamps and their subsequent recovery over time.	Subsidence discussion provided in Appendix B
29.	DP&E	8) Such a view is strongly supported, and is in line with some of the recommendations from the Southern Coalfield Review Panel Report (2008). The issue then becomes, how is such a review and further investigation possible without mining progressing in the vicinity of such swamps in order to generate further data? It is proposed that an incremental approach be adopted, with the first stage being a summary of historical impacts and evidence of recovery; followed by more precise monitoring of subsequent impacts as mining proceeds – preferably in relation to less significant swamps in the first instance.	Subsidence discussion provided in Appendix B

Ref	Regulator	Issue	Where Addressed
30.	DP&E	9) Summary, pp(iv-vi) – Further summary impacts are discussed, with conclusions that impacts on sandstone cliff formations, aboriginal sites, Mount Ousley Road, Cataract Reservoir, and the Illawarra Escarpment are likely to be minimal to negligible. This view is supported. In relation to electricity transmission towers, it is noted that some protection and remedial actions will be required. In regard to the use of a barrier between mining and the Full Supply Level (FSL) of Cataract Reservoir, a horizontal protection barrier of at least 0.7 times depth has been applied around the FSL which seems reasonable. However SCT then notes on p(vi) that *"the presence of these goafs reduces the effectiveness of the 0.7 times depth barrier".* This is referring to goafs from old workings. If this reduction in effectiveness is real, as stated here by SCT, then surely this requires further justification of the adequacy of the 0.7 barrier, or else a modification to the barrier width or control measure for the FSL? Such an explanation is lacking, but should be provided.	Subsidence discussion provided in Appendix B
31.	DP&E	10) Summary, p(vii) – Discussion of the other submissions includes comments in relation to the subsidence prediction technique(s). It is noted and agreed that prediction techniques are being continually improved, based on available data, to enable better understanding of the subsidence processes involved. The following sentence is then included in this discussion: *"Although there is somewhat greater uncertainty for subsidence predictions in a multi-seam environment, the available data indicates that the behaviour observed is repeatable and consistent with the mechanics of the processes involved".* This statement does not yet appear to be supported by a substantial body of factual data. On the evidence presented to date, there is still a reliance on hypotheses and estimates, to provide a complete understanding of the multi-seam behaviour. It is, to put it simply, early days in relation to this topic, with very little comprehensive quality data available, and I therefore find it difficult to support such a bold statement at this time.	Subsidence discussion provided in Appendix B
32.	DP&E	11) Summary, p(vii) – It is noted that the presence of the old workings in other seams provides valuable data with respect to geological structures, and there are only two major structures in the area, which have been accounted for in the PPR mine design.	Subsidence discussion provided in Appendix B Geology discussed in Appendix K

Ref	Regulator	Issue	Where Addressed
33.	DP&E	12) Summary, p(vii) – SCT concedes correctly that the prediction of valley closure, upsidence and far-field movements are only approximate, since these techniques are still under development. However, to their credit, SCT has made such predictions (which were absent in the earlier prediction reports), using the best available techniques and sources of data. Reference is again made, with respect to valley closure in the vicinity of Cataract Creek, to *"NRE's commitment to stop the longwalls short if closure movements become likely to cause unacceptable impacts"*. As discussed above, the ability, practicality and processes for achieving such a management control require further explanation and justification.	Subsidence discussion provided in Appendix B
34.	DP&E	**C. Section 2. Site Description** 1) Section 2, p4 – This includes a useful summary of the subsidence constraints used in the redesign of the mine plan for the PPR. These constraints all seem reasonable and appropriate, however the constraint with respect to the significant upland swamps lacks any quantitative or measurable definition, in terms of how does this translate to a design constraint. Figure 2 is a copy of Figure 2 from the SCT report, showing both original and the revised PPR mine layouts, together with the various constraints identified above.	Subsidence discussion provided in Appendix B
35.	DP&E	2) Section 2, p6 – This provides an appropriate definition of the assessment area as extending 600m horizontally from any proposed longwall panels, and up to 1.5km to allow for far-field horizontal effects on any significant features, such as the Illawarra Escarpment.	No response required
36.	DP&E	3) Section 2, p6 – It is acknowledged that the single seam subsidence seam prediction methodology used in the original assessment was not appropriate, given the measured subsidence values over the current longwalls (LW4) being well above the predictions.	Subsidence discussion provided in Appendix B
37.	DP&E	4) Section 2, Figures 6, 7 and 8 – These figures provide a useful record of the previous workings in each of the Bulli and Balgownie Seams, together with the proposed Wongawilli Seam longwall panels. The location of the major geological structures is also discussed (pp10-16), and it is noted that the major fault structure, known as the Corrimal Fault, while significant in throw towards the southern end of the lease (away from the proposed longwalls), diminishes to the northwest, to the extent that it is believed to be insignificant at the point where it will be intersected by LW6.	Structural geology is discussed in Appendix K

Ref	Regulator	Issue	Where Addressed
38.	DP&E	**D. Section 3. Previous Mining Activity** 1) Section 3, p18 – It is noted that subsidence from previous mining in the Bulli Seam has been estimated, but for the Balgownie Seam, measurements were taken at the time of mining. The recent mining of LWs 4 and 5 in the Wongawilli Seam has confirmed that observed subsidence does not match single-seam prediction behaviour, although it is claimed that the multi-seam effects are largely restricted to within the chain pillar boundaries of the currently mined panels. SCT again uses the expression "essentially predictable" when referring to multi-seam behaviour, although the basis for such a claim is yet to be substantiated.	Subsidence discussion provided in Appendix B
39.	DP&E	2) Figure 3 provides a good overlay of the proposed Wongawilli longwall panels, together with the location of the previous Balgownie Seam longwalls and the areas of old Bulli Seam bord and pillar workings. This is reproduced from Figure 11 of the SCT report.	No response required
40.	DP&E	3) Section 3, p20 – SCT explains that their estimates of Bulli Seam subsidence have been obtained on the basis of previous experience *"from mining in the Bulli Seam further to the west above the T and W (200 and 300 series) longwall panels at South Bulli and subsequent pillar extraction operations"*. Whilst it seems reasonable to develop an understanding of subsidence over Bulli Seam bord and pillar workings, the detail is not provided to allow any assessment of the validity or accuracy of this approach, and regardless, it would be very difficult to gain any high levels of confidence in what are no doubt a range of different mining panel geometries and extraction scenarios. This approach is therefore a reasonable one, but there must be a significant note of caution with respect to the confidence in the magnitude or variability of the predicted values, relative to the current areas of interest.	No response required
41.	DP&E	4) Section 3, p20 notes that an extensive underground inspection was undertaken on 21 June 2013 which has identified an area of pillar workings in the Bulli Seam above/adjacent to the proposed Wongawilli panels which are likely to be destabilised as a result of Wongawilli undermining. (This is backed up by evidence of pillar destabilisation caused by the previous Balgownie longwalls, in a similar area of Bulli Seam pillar workings). It is noted that such effects are likely to be localised, and confined close to the new goaf edge, but need to be taken into consideration. This has already been discussed under section A(4), and relates to an area near Longwall 1 (further discussed on SCT Report p23).	Subsidence discussion provided in Appendix B
42.	DP&E	5) Section 3, p23 – Discussion of measured Balgownie Seam longwall-related subsidence confirms that there is evidence from the data that there was additional subsidence at the time due to associated, remobilised pillar instability.	Subsidence discussion provided in Appendix B

Ref	Regulator	Issue	Where Addressed
43.	DP&E	6) Section 3, p23 – Further discussion addresses the question of pillar run potential. SCT states that such a scenario is certainly possible, in the context of localised pillar regions, as discussed above, but is unlikely to extend over any large distances, based on a combination of assessment of the old mine plans, and underground inspection. This opinion and conclusion is considered reasonable. SCT then extends the definition of "pillar run" to include the impact of additional abutment stresses on pillar regions causing, not instability, but simply an additional increment of elastic compression of the pillars, hence an additional increment (albeit small) of surface subsidence, without pillar failure. This is certainly not only feasible, but a certain outcome, where regional load transfers and abutment stresses change the loading regime on standing pillars. However, it is not considered appropriate to include this under the heading of a "pillar run" which historically has been a term used to describe large scale, dynamic pillar instability and failure. The issue of incremental elastic compression does not fall under this description and it is strongly recommended that such terminology should not be used for such behaviour.	Subsidence discussion provided in Appendix B
44.	DP&E	7) Section 3, p24 and following – Section 3.2 discusses the Balgownie Seam subsidence effects. Firstly, it is noted that in areas where there was overlying Bulli Seam goaf, the measured goaf edge region subsidence extends further, but only to the extent of being a secondary effect. It is also noted (pp26-27) that where the Bulli Seam goaf areas were narrow and possibly bridging, the effect of underlying Balgownie workings is to cause a greater increment of additional subsidence, such that the resultant surface subsidence extends up to 100% (1.4m) of the Balgownie Seam mining height, i.e. the Balgownie goaf formation has reactivated the goaf above the Bulli Seam and caused this additional subsidence, over and above what would have been expected from single-seam Balgownie subsidence prediction.	Subsidence discussion provided in Appendix B
45.	DP&E	8) Section 3.2 also discusses both horizontal strains and tilts, and then valley closure effects associated with Balgownie subsidence (p29). The ACARP method of predicting valley closure and upsidence is applied to these sites and compared to measured data in regions around Cataract Creek where previous Bulli Seam mining had taken place. It is found that this method provided good correlation between measured and predicted data and so is considered applicable for assessing upper bound valley closure and upsidence effects in multi-seam applications. This is a reasonable conclusion going forward, in the face of no other current methodology being available. However it is a conclusion based on a very small dataset, and should be applied with great caution, and a lower level of confidence than when working in single-seam situations.	No response required

Ref	Regulator	Issue	Where Addressed
46.	DP&E	9) Section 3, p32-35 – It is unfortunate that having discussed the Balgownie Seam subsidence data with respect to subsidence effects and impacts, strains, tilts, valley closure, surface cracking, rock falls, Cataract Creek etc, there is no discussion about the subsidence effects in the vicinity of upland swamps that were impacted by the Balgownie longwalls (such as are indicated to exist in Figure 2 in the middle of proposed Wongawilli LW6, which in reference to Figure 3, lies directly above some of the Balgownie longwall panels). It would be extremely valuable to know how much subsidence and strains, tilts etc occurred in the vicinity of those (and any other) swamps, and then to assess what was the immediate impact on the swamps, if that was recorded at the time, and what is the current state of recovery in such swamps to any adverse impacts that occurred. Such a correlation between quantitative subsidence data and resultant impacts is the major missing element in this project assessment. If, as SCT states, such data was collected, it is essential that it be reported in the above manner to provide a valuable benchmark dataset and case study (c/f paragraph A(7) above). (Note: There is some discussion on this point later in the SCT report, and some data is included in Appendix 1 of the report, but there is no discussion of it here in the context raised above).	Subsidence discussion provided in Appendix B
47.	DP&E	**E. Section 4. Subsidence Prediction Methodology** 1) Section 4 provides a comprehensive discussion of the methodology adopted for subsidence prediction, based on the available empirical data and understanding of subsidence mechanics behaviour. It is largely based on the experience, to date, from monitoring subsidence above Wongawilli LWs 4 and 5, where previous overlying workings exist in both the Bulli and Balgownie Seams. It is a valuable contribution to understanding the multi-seam subsidence behaviour, and is a sound, and best available source of information on which to base the future prediction methodologies for this project. However, it is important to recognise that it is still a relatively small database, and so predictions must be made with caution, whilst the database is continually expanded, and regularly re-evaluated. A critical part of the management strategy for this project moving forward must be to conduct continual high level comprehensive monitoring; regular data analysis; and regular re-evaluation of the subsidence behavioural models and hence predictions based on such models.	No response required

Ref	Regulator	Issue	Where Addressed
48.	DP&E	2) Section 4, p37 – SCT draws the appropriate conclusion that in the multi-seam environment, the effect of the overlying goaf areas is to reduce the shear stiffness and rigidity of the overburden strata. Some subsidence data is provided to support this hypothesis. On p43, the logical conclusion from this effect is stated to be *"the reduced shear stiffness leads to reduced bridging capacity of the overburden strata and significantly increased maximum subsidence for the same overburden depth and longwall panel geometry".* This is a particularly important and valid conclusion, and is significant in terms of providing forward predictions of subsidence behaviour. The challenge remains as to how to quantify the magnitude of such increases, and define the conditions under which they occur. SCT does proceed to do this in the best manner available, but the caution remains that (a) it is based on a very limited dataset, and (b) the full knowledge of the nature of the overlying workings and subsequent subsidence is based on estimates only (at least in the case of the Bulli Seam). Therefore the subsequent predictions made (see Section 5) are appropriate, but must be applied with caution.	No response required
49.	DP&E	3) Section 4, p44 – The point that has already been made about the additional subsidence due to these effects being largely confined to within the current panel geometries is an important and positive one. However, the only scenario where this may not be the case is where overlying standing pillars are destabilised, in which case the additional subsidence effects due to such pillar failures may extend to the extent of the overlying pillar regions. This point is made on p45 with respect to the region of Bulli Seam pillars in proximity to Wongawilli LW1. SCT makes some specific recommendations with respect to the length of LW1 and the need to carefully manage this situation. This opinion is strongly endorsed.	No response required
50.	DP&E	4) Section 4, p46 and following – The remainder of this section discusses specific subsidence parameters, effects and impacts – all of which are accepted as stated, based on the previous qualifications discussed above with regard to the prediction methodologies.	No response required
51.	DP&E	5) Section 4, p48 and following – SCT confirms the adoption of a purely empirically-based subsidence prediction methodology, for all of the reasons already discussed. The more traditional analytical methods using Influence or Profile Function methods, or the single seam empirical Incremental Profile methods are not considered appropriate to this type of multi-seam subsidence behaviour. This conclusion is accepted as reasonable under the circumstances of this project, albeit that the methodology adopted is in a very preliminary or prototype stage, as discussed previously.	No response required
52.	DP&E	6) Section 4, p50 – In discussing strains and tilts, it is worth emphasising the point made by SCT that it is simply not possible to predict exact locations of maximum or peak strains, and hence potential crack locations, for example. Regions where such strains might occur can be identified, but it is never going to be possible to predict in advance the actual location of actual cracks in the rock mass.	No response required

Ref	Regulator	Issue	Where Addressed
53.	DP&E	7) Section 4, pp50-52 – SCT discusses accuracy and sensitivity assessment for their prediction methodologies. This leads to the statement discussed earlier, that *"subsidence associated with multi-seam subsidence in this area is essentially similar to the subsidence behaviour in a single seam".* Once again, although it is only semantics, it is hard to see what is essentially similar about the behaviour predicted. SCT has just discussed significant changes in behaviour due to changes in the overburden characteristics, rendering traditional prediction relationships invalid. This statement is therefore not considered an appropriate description of a quite different world of multi-seam subsidence behaviour, the understanding of which is still relatively embryonic. SCT's own excellent approach to understanding this is still only based on data from two current longwalls (LWs 4 and 5).	Subsidence discussion provided in Appendix B
54.	DP&E	8) Section 4, p52 – SCT makes a very important and valid conclusion, having discussed the impact of softened overburden leading to a change in bridging characteristics and potential increased subsidence. It is noted that in spite of this changed behaviour, all of the proposed panels within the PPR are of a reduced panel width such that there remains a significant subsidence-limiting control factor present due to the panel widths, such that full subsidence will not develop above these panels, compared to if they were wider, under the multi-seam environment.	No response required
55.	DP&E	**F. Section 5. Predicted Subsidence** 1) This section simply presents the factual predictions for the full range of scenarios and features present – based on all of the assumptions already discussed. These predictions are all accepted at face value, together with the various caveats already mentioned, especially with regard to confidence levels.	No response required
56.	DP&E	**G. Section 6. Subsidence Impacts** 1) Section 5, p61-62 – This section returns to the issue of upland swamps and refers to the data contained within the Appendix regarding past estimates, and future predicted subsidence effects. However it still does not address any detail with respect to either previous impacts or future likely impacts (accepting that some of these issues fall outside of the brief of SCT). The most relevant and pertinent statements made on these issues are: o *"It is unclear how sensitive swamps are to mining subsidence"* o *"the swamps located having been previously subsided to levels that expected above future longwall panels"* o *"the drop in piezometric pressure observed when some swamps are mined under may not have a significant impact on their long term condition"* o *"It is considered that more work is required to determine the relationship between mining subsidence and the long term health of swamps"* Clearly there is a need for a more quantity relationships between the swamps and the impact factors – both immediately, based on the known and estimated subsidence data reported here; and also through further work in the future.	Subsidence discussion provided in Appendix B Impacts on swamps are discussed in Appendix G

Ref	Regulator	Issue	Where Addressed
57.	DP&E	**H. Section 7. Management Strategies** 1) The recommended strategies discussed here are all considered of value and worth pursuing. These include the adoption of a higher standard of survey monitoring, including the use of three dimensional GPS arrays, in support of conventional survey data, and also high precision point to point measurement of valley closure.	No response required
58.	DP&E	2) The concept of an adaptive management strategy discussed earlier is not specifically referenced in this section, but is an essential process that brings together the data from various sources of monitoring data and analysis, in order to inform operational mine management and planning decisions. It is critical that an appropriate management system is established to handle this in an effective manner, as previously discussed under paragraph A (6) and elsewhere. This system needs to be developed well in advance, and clearly enunciated including answers to the questions posed in A (6).	Subsidence discussion provided in Appendix B
59.	DP&E	**I. Section 8. Response to Submissions** 1) The issues raised in this section are all ones that have been discussed in earlier sections of the report, and as such, do not warrant further review or comment.	No response required

Ref	Regulator	Issue	Where Addressed
60.	DP&E	• There is only very limited data available with respect to prediction of cracking above multiple mined coal seams, leading to a calculation of height of desaturation, or depressurisation (H), as discussed by Tammetta. • Mr Tammetta has done considerable work on this issue and has collated valuable data to enable prediction of this parameter, H, though primarily from single seam sources. • In the case of multiple mined (extracted) seams, the initial approach for calculation of H is to use an accumulated seam thickness from the multiple seam thicknesses. • It is agreed by all parties that if the height of desaturation intersects the surface, then there is a real risk of water loss from any intersecting surface water flows. • It is understood that Mr Tammetta's original reported results which suggested an intersection with the surface were based on using the sum of all three mined or proposed to be mined seams, i.e. Balgownie, Bulli and Wongawilli. However, further analysis by Dr Mills suggests that in the area in question above Wongawilli LW7, the Bulli Seam workings only consisted of development roadways, not extraction. As such, it is considered inappropriate to include the thickness of the Bulli Seam workings in the calculation for H. Without the Bulli Seam thickness, the calculated value of H using Tammetta's equations, does not intersect the surface. Therefore based on the above interpretation, the risk of inter-connective cracking is considered low in the vicinity of LW7 (or any other part of the proposed workings). • It is agreed by all parties, however, that whilst the Tammetta approach and the database from which it has been developed is the best available, it still lacks sufficient data and understanding with respect to the effects of multi-seam workings on the height of desaturation, and hence cracking propagation and continuity; and should therefore be backed up by further investigation in a multi-seam environment.	Addressed in previous items.
61.	DP&E	• All three parties to these discussions agree that it would be prudent with respect to the Gujarat planning; as well as invaluable for future industry understanding; for some instrumented boreholes to be installed to measure the appropriate hydrological data in a multi-seam environment. It is agreed that an instrumented borehole over the current Longwall 4 workings where all three seams have been mined would be extremely beneficial. A further similar borehole ahead of the proposed longwall 7 workings would also provide invaluable data on this subject. It is therefore recommended that both such holes be requested as part of the planning and approval process. Furthermore, the data and interpreted results from such boreholes should be reported to the Department and to the wider mining and technical community.	No response required

Ref	Regulator	Issue	Where Addressed
62.	DP&E	**2 Impacts of Mining** **2.1 Subsidence Predictions** The *PPR*, in particular the *Subsidence Assessment* (Annexure B), provides an assessment of the estimated subsidence that occurred as a result of previous mining in the Bulli and Balgownie Seams and the predicted additional subsidence as a result of mining the Wongawilli Seam. It is not the purpose of this review to comment on the subsidence methodology and assumptions. Accordingly, it is assumed that Annexure B provides reasonable estimates of the magnitude and location of subsidence impacts.	No response required
63.	DP&E	The Bulli Seam was mined from the late nineteenth century through to the 1950's using a variety of mining systems including mechanised pillar extraction in the later stages. The Balgownie Seam was mined as one of the first longwall mining operations in Australia from 1970 through to 1982. Consequently, any gradual changes in the vegetation within the headwater swamps as a result of increased drainage resulting from subsidence impacts have had over 30 years to become apparent.	No response required
64.	DP&E	The *PPR* and Annexures contain various figures that separately show the location of the headwater swamps and the estimated subsidence contours resulting from previous and proposed mining. However, none of the figures show all of the features of relevance together: • Location of swamps and creeks; • Land surface contours; • Estimated subsidence. In order to provide a basis to better understand the spatial relationship of these features, and the surface water context surrounding the swamps, Gujarat NRE provided maps showing these features for historic and predicted subsidence. **Figure 2.1** and **Figure 2.2** are reduced size copies of the original plans that were provide at A1 size to assist with analysis. As shown on both these figures, the modified layout has all longwalls offset by a minimum of 50 m from Cataract Creek and its third order tributaries. All other longwalls except LWs 4, 9, 10 and 11 run under at least one first or second order watercourse.	No response required
65.	DP&E	For purposes of the *EA* and *PPR* all swamps mapped have been mapped on the basis of common features of the relevant vegetation community. This has led to the swamps having highly irregular shapes that do necessarily reflect all the surface water factors that would influence the hydrologic behaviour of the swamps such as any contributing up-slope catchment area and variations in soil characteristics and depth. The likely variation in soil characteristics and depth within a single swamp (defined by the vegetation community), and the area and lateral extent of some swamps implies that each vegetation community is capable of surviving in a variety of hydrologic conditions.	Biodiversity discussion provided in Appendix G

Ref	Regulator	Issue	Where Addressed
66.	DP&E	**Table 2.1** summarises the subsidence data for swamps most likely to be affected by mining in the Wongawilli Seam (taken as maximum tensile strain > 1 mm/m). The data has largely been drawn from the table "*Incremental Subsidence for Proposed Mining in the Wongawilli Seam*" in Appendix 1 of Annexure B to the *PPR* with the exception of the following data taken from Table 15 in Annexure A to the *PPR*: • 'Maximum Subsidence within Swamp' (Column 2); • 'Overburden Depth' (Column 4); • 'Longwall Panel Width' (Column 5); and • 'Ratio of Overburden Depth to Longwall Panel Width' (Column 6).	No response required
67.	DP&E	In the process of compiling the data for **Table 2.1**, a number of differences were noted in the data drawn from the two sources. In particular: • The values of 'Adjacent Subsidence Used to Calculate Strains and Tilts' (Column 3) in Table 15 of Annexure A are inconsistent with the equivalent values quoted in Appendix 1 of Annexure B. It is assumed that this is a transcription error and that the values in Annexure B are correct. • The 'Overburden Depth' quoted in Appendix 1 of Annexure B appear to be the overburden depth above the Wongawilli Seam whereas the values in Table 15 of Annexure A represent the minimum overburden depth above the Bulli Seam. The latter values have been adopted for Table 2.1.	Subsidence discussion provided in Appendix B
68.	DP&E	Unfortunately, the data provided in the *PPR* and Annexures does not include mapping to show the location of maximum tensile stress. For subsequent assessment of the most likely location of any surface cracking (see **Section 4** below), it has been assumed that this would be most likely to occur in the region of maximum convex curvature (as inferred from the subsidence contours).	No response required

Ref	Regulator	Issue	Where Addressed
69.	DP&E	**2.2 Potential Subsidence Effects** The potential effects of subsidence on headwater swamps include: • Differential settlement leading to change in the bed level relative to any drainage outlet (if one exists), and: o Increased water storage capacity of the swamp if the subsidence occurs up-slope of any drainage outlet; o Decreased water storage capacity if the subsidence occurs at the outlet; o Change in flow pathways through the swamp due to changes in ground level (tilt) (as assessed by Biosis using 'flow accumulation modelling'). The *RTS* (**Section 3.1.3**) acknowledges that this analysis is primarily applicable to valley-fill swamps.) Notwithstanding these possible effects, because the surface slope of the headwater swamps is of the order of 10% (10 m in 100 m), subsidence of the order of a few metres is unlikely to significantly impact on the water storage characteristics or flow pathways of these swamps.	No response required
70.	DP&E	• Cracking due to tensile or compressive strains, or unconventional subsidence. The impact of any cracking will depend significantly on nature of the cracking (depth and any sub-surface shearing) and the location of any cracking with respect to the local topography: o Cracking towards the up-slope edge of the swamp has the potential to re-direct surface runoff from the contributing catchment; o Cracking within the body of the swamp or towards the down-slope boundary has the potential to drain any seasonal perched water table; o Cracking towards the sides of the swamp is unlikely to have a significant impact on any runoff contribution from up-slope or the balance of incident rainfall and evapotranspiration loss that leads to a seasonally varying perched water table.	No response required

Ref	Regulator	Issue	Where Addressed
71.	DP&E	In addition, as noted in the *Bulli Seam Operations PAC Report* (PAC, July 2010): *"Consequences of these impacts depend upon a wide variety of factors such as how much water is lost, over what period, whether "self-healing" occurs and to what degree, and whether there are severe rainfall events or fire events. Depending on these factors and their interactions, a swamp could show no evidence of change, or be severely damaged over a relatively short space of time."* It is recognised that subsidence prediction is an imprecise science, particularly in the case of multiseam mining. In his review of the subsidence assessments in the *PPR*, Hebblewhite (November 2013), noted that: *"In discussing strains and tilts, it is worth emphasising the point made by SCT that it is simply not possible to predict exact locations of maximum or peak strains, and hence potential crack locations, for example. Regions where such strains might occur can be identified, but it is never going to be possible to predict in advance the actual location of actual cracks in the rock mass."*	No response required
72.	DP&E	**2.3 Connective Cracking** The *PPR* (Section 2.2.9.3) acknowledges the additional possibility of connective cracking from surface to seam but notes that this has not been observed over longwalls LW4 or LW5 and is considered extremely unlikely. In his review of the groundwater assessment for the project, Tammetta (20/12/2013), (page 11) notes: *"The PPR states that swamps have undergone subsidence due to previous mining, and that despite this, they are reported as thriving. The height of the collapsed zone from previous mining is calculated to not have reached the surface tensile cracking zone, therefore permanent drainage from the swamp to a goaf is unlikely to have occurred. If H intersects the ground surface, permanent drainage will occur. Where H does not reach to surface, filling of only a finite surface storage (increased void ratio from surface tensile fracturing) occurs, frequently resulting in temporary water loss.*	Subsidence discussion provided in Appendix B
73.	DP&E	Notwithstanding the possibility of connective cracking raised by Tammetta, Hebblewhite 18/12/2013) reports on joint discussions with Tammetta and Dr Mills (of SCT): *"It is understood that Mr Tammetta's original reported results which suggested an intersection with the surface were based on using the sum of all three mined or proposed to be mined seams, i.e. Balgownie, Bulli and Wongawilli. However, further analysis by Dr Mills suggests that in the area in question above Wongawilli LW7, the Bulli Seam workings only consisted of development roadways, not extraction. As such, it is considered inappropriate to include the thickness of the Bulli Seam workings in the calculation for H. Without the Bulli Seam thickness, the calculated value of H using Tammetta's equations, does not intersect the surface. Therefore based on the above interpretation, the risk of inter-connective cracking is considered low in the vicinity of LW7 (or any other part of the proposed workings)."*	No response required

Ref	Regulator	Issue	Where Addressed
74.	DP&E	Connective cracking between the surface and the mine workings would provide a pathway for water to drain from a creek or swamp. In both cases, it is possible that some reduction in water loss might occur over time as fine sediments gradually fill the surface cracks. However the occurrence and effectiveness of any sealing will be highly dependent on the size of the cracks in the sandstone and the availability of suitable sized soil particles to create a full or partial seal. While the possibility of such self-sealing has been contemplated by others (e.g. the *Bulli Seam Operations PAC Report*, quoted above), there does not appear to be any quantitative evidence of the effectiveness of this mechanism.	Groundwater discussion provided in Appendix C
75.	DP&E	**Hydrology of Headwater Swamps** **3.1 Upland Swamps** Upland swamps are found on sandstone plateaux areas with rainfall in excess of about 1,200 mm. Any consideration of potential impacts of subsidence on upland swamps needs to clearly distinguish between: • **Valley fill swamps** located either side of drainage lines. These swamps have relatively shallow down slope gradient dictated by the gradient of the drainage line and contain areas of open water. No valley fill swamps are located in the vicinity of the proposed Wonga East mining operations. Because of their topographic location, valley fill swamps are likely to receive some groundwater baseflow. • **Headwater swamps** located on the hillside with typical gradient of the order of 10% in the Wonga East area. Some, but not all, of these swamps drain via first order streams. Because of their topographic position, headwater swamps are reliant on direct rainfall and any contribution of surface runoff from the up-slope contributing catchment. Headwater swamps exhibit seasonally varying perched water tables that are independent of the regional water table in the underlying Hawkesbury Sandstone. All swamps in the vicinity of the proposed Wonga East mining operations are headwater swamps. These swamps vary in area from 0.26 to 9.84 ha and typically extend between 100 and 430 m in the down slope direction.	No response required

Ref	Regulator	Issue	Where Addressed
76.	DP&E	**3.2 Published Assessments and Reviews** Because of the wide distribution of upland swamps on the Woronora plateaux and the potential impacts of underground mining, the hydrology of upland swamps has received considerable public scrutiny, particularly in: • *Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield: Strategic Review* (Department of Planning, July 2008); • *Bulli Seam Operations – PAC Report* (Planning Assessment Commission, July 2010). In addition, the Office of Water Science (Department of the Environment, Canberra) commissioned • *Peat Swamps – Ecological Monitoring* • *Peat Swamps – Engineering Subsidence* These two reports are not yet in the public domain. *Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield: Strategic Review* quotes various sources that indicate the dates of basal sediments vary between roughly 2,000 – 17,000 years. Fryirs et al (2012) describe the upland swamps in the Blue Mountains as *"accumulations of mineral sands and organic pert that started forming around 13,000 years BP and have accumulated throughout the Holocene to today"*.	No response required
77.	DP&E	As reported by Ross (2009), monitoring of headwater swamps in the Kangaloon area by SCA suggests the water table in the swamps is perched; the water table in the underlying sandstone is situated some 4 to 5 m below the swamp(s). This finding is consistent with the location of headwater swamps away from the main drainage lines.	No response required
78.	DP&E	**3.3 Swamps in the Wonga East Area** Annexure A to the PPR (*NRE No. 1 Colliery – Underground Expansion Project: Preferred Project Report – Biodiversity*, Biosis, 2013) provides additional detail relating to a number of piezometers installed to measure the perched water table levels in a number of the swamps located along the ridge that separates the catchments of Cataract Creek and Cataract River. **Figure 3.1** is a reproduction of the piezometer data depicted in Graph 2 of the Biosis report (raw data provided by Gujarat NRE) together with daily rainfall data for the Bureau of Meteorology site at Darkes Forest (Station No. 068024).	No response required

Ref	Regulator	Issue	Where Addressed
79.	DP&E	For purposes of the analysis provided below, the rainfall data from Darkes Forest has been adopted for **Figure 3.1** because the data from the No 4 Site (collected by Gujarat NRE) has some missing data. As indicated on the rainfall isohetal map of the area (Figure 4.4 in *NRE No 1 Colliery Surface Water Modelling*, WRM, 2012 which forms an appendix to Annex O of the EA), the average annual rainfall at Darkes Forest is comparable to that of the Wonga East project area. **Figure 3.2** shows the vertical profiles of the piezometers taken from Figure 11 of the *Groundwater Assessment* (GeoTerra 2012). The figure shows that all piezometers were constructed to a depth below the interface between the swamp material and the weathered sandstone. **Table 3.1** summarises details of the piezometers extracted from Table 3 of the *Groundwater Assessment*.	No response required
80.	DP&E	The assessment of the groundwater behaviour provided in the text by Biosis is limited to how rapidly the water levels fall following significant rainfall. No assessment has been provided of the hydrologic processes associated with the different behaviour.	Groundwater discussion provided in Appendix C
81.	DP&E	For purposes of further detailed analysis set out below, the slope of each hydrograph has been compared to the average seasonal point potential evapotranspiration rate that would occur if water supply to vegetation was not limited (derived from the point spatial data on CD for *Climate of Australia: Evapotranspiration*, BoM 2003). The analysis also assumes an effective porosity of 50% for the soils characterised in **Table 3.1**. While values that are more precise could be adopted following field analysis, the assumed value provides a reasonable basis for an indicative analysis.	No response required
82.	DP&E	The analysis indicates that the hydrographs fall into four categories: 1) Water level reduction that can be accounted for by evapotranspiration loss. This category includes piezometers PCc5A and PCc5B, both of which are located in swamp CCUS5 in which the water level was drawn down below the interface between the swamp and the underlying weathered sandstone in January 2013. This swamp was subject to an estimated 0.6 m maximum subsidence along its south-eastern edge as a result of mining of the Bulli and Balgownie Seams (see **Figure 2.1**). While the estimated subsidence occurred to the southeast of the locations of the piezometers, the hydrographs infer that water retention characteristics of CCUS5 have not been affected by subsidence.	No response required

Ref	Regulator	Issue	Where Addressed
83.	DP&E	2) Water level reduction that can be largely, but not fully, accounted for by evapotranspiration loss. This category includes piezometers PCc4 and PCr1, located in swamps CCUS4 and CRUS1 respectively. **Figure 2.1** shows the cumulative subsidence as a result of mining of the Bulli and Balgownie Seams as 0.9 m and 0.6 m respectively. The slope of the water level drawdown after rainfall cannot be fully explained by evapotranspiration. In particular: • The rapid fall in water level in PCc4 following rainfall in the middle of October 2012 which led to a rise of about 0.4 m in PCc4 followed by a return to a 'base' level (assumed to be the interface between the swamp and the underlying sandstone) within about 5 days; • Similar rapid falls in the water level following the rainfall events in February to May 2013; • In the case of PCr1, the water level shows relatively muted response to rainfall in the period up to the end of July 2012. The hydrograph shows no response to the rainfall events in mid-September and mid-October 2012, suggesting that the water level recorder malfunctioned. • For the rainfall events between February and May 2013, the rate of the fall in the water level is significantly greater than can be accounted for any evapotranspiration. It is interesting to note that the recorded water level in PCc4 fell to a level of about 0.95 m below ground level in the period between November 2012 and late January 2013. As this level is below the quoted depth of the base of the piezometer, the accuracy of the level measurements is questionable.	Groundwater discussion provided in Appendix C
84.	DP&E	3) Water level lowering that follows a characteristic gradual slowing in the rate that suggests drainage from a swamp to a creek, which would help sustain baseflow. This behaviour is exhibited by piezometer PCc2 in swamp CCUS2. This swamp, which is located in the vicinity of proposed longwalls LW2 and LW3, was subject to estimated maximum subsidence of 1.1 m as a result of mining in the Bulli and Balgownie Seams. While the hydrograph recession suggests drainage to a creek, the mapping (**Figure 2.1**) shows the nearest identified drainage line starting about 150 m down-slope of the swamp.	Groundwater discussion provided in Appendix C

Ref	Regulator	Issue	Where Addressed
85.	DP&E	4) Rapid water level lowering following rainfall, typically falling back to a 'base' level within 5 to 10 days of rainfall, which suggests that water is being lost from the base of the swamp into the underlying sandstone. Piezometers PCc3 and PCc6 (swamps CCUS3 and CCUS6) are examples of this behaviour. Both these swamps are located over LW4 and LW5 and were subject to 1.0 m and 1.8 m maximum subsidence respectively, as a result of previous mining (see **Figure 2.1**). LW4, which runs beneath CCUS6, was extracted between 19 April and 18 September 2012. Because the site of the piezometer is about 30% of the way along the longwall, the site of piezometer itself is unlikely to have been undermined before the start of June 2012. The start of mining occurred after the rise and rapid fall of water level following rainfall in February and early March 2012 (which led to persistent elevated water levels at PCcs5A in Swamp CCUS5). The fact that rapid water level lowering occurred before the influence of subsidence from longwall LW4 infers that the rapid drawdown cannot be attributed to mining of LW4. Notwithstanding the apparent rapid drainage of these 'swamps', the vegetation communities have been classified as consistent with the vegetation communities that define an upland swamp: • CCUS3 Banksia Thicket (MU42) and Sedgeland (MU44a); • CCUS6 Banksia Thicket (MU42). It is interesting to note the fact that only one of the headwater swamps, out of six, exhibits behaviour consistent with the hypothesised significant contribution to baseflow from upland swamps in general. This suggests that the dominant contribution to baseflow may be valley-fill swamps rather than headwater swamps, not upland swamps in general as is commonly supposed.	Groundwater discussion provided in Appendix C

Ref	Regulator	Issue	Where Addressed
86.	DP&E	The Biosis report links the different behaviour of the perched groundwater systems to differences in the vegetation: *"Groundwater data from piezometers located in upland swamps within the study area indicates that there are varying degrees of contact with groundwater resources in these upland swamps. CCUS4 and CCUS5 show significant groundwater contact for prolonged periods, CCUS2 shows some contact but recedes rapidly, while CCUS3 and CCUS6 show little groundwater recharge following rainfall. This corresponds with the vegetation communities within these upland swamps, with CCUS4 and CCUS5 supporting areas of MU43 Tea-tree Thicket (both upland swamps) and MU44c Cyperoid Heath (CCUS4 only), which both rely on permanent to intermittent waterlogging. In contrast, CCUS2, CCUS3 and CCUS6 support MU42 Banksia Thicket (CCUS3 and CCUS6) or MU44a Sedgeland and MU44b Restioid Heath (CCUS2) which are less reliant on waterlogging.* *CRUS1, which supports a mix of MU42 and MU43, is an anomaly. This upland swamp has shallow soils and areas of MU43 are likely to be located in areas of terracing, resulting in water accumulation in depressions in bedrock."* The conclusions with respect to the vegetation in CCUS3 and CCUS6 suggest that the episodic perched groundwater conditions in these swamps pre-date the recent mining of longwalls LW4 and LW5. However, the rapid draw down of the water level following rainfall suggests that water is being lost through the base of these swamps, possibly as a result of cracking due to subsidence from previous mining activities. Given that the previous mining occurred 30 years ago, it is possible that the existing vegetation has had time to adapt to any change in swamp hydrology.	Biodiversity discussion provided in Appendix G
87.	DP&E	Biosis (Attachment A to the PPR) concludes that: *"It is worth noting that all of the upland swamps listed above have been subject to significant tilts and strains from past mining (see Table 13 and Table 14), substantially above what has been predicted by MSEC to result in fracturing of bedrock in waterways (DoP 2010) and the criteria listed in OEH (2012) for assessing the risk of negative environmental consequences to upland swamps. These levels of tilts and strains are likely to have resulted in fracturing of the bedrock beneath these upland swamps from past mining. However, monitoring data is not available to confirm whether this has occurred."* Overall, it appears that the majority of the headwater swamps that have been subject to subsidence from previous mining have maintained a perched groundwater system that does not show evidence that cracking may have occurred. The exceptions are swamps CCUS3 and CCUS6. Notwithstanding, it appears that the vegetation in these swamps has similar characteristics to other swamps in the area. Therefore, any link between possible cracking of the base of a swamp and change in vegetation remains an unanswered question.	Subsidence discussion provided in Appendix B Biodiversity discussion provided in Appendix G

Ref	Regulator	Issue	Where Addressed
88.	DP&E	In terms of subsidence impacts on swamps, Biosis acknowledges the lack of direct linkage between subsidence and hydrologic changes leading to changes in the vegetation community (**Section 3.1.3** of the *RTS*): *"Biosis does not assert that subsidence associated with longwall mining does not result in impacts to upland swamps, or that changes in groundwater availability are not an impact to upland swamps. Rather, that the maintenance and persistence of upland swamps is much more complex than has been recognised, and that further research and assessment is required to understand the complex processes that maintain upland swamps, particularly in relation to changes brought about by longwall mining."*	No response required
89.	DP&E	**3.4 Groundwater Interactions** The interaction between the perched groundwater in upland swamps and the deeper regional groundwater system in the Hawkesbury Sandstone is not well understood. Golder Associates, (December, 2013) offer the following comments (page 32): *'Water levels within these shallow perched 'swamp' systems are highly variable, subject to climatic and seasonal variations in local rainfall amounts. Post-storm surface runoff into a swamp typically occurs via indistinct drainage channels or flow paths to the swamp.* *Water levels within these shallow swamp systems are entirely separate from the deeper, regional Hawkesbury Sandstone water table…. However in some areas the swamp waters might be at least temporarily hydraulically connected to the uppermost portions of the Hawkesbury Sandstone, where bedding discontinuities or low permeability zones in the sandstone promote lateral flow into or out of a swamp after high rainfall periods. Depending on the relative water levels established soon after rainfall events, ephemeral groundwater seepage from the shallow sandstone might flow to the swamps, or conversely, swamp water might migrate into the underlying shallow ephemeral sandstone aquifer (GeoTerra, 2012).'* Whilst hydraulic connection between a swamp and a temporarily elevated water table in the sandstone is plausible, the overall contribution to the water balance of a swamp will be dependent on specific local topography and geology. Also, it must be noted that, because of their position on the landscape, it is less likely that headwater swamps would receive a significant contribution from the regional groundwater system compared to valley fill swamps which are likely to receive some 'baseflow' in a similar manner to creeks.	Groundwater discussion provided in Appendix C

<table>
<tr><th>Ref</th><th>Regulator</th><th>Issue</th><th>Where Addressed</th></tr>
<tr><td>90.</td><td>DP&E</td><td>3.5 Monitoring and Management
The monitoring undertaken for the piezometers discussed in Section 3.3 provides an excellent basis for achieving a better understanding of the hydrology of headwater swamps. Useful additional monitoring and analysis activities would include:
• Establishment of a recording meteorologic station within the Wonga East area to measure rainfall and potential evapotranspiration;
• Establishing piezometers at the upslope end and downslope end of a minimum of two swamps in order to understand the down-slope movement of shallow groundwater;
• Adding two flow monitoring points to swamps in which pairs of piezometers (upslope and downslope) are to be installed;
• Monthly review of the water balance of each monitored swamp based on recorded rainfall, estimated evapotranspiration and recorded water levels and outflow measurement.
• Characterisation of soils within the swamps to determine:
− the porosity - in order to provide a basis for relating piezometer water levels to rainfall and evapotranspiration;
− the presence, or absence, of clay materials at the interface with the underlying sandstone which could mitigate water loss from the swamp to the underlying sandstone in the event that subsidence induced cracking of the sandstone occurred under a swamp.</td><td>Groundwater monitoring measures discussed in Appendix C</td></tr>
<tr><td>91.</td><td>DP&E</td><td>4 Impact of Proposed Mining on Headwater Swamps
Figure 4.1 shows the location of headwater swamps with respect to the location of the proposed longwall mining in the Wongawilli Seam.
4.1 Predicted Subsidence and Impacts
Table 4.1 summarises the predicted subsidence effects on swamps in the Wonga East project area subject to more than 1 mm/m tensile stress from mining in the Wongawilli Seam (from Table 2.1), together with some of the factors that influence the hydrologic characteristics including:
• Area of the swamp itself;
• Effective contributing catchment area, after accounting for any up-slope swamps;
• Downslope distance from the nearest ridge;
• The down-slope gradient of the swamp; and
• The presence of a defined drainage outlet.</td><td>No response required</td></tr>
</table>

Ref	Regulator	Issue	Where Addressed
92.	DP&E	**Table 4.2** (data from Annexure Q of the *EA*) summarises the various upland swamp vegetation communities and their reliance on waterlogging. The table shows that a number of the communities, while classified as 'swamps' in terms of the vegetation, have vegetation that is less reliant on waterlogging than others. This classification from a vegetation community perspective, together with the recorded behaviour of the piezometers in swamps CCUS3 and CCUS6, suggests that some vegetation communities may lack the characteristics that would classify them as swamps from a hydrologic perspective.	Biodiversity discussion provided in Appendix G
93.	DP&E	The previous analysis of potential subsidence risks to swamps undertaken by Biosis and documented in Annex Q of the *EA* has been updated to account for the modified mine plan described in the *PPR*. The revised analysis identified two swamps in the Wonga East area (BCUS4 and CCUS4) as being at 'moderate' risk. Biosis conclude: • *"The revision of the mine plan has resulted in a reduction in risk for several upland swamps, including CRUS2, CRUS3 and CCUS5, and will result in low risk of impact for all upland swamps except BCUS4 and CCUS4."* • *"The revised mine plan and revised subsidence predictions have resulted in an increase in risk to one upland swamp, CCUS4."*	Biodiversity discussion provided in Appendix G
94.	DP&E	For purposes of this review, a further assessment of the hydrologic risks to the swamps in the Wonga East area has been undertaken considering the topographic and hydrologic features of the swamps set out in **Table 4.1**. As noted in **Section 2**, the *PPR* and Annexure B do not include mapping to show the location of maximum tensile stress. It has therefore been assumed that the most likely location for any surface cracking would be in the area of maximum convex curvature (as inferred from the subsidence contours). **Table A1** in **Appendix A** provides details of this assessment including the risk of subsidence induced cracking and the most likely location of impacts, taking account of the topographic position of the swamp. **Table 4.3** provides a summary of those assessments, together with the risk as assessed by Biosis (based on subsidence impacts occurring anywhere within the swamp).	No response required

Ref	Regulator	Issue	Where Addressed
95.	DP&E	The analysis summarised in Table 4.3 indicates that, notwithstanding the additional features of the individual swamps included in the assessment, the majority of the swamps have a low risk of cracking that would affect the swamp itself or intercept runoff from the contributing catchment. (In this regard, it is acknowledged that the relative contribution of surface runoff or shallow subsurface runoff – at the interface between the soil and underlying weathered rock – is not understood in the context of the overall water balance of a swamp.). Two swamps that show up as having some risk (using either method of analysis) are: • BCUS4 which is located over the footprint of longwall LW10. The Biosis analysis provides a risk rating of 'moderate' whereas the separate analysis for this review rates it as 'minor'. The difference is not just one of semantics. The 'minor' rating was assessed on the basis that convex curvature would, occur through the middle of the swamp.	Subsidence discussion provided in Appendix B Biodiversity discussion provided in Appendix G
96.	DP&E	• CCUS4 which is located over the footprint of LW6. The 'minor' rating was assessed on the basis that, while the main body of the swamp would be subject to subsidence, the greatest convex curvature would occur along the up-slope edge. While this might alter the contribution of up-slope runoff, the majority of the swamp is unlikely to be affected.	Subsidence discussion provided in Appendix B Biodiversity discussion provided in Appendix G
97.	DP&E	In addition, the assessment carried out for this review indicates there could also be a 'minor' risk to swamp CCUS10 located above the footprint of longwall LW10. The 'minor' assessment for this swamp was assessed on the basis that the greatest convex curvature would occur along the up-slope edge, affecting the contribution of up-slope runoff.	Subsidence discussion provided in Appendix B Biodiversity discussion provided in Appendix G

Ref	Regulator	Issue	Where Addressed
98.	DP&E	**4.2 Management, Monitoring and Mitigation** The *EA* (pages 385-386) identifies a range of possible mitigation techniques: • Use of coir logs to control erosion. This is only applicable where there is a distinct flow path through the swamp and relates to conditions in valley fill swamps rather than headwater swamps. • Water spreading to redirect flow. This is also only applicable to valley fill swamps where there is a distinct flow path. • Sealing of observed surface cracks. Because this required cracks to be identified, it is only applicable to the margins of swamps, not the main body of the swamp. • Injection grouting to seal cracks in the sub-surface rock. While technically possible, this option relies on the precise location and extent of any crack to be identified and is of no practical value where a crack occurs in the body of a headwater swamp. It can be seen that none of these techniques are applicable to remediating the effects of cracking of the rock underlying a headwater swamp.	No response required
99.	DP&E	The *RTS* (page 284) acknowledges that it is not feasible to remediate bedrock fractures and changes in groundwater availability in upland swamps because the impacts from the remediation works would likely be far greater than the degree of benefit. Accordingly, in this instance, the primary management mechanism is to design a mine plan that minimises potential subsidence impacts. However, ongoing monitoring of groundwater levels at key locations in potentially affected swamps should continue in order to provide further evidence of any impacts and provide an opportunity to regularly reassess the mine plan in terms of stopping longwalls short of the current layout. The Subsidence Assessment notes that *"It is considered that more work is required to determine the relationship between mining subsidence and the long term health of swamps. The extended baseline of subsidence impacts over 60-100 years in the Bulli Seam and 30-40 years in the Balgownie Seam provides a rare opportunity to study these effects. The changes that are expected from proposed mining are nominally sufficient to cause significant impacts to the rock strata and to surface and near surface water flows in the areas directly mined under, so it would be helpful to study how and if the wide range of swamps present above the site are significantly impacted by further mining."*	No response required

Ref	Regulator	Issue	Where Addressed
100.	DP&E	In this regard, the *RTS* notes that: *"NRE are currently re-designing the monitoring plan to integrate surface water, groundwater and ecological monitoring programs to ensure a comprehensive assessment of the ecosystem function of upland swamps within the study area."* A key element of this monitoring should be the expansion of the existing network of shallow swamp piezometers, and regular review (say monthly) to assess any abnormal behaviour that cannot be attributed to evapotranspiration or drainage to a watercourse. A further relevant undertaking is provided in the *PPR* (page 198): *"Due to the disagreement over the potential impacts of subsidence with regard to subsurface water flow and stream networks that is currently prevalent in the scientific and regulatory community, primarily due to inadequate data on both sides of the argument, a network monitoring methodology is being designed, based around CCUS4 and possibly CCUS5, to capture the total water balance of representative sections of surface waterways in order to determine the effects and impacts of subsidence on stream networks from Upland Swamps to Reservoir. This approach will be designed with input from specialists and agencies to ensure the monitoring is reasonable, effective and scientifically robust."* Overall, the proposed monitoring is likely to significantly enhance the body of knowledge relating to the hydrology of headwater swamps, their role in sustaining different vegetation communities and their role in providing baseflow to the creek system.	Section 2.1.2
101.	DP&E	**5 Potential Mine Impacts on Creeks** **5.1 Geological Setting** The potential effects of subsidence on streamflow and pools are heavily influenced by the geology of the creek bed. The *Subsidence Assessment* (Attachment B to the *PPR*) makes the following general points in relation to the geology of Cataract Creek and its tributaries: • Almost all the second order and higher sections of Cataract Creek that are likely to be influenced by mining flow within Bald Hill Claystone outcrop. However, despite Longwall 11 in the Balgownie Seam causing the creek bed to subside 1.4 m, there have not been any significant long-term effects on the bed of the creek or the character of the creek. • Where valley closure is less than 200 mm, experience in Hawkesbury Sandstone channels elsewhere indicates that there has been not been total loss of surface flow.	No response required

Ref	Regulator	Issue	Where Addressed
102.	DP&E	**5.2 Extent and Magnitude of Subsidence** The *Subsidence Assessment* includes an analysis of the changes in the profile of Cataract Creek as a result of predicted subsidence. **Figure 5.1** below reproduces part of Figure 25 from the subsidence assessment which shows the profile of the Southern Tributary, which crosses LW1 – LW3 and joins the main creek about 350 m downstream of LW3 as shown on **Figure 5.2**.	No response required
103.	DP&E	The profile in **Figure 5.1** shows the following features of note: • Significant vertical subsidence in the reach between Chainage 100 m and 500 m, corresponding to longwalls LW1 and LW2. Although not quoted in the Subsidence Assessment, it appears that maximum subsidence of up to 1.8 m may occur in this area and that the sharp end to the subsidence zone could lead to ponding in this area; • Minor vertical subsidence is predicted upstream of about Chainage 1,650 m, which corresponds to the alignment of the south-east corner of longwall LW6. The maximum magnitude of the predicted subsidence appears to be about 0.5 m and to lead to a relatively sharp downstream 'lip' that could lead to minor additional ponding; • A reach between about Chainage 1,880 m and 2,100 m in which up to 1.2 m vertical subsidence is predicted. These chainages align with the north-eastern end of longwall LW7. • A reach between about Chainage 2,100 m and 2,370 m where up to 0.5 m vertical subsidence is predicted.	No response required
104.	DP&E	The *Subsidence Assessment* also notes other subsidence effects on creeks that are not shown on **Figure 5.1:** • Vertical subsidence is predicted to mainly influence second order creeks above longwalls LW1 to LW3; • Up to 2.6 m of vertical subsidence may occur below these second order creeks above longwall LW1.	No response required

Ref	Regulator	Issue	Where Addressed
105.	DP&E	**5.3 Connective Cracking** The main potential for connective cracking appears to be at the northern corner of Longwall 7 which has been relocated as part of the revised project described in the *PPR*. This relocation has moved the northern corner of the longwall in a south-easterly direction by about 45 m. However the horizontal distance from the vertical projection of the longwall to Cataract Creek remains about 45 m. In this regard, Tammetta (December 2013) notes that: *'Despite the absence of existing full extraction workings over a small strip of about 50m width, there may still be a risk to the capacity of the channel of Cataract Creek to transmit surface water. There may also still be a risk of direct hydraulic connection between the creek channel and goaf, through the collapsed zone, where the channel comes to close to the panel edge. The significance of these risks cannot be quantified, but warrants consideration.'* Whilst there remains some uncertainty regarding the potential for connective cracking, as noted in Section 2.3, the report by Hebblewhite (18/12/2013) on joint discussions with Tammetta and Dr Mills (of SCT) concludes: *"Therefore based on the above interpretation, the risk of inter-connective cracking is considered low in the vicinity of LW7 (or any other part of the proposed workings)."* In addition, it should be noted that the creek bed in this vicinity is predominantly on rock and, therefore, the chance of any cracking being identified and repaired would be greater than if cracking occurred in a section of alluvial creek bed.	Height of depressurisation is discussed in Appendix C
106.	DP&E	**5.4 Impacts on the Flow in Creeks** Key aspects of the potential impacts on ponding and flow identified in the *Subsidence Assessment* include: • Although there is potential for water to pool in second order creeks above LW1 – LW3, valley closure effects are expected to increase the potential for sub-surface flow. Accordingly pooling may only be short lived during periods of heavy rain. • Valley closure is expected to cause perceptible cracking and surface flow diversion in the upper reaches of the southern branch of Cataract Creek, particularly where it flows across Hawkesbury Sandstone outcrop above LW1 leading to some loss of surface water and iron staining. • Further downstream where the bed of the stream is located mainly in Bald Hill Claystone, low levels of perceptible impact are expected. Iron staining and flow diversion into the surface strata are not expected.	Impacts on stream flow due to cracking are discussed in Appendix E and Appendix F

Ref	Regulator	Issue	Where Addressed
107.	DP&E	Section 2.2.9.3 of the *PPR* also notes that: *"Subsidence impacts on Upland Swamps and 1st and 2nd order tributaries are anticipated to have localised effects on the affected tributary stream flow and longevity and increased Fe, reduced DO, increased salinity and potentially increased metal concentrations in the downstream re-emergence and discharge zone*." In addition, the *PPR* (Section 2.2.9.3) notes that the main effect on overall stream discharge into Cataract Reservoir is expected to be attributable to any regional groundwater depressurisation effects. These effects have yet to be quantified on the basis of the remodelling of catchment groundwater impacts which is underway (as at December 2013). Some indication of the potential impacts of baseflow reduction as a result of regional groundwater depressurisation effect can be gained from the initial analysis in the *Groundwater Assessment* for the EA (data reproduced below). The data in **Table 5.1** indicates that, in the main, Cataract Creek is a 'gaining' stream but there is a small section which is a 'losing' stream. However, no details are provided to indicate where the gaining and losing sections are located. In order to provide a basis for the assessment of potential impacts on stream ecology, the updated surface water modelling should assess the predicted loss of groundwater derived baseflow in the context of flow duration characteristics, not just average flow. The analysis should include a 'worst case' sensitivity assessment that considers the possibility of both shallow bedrock cracking (leading to loss of water in pools, but possible return flow downstream) as well as connective cracking to the mine workings. In both cases it would be useful to consider situations in which no repair work was undertaken and if repairs were undertaken in a similar manner to repairs undertaken on other creeks in the Southern Highlands. A flow duration graph showing existing and predicted flow characteristics would be desirable.	Groundwater discussion is provided in Appendix C. This includes an assessment of the effects of groundwater depressurisation on baseflow. Impacts on streams are discussed in Appendix F. This assesses the potential impacts of cracking on stream flows.

Ref	Regulator	Issue	Where Addressed
108.	DP&E	**5.5 Water Quality Impacts** Sections 10.5.3 and 10.5.4 of the *Stream Assessment* provide an overview of the water quality monitoring program including locations and periods over which monitoring has occurred. The monitoring program includes: • Bi-monthly monitoring of four sites on Cataract Creek upstream of Mount Ousley Road and one immediately downstream since August 2008; • Bi-monthly monitoring of one site within Cataract Reservoir since August 2008; • Progressive expansion of the monitoring on Cataract Creek to include an additional six sites on Cataract Creek and one of its tributaries since July 2010; • Commencement of monitoring outflow from three swamps and one piezometer since March 2012. The *Stream Assessment* provides graphs of the longitudinal profiles of median values of pH, conductivity, iron (total and filtered) and manganese (total and filtered) as well as graphs of the variability of pH and conductivity over time. • pH shows a slight increasing trend from a median of about 5.6 at the upstream monitoring point to 6.3 upstream of Cataract Reservoir; • Conductivity declines from a median of about 145 µS/cm at the upstream monitoring point to about 120 µS/cm just upstream of Cataract Reservoir; The assessment of overall water quality is summarised in the following quotations: *"In general, enhanced rainfall in the catchment has the effect of reducing salinity, marginally raising pH, increasing dissolved oxygen, diluting ferruginous discolouring (or deposition), diluting major metals and generally increasing nutrients, with the degree of change relating to the degree and duration of rainfall runoff dilution in the stream."* *"Hydrous ferruginous seeps are relatively common in Cataract Creek, although their exact inflow location has not yet been identified as ferruginous precipitation is relatively ubiquitous in the creek both upstream and downstream of the freeway.*	Water monitoring is discussed in Appendix E

Ref	Regulator	Issue	Where Addressed
109.	DP&E	**5.6 Monitoring and Management** **5.6.1 Monitoring** The *Stream Assessment* (GeoTerra, 2012 – Annex O to the EA) describes the stream monitoring program together with proposed additional monitoring. Tables 16 and 17 in the *Stream Assessment* list the locations of the various monitoring locations but does not specify the precise monitoring activities at each site. **Table 5.2** is an attempt to consolidate the range of surface water monitoring activities based on the text and graphs in the *Stream Assessment.* The term 'observed flow' in the table is used to designate locations where visual observations of streamflow are made at the time of other monitoring, principally collection of water quality samples. The table shows that Gujarat NRE has established a reasonably comprehensive set of monitoring sites in the Wonga East area. Notwithstanding, in response to one of the submissions regarding water quality monitoring, the *RTS* (page 315) commits as follows: *"The spatial and temporal distribution of water quality monitoring of streams within the project area will be detailed, including the analytes monitored and tables showing key statistics and justification of proposed triggers when the remodelling is complete."* A further relevant undertaking is provided in the PPR (page 197): *"LW5 is currently mining beneath the Cataract Creek tributary CT1. NRE will continue to monitor CT1 tributary flow, water levels and water chemistry as LW5 passes beneath the tributary to clearly identify impacts that mine subsidence may have. There may be some effects on surface flow volumes but little impact on discharge into Cataract Creek. NRE is in the process of establishing monitoring points close to the mouth of CT1 and other tributaries along Cataract Creek to improve its understanding of the effects of mining on tributary discharge volumes."* In addition, the *RTS* (page 314) notes that the available stream level data (sites CC2, CC3, CC6, CC7, CC8 in Cataract Creek and the SCA site in Cataract River) will be used to back calculate streamflow as part of the remodelling of the surface water impacts from the Preferred Project in order to assess the degree of flow loss / gains in the streams.	Water monitoring is discussed in Appendix E

Ref	Regulator	Issue	Where Addressed
110.	DP&E	**5.6.2 Management** In relation to monitoring of subsidence impacts on creeks, the *Subsidence Assessment* (page 59/60) proposes: *"A management strategy based on closure monitoring and cessation of mining if there is a likelihood of significant perceptible impacts becoming apparent is considered to be an effective method of managing the potential for subsidence impacts on Cataract Creek."* More generally, the PPR (page 198) states: *"Monitoring and management are not intended to vary significantly but will be reviewed on the basis of the revised surface water model and assessment outcomes during the approvals process. A stream network monitoring program is being developed around CCUS4 and possibly CCUS5 and the Cataract Creek tributaries they feed to determine the actual impacts on surface and near surface water balances within a defined catchment area."* As noted in the *Review of Surface Water Issues* (Evans & Peck, June 2013), baseline water quality data has been collected for range of relevant analytes. This data should provide an appropriate basis for establishing baseline water quality for purposes of identifying any water quality impacts as a result of mining. Further analysis of the water quality statistics should also be provided along with justification for any proposed water quality 'trigger' levels that differ from the default values in the ANZECC Guidelines. Provided an appropriate range of analytes has been monitored for sufficient length of time (monthly over 2 years minimum recommended in ANZECC) any proposal to establish locally specific water quality 'trigger' levels (for further investigation) would be consistent with the principles set out in the ANZECC Guidelines.	Subsidence discussion provided in Appendix B Water monitoring is discussed in Appendix E

<table>
<tr><th>Ref</th><th>Regulator</th><th>Issue</th><th>Where Addressed</th></tr>
<tr><td>111.</td><td>DP&E</td><td>6 Pit Top Water Management
6.1 Russell Vale
The PPR includes all the surface facility upgrades described in the EA including the following relating to surface water management:
Stormwater Management:
• Improved separation and control of conveyance of water from the different catchments;
• Upgrading of about 560 m of the Southern Stormwater Channel to ensure separation of ‘clean’ water from the site and up-slope from ‘dirty’ stormwater from the coal stockpile area;
• Construction of a stormwater energy dissipater and settlement area with a low flow outflow pit to control discharge from the Southern Stormwater Channel into Bellambi Gully;
• Construction of a dry sediment basin to provide pre-treatment of stormwater from the coal stockpile area before it drains to the existing settling ponds;
• Cleaning out and reconfiguration of the existing settling ponds into a single pond.
Flooding and Channel Stability
• Channel protection works including Reno mattresses and gabion basket drop structure at various locations on major conveyance channels (as set out in Annexure B to the EA, Water Management);
• Improvement works to the ‘M3 Culvert’ (to prevent the recurrence of the flooding event of August 1998). Options include:
− Increasing the capacity of the pipe culvert and provision of an overland flow path that would convey water back to Bellambi Creek Gully;
− Increase the capacity of the culvert to sufficient capacity to ensure that it does not become fully blocked and has a freeboard of 500 mm above the 100 year ARI flow conditions.
Subject to clarification or a range of issues identified in Section 4.1.2 of the Review of Surface Water Issues (Evans & Peck, June 2013), these proposed upgrades can be expected to significantly improve on site water management and provide appropriate mitigation against a recurrence of the August 1998 flood event.
Currently stormwater and treated mine water are both discharged to Bellambi Gully. This results in an un-naturally persistent flow regime in the gully and elevated salinity levels compared to what could be expected in a natural creek. Although not documented, the flow and water quality have probably contributed (along with urban runoff) to a severely degraded creek. No consideration has been given to the feasibility or benefit of alternative means of conveyance of the treated mine water (such as via a pipeline)</td><td>Section 2.1.3

Flood Study will be provided separately</td></tr>
</table>

Ref	Regulator	Issue	Where Addressed
112.	DP&E	The main issue arising from the *PPR* is the proposed staging of the site rehabilitation works including those to address stormwater management and flooding issues. Table 6 of the *PPR* (copy included as **Table 6.1** below) indicates that highest priority for construction is proposed for facilities concerned with the transport of coal (2.5 years), with works associated with water management taking a further year. Some of the works related to stormwater quality control and flooding are considered to warrant higher priority, particularly: • Improvement works to the 'M3 Culvert'; • Cleaning out and reconfiguration of the existing settling ponds into a single pond.	Flood Study will be provided separately
113.	DP&E	**6.2 Mine Groundwater Inflow and Site Water Balance** Estimates of the groundwater inflow to the workings have been updated for the *PPR* to reflect the reduced scope of mining. Data presented in the *PPR* shows that the average inflow to the workings for 2011 and 2012 was about 460 ML/year. **Figure 6.1** shows that the inflow associated with extraction from Longwalls 4 and 5 (from early 2012) was significantly higher than had been previously experienced at the mine. Estimates of future inflows are to be prepared once further groundwater modelling has been undertaken. At that stage it would be appropriate for the site water balance to be re-visited and a range of issues identified in the *Review of Surface Water Issues*.	Groundwater discussion is provided in Appendix C.
114.	DP&E	**6.3 No 4 Shaft** The *Review of Surface Water Issues* questioned some aspects of the effluent irrigation system at the No 4 Shaft site. On the basis that, as part of the activities to be undertaken to implement the mining described in the *PPR*, the number of employees would remain about the same as currently (13), it is accepted that the effluent disposal system has adequate capacity.	No response required

<table>
<tr><th>Ref</th><th>Regulator</th><th>Issue</th><th>Where Addressed</th></tr>
<tr><td>115.</td><td>DP&E</td><td>7 Commitments and Conditions of Approval
Is Section 4 of the PPR, the Proponent seeks to remove all commitments set out in Table 29.1 of the EA and proposes requests the Department to consider the a range of conditions, if considered necessary, to ensure that specific environmental outcomes are met. The proposed conditions include the following of relevance to matters considered in this review.
1. A general condition in any approval requiring:
• NRE to comply with all relevant legislation related to its operational environmental impacts.
2. Specific conditions for the Pit Top areas requiring the preparation of arrange of plans including:
• Construction Management Plan/s;
• Surface Facilities Water Management Plan.
3. Specific conditions for Mine Subsidence areas requiring the preparation of an:
• Extraction Plan.
Presumably, any Extraction Plan would include a whole series of sub-plans including:
• A Subsidence Management Plan that included specific proposal regarding cessation of mining in the event of certain subsidence criteria being exceeded (such as valley closure of more than 200 mm).
• A Creek Monitoring and Management Plan (including pool levels, flow and water quality) as well as criteria for undertaking remediation of any excessive cracking in the creeks;
• A Swamp Management Plan that included:
- a comprehensive program of water level and outflow monitoring;
- on-site climate monitoring to enable water balance analysis to be undertaken for individual swaps;
- soils investigations to define the water holding characteristics of the soils within the swamps for purposes of relating the observed water levels to a depth of water and assessing the likelihood of ‘self-sealing’.</td><td>No response required</td></tr>
<tr><td>116.</td><td>NSW Office of Water (NOW)</td><td><u>Refinement of numerical model</u>
Numerical computer modelling was undertaken as part of the Environmental Assessment for the original application. That modelling was used to predict the impacts of the originally proposed configuration for both the Wonga East and Wonga West workings. Given the modifications identified within the Preferred Project Report, refinement of the model and generation of new impact predictions based on the current layout is warranted. The proponent has identified that a new groundwater model will be developed to allow the prediction of impacts based on the new mining plans, however the process is indicated as taking up to 3 months (page 128). This prevents the Office of Water from being able to adequately assess the likely impacts of the proposed mining operation.</td><td>Groundwater discussion is provided in Appendix C</td></tr>
</table>

Ref	Regulator	Issue	Where Addressed
117.	NOW	<u>Authorisation of groundwater take</u> The PPR indicates that preliminary estimates of mine water make (in lieu of the results of the revised modelling) indicates volumetric inflows of 840 ML per year could be expected (page 131). The Office of Water previously advised that the proponent is authorised to extract a volume of 365 ML/y under an existing licence. The PPR does not elaborate on the licensing requirements identified in previous agency correspondence, nor does it provide even preliminary advice on the possibility of the proponent obtaining the necessary entitlement for the current or potential future applications. This is despite the Office of Water specifically requiring the proponent to demonstrate an ability to obtain the required entitlement in previous correspondence.	Groundwater discussion provided in Appendix C
118.	NOW	<u>Changes to Panel Dimensions</u> It is noted that the changes to longwall dimensions (page 20) have resulted in reductions in Maingate pillar widths in some locations (from 60 m to 45 m for LW 6, 7, 9 and 10), and widened longwall panels in other places (from 105 to between 125 and 150 m for LW 1, 2 and 3). Whilst the reduced length of the panels is likely to constrain the associated subsidence trough longitudinally, the lateral ground surface settlement effects of multiple parallel longwalls is cumulative and can be substantial. Mining engineering theory suggests that the height of ground displacement is related to the width of the extracted panel, therefore the widening of individual longwalls could result in disturbance of strata at levels closer to the ground surface. Similarly, the height of complete groundwater drainage above the caved zone of mined longwall is related to panel width. As well, a reduction in pillar size is likely to change the tensional and compressional forces around and above each support, thereby potentially changing the bedding plane separation behaviour and extent within overlying strata. Whilst the PPR suggests that the “longwall dimensions are approximately 25% smaller in Wonga East than the original proposal”, there is no recognition of the potential changes to engineering behaviour within overlying strata as a result of panel widening. In addition, the repositioning of the proposed longwalls could significantly alter stress and strain dynamics within the overlying strata depending on the final panel orientation in relation to the maximum stress direction. Therefore, despite the reduction in overall area of extraction, the localised impacts could be significantly exacerbated due to the changed widths and orientations.	Subsidence discussion provided in Appendix B

Ref	Regulator	Issue	Where Addressed
119.	NOW	Volumes of water from affected sources The Office of Water previously advised that additional assessment was necessary to identify the "potential for the proposed mining to induce connections to the surface water systems", with particular reference to upland swamps, local creeks and Cataract Dam. The PPR has identified that it would be possible to determine the potential leakage from Cataract reservoir using a probabilistic assessment of a transiently calibrated model (page 129). It has also been identified that such a simulation would require weeks of computer run time for each individual stag and months for multiple stages, therefore it was not proposed for the initial modelling study but "could be done at a later stage, if considered necessary". In order for the proponent to meet the requirements of the Office of Water, as well as those of the NSW Aquifer Interference Policy, this modelling is considered necessary and its commencement should not be deferred until some undefined 'later stage'.	Groundwater discussion provided in Appendix C. This includes a probabilistic analysis using 30 model runs. The requirements of the AIP have been addressed.
120.	NOW	Comments/options The application for consent to undertake longwall mining in the Wonga East area could be supported in the absence of the results of new numerical modelling, provided any recommended conditions stringently bind the proponent to the required actions as well as applying specific time frames and deadlines. In regard to predicted impacts, detailed assessment of the model conceptualisation, structure and adequacy should be undertaken by the Office of Water once the revised modelling has been provided by the proponent. Notwithstanding, the reduced area of mining identified within the PPR, there remains a need for the proponent to meet the requirements of the NSW Aquifer Interference Policy.	Groundwater discussion provided in Appendix C
121.	NOW	Recommendations 1. The proponent commit to the further development of a numerical groundwater flow model designed to meet the modelling requirements specified in the AIP 2. The proponent commit to acquiring sufficient entitlement to account for the volume of estimated water take from all affected water sources. 3. Conditions of consent should be stringently binding on the proponent to meet necessary tasks and deadlines, and incorporate provisions for future changes once the revised modelling has been completed 4. The proponent should address the potential impacts of the proposed widening of the longwall panels 5. The proponent be required to determine the potential leakage from Cataract Reservoir.	Groundwater discussion provided in Appendix C

Ref	Regulator	Issue	Where Addressed
122.	Wollongong City Council (WCC)	Council notes that Gujarat NRE Coking Coal Ltd through the Preferred Project Report process has significantly modified the original proposal, in response to issues raised by government agencies, Council and public submissions. The main changes in the revised proposal include removing the originally proposed Wonga West longwalls and restricting longwall extraction to the Wonga East area only with a corresponding lesser total resource yield of 4.7 million tonnes of coal, instead of the originally proposed yield of 31.1 million tonnes. In light of these changes, the revised project life for the mine is also reduced from 18 years to 5 years.	Response not required
123.	WCC	Council requests that the attached submission be taken into consideration during the Department's assessment of the Preferred Project Report. In this regard, the removal of the Wonga West longwalls as per this revised proposal has resolved a number of issues previously identified by Council in its submission at the time of the original Environmental Assessment review. However, several issues remain unresolved, including the necessary construction of three (3) acoustic barriers, in order to protect surrounding residential areas from noise emanating from the mine's pit top operations. Additionally, the proposed Wonga East longwall panels A2 LW6 and A2 LW7 still sit beneath three (3) 'special significance' swamps and hence, it is recommended that these longwalls either be deleted, reorientated or shortened in length, in order to protect these swamps from subsidence related impacts.	Section 2.3.1 Noise Impact Assessment to be provided separately
124.	WCC	The longwall panel A2 LW7 is recommended to either be deleted, reorientated or shortened in length to minimise any potential subsidence related impacts upon the 'special significance' upland swamp CCUS5.	Subsidence discussion provided in Appendix B
125.	WCC	The longwall panel A2 LW6 is recommended to eíther be deleted, reorientated or shortened in length to minimise any potential subsidence related impacts upon the 'special significance' swamps CCUS4 and CRUS1.	Subsidence discussion provided in Appendix B
126.	WCC	The longwall panel A2 LW7 is recommended to either be deleted, reorientated or shortened in length to minimise any potential subsidence related impacts upon the 'special significance' upland swamp CCUSS and to further protect the habitat of the Stuttering Barred Frog.	Subsidence discussion provided in Appendix B

Ref	Regulator	Issue	Where Addressed
127.	WCC	The original Noise Assessment report by ERM dated 30 November 2012 involved detailed acoustic modelling which was based on certain noise attenuation/mitigation measures being provided on-site, including (iv) A 3 metre high acoustic barrier to the south of Broker Street; (v) A 3.6 metre high roadside type barrier to the north of the internal access road from the weighbridge to the Princes Highway; and (vi) Noise mitigation of certain equipment such as mine ventilation fans and dozers. Therefore, concern is raised about potential noise impacts upon surrounding residential areas from pit top activities, if the noise barriers are not installed. Further, the recent noise audit report (ie referred to in the Preferred Project Report) does not properly consider how certain weather conditions (ie wind speed and direction, cloud cover etc) influence noise emanating from the pit top activities. Therefore, Council reiterates its original EA comments that the three (3) acoustic barriers are necessary and should be subject to appropriate conditions of consent, in the event that the Department ultimately approves the revised proposal.	Section 2.3.1 Noise Impact Assessment to be provided separately
128.	WCC	The Preferred Project Report fails to provide conclusive advice as to what noise mitigation measures will be introduced in order to address potential noise impacts from the Pit Top area activities, especially truck loading activities and dozers working upon the stockpile areas. Noise impacts along Bellambi Lane also remain unresolved. Therefore, Council requests that the NSW Department of Planning and Infrastructure guarantee that appropriate noise mitigation measures are implemented as part of any such Part 3A approval.	Section 2.3.1 Noise Impact Assessment to be provided separately
129.	WCC	The construction of the new screening and sizing station should be a condition of consent if the application is ultimately approved. Appropriate conditions of consent should also be required which satisfactorily address the air quality (PM10 particulate and total suspended particulate) issues.	Section 2.3.2
130.	WCC	Council requests that traffic modelling be required for the next 5 years (2018) which deals with affected intersections and midblock performance, prior to the determination of the application.	Traffic impacts are discussed in Appendix I

Ref	Regulator	Issue	Where Addressed
131.	WCC	Therefore, Council requests that the Department impose a condition of consent requiring that appropriate negotiations take place with both Wollongong City Council and the NSW Roads and Maritime Services concerning funding towards road maintenance works as a result of the additional trucks using local and regional roads between the site and the Port Kembla Coal Terminal.	Traffic impacts are discussed in Appendix I. Such a condition is not required as the traffic modelling has demonstrated that there will not be any significant impact on the road network.
132.	WCC	Council requests that appropriate conditions of consent be imposed requiring the sealing and line marking of the employee's carpark. However, given that the revised life of the mine is for a maximum 5 year period, it is considered reasonable not to require the construction of a new haulage road or employee access road. In the event that a separate new application is ultimately lodged for the Wonga West mine lease area, then a new haulage road or employee access road should be considered at that time.	Section 2.3.3
133.	WCC	Hydraulic modelling under the NSW Office of Water guidelines is recommended to be undertaken by a suitably qualified groundwater expert, prior to the determination of the Part 3A application.	Groundwater discussion provided in Appendix C

Ref	Regulator	Issue	Where Addressed
134.	DRE	Subsidence While DRE is supportive of the proposal, consistent with the Division's previous advice DRE is of the opinion that additional subsidence investigations are required. In particular, further under mining by longwalls within the old Bulli Pillar Workings will have the following risks, which require site specific investigations: • The development of irregular subsidence profiles, which often leads to concentrations of surface deformations and adverse subsidence impacts on the surface features within affected areas; and • Pillar runs, ie propagation of instability and/or reworking of the Old Bulli Pillar workings beyond the normal limit of mine subsidence. Note that this definition differs from what is normally considered as pillar runs for underground safety. In the context of mine subsidence, pillar runs do not have to be a catastrophic event as being assessed by the Applicant. Without these investigations, there will be uncertainty about the predictions made for important surface features, such as Cataract creek or Cataract reservoir, which may be affected by the proposed longwalls 6, 7 & 9 to 11. In regard to Longwalls 1-3, DRE has previously advised that critical surface features, including angled voltage transmission towers, the Illawarra Escarpment and Mount Ousley Road may be affected by longwall mining and require site specific investigations. Geotechnical investigations need to be undertaken prior to the submission of an extraction plan.	Subsidence discussion provided in Appendix B

Ref	Regulator	Issue	Where Addressed
135.	DRE	<u>Recommended Conditions of Approval</u> Rehabilitation Plan 1. The Proponent must prepare and implement a Rehabilitation Plan to the satisfaction of the Director General of Department of Trade & Investment, Regional Infrastructure and Services. 2. Rehabilitation Plan must: a. Be submitted and approved by the Director general of department of trade and investment, regional infrastructure and services prior to carrying out any surface disturbing activities of the development, unless otherwise agreed by the Minister; b. Be prepared in accordance with DRE guidelines and in consultation with the department, Office of Environment and Heritage, Environmental Protection Authority, Office of Water, Council and the mine Community Consultative Committee; c. Incorporate and be consistent with the rehabilitation objectives in the EIS, the statement of commitments and table 1; d. Integrate and build on, to the maximum extent practicable, the other management plans required under this approval; and e. Address all aspects of mine closure and rehabilitation, including post mining land use domains, rehabilitation objectives, completion criteria and rehabilitation monitoring and management. It is the intention of DRE that the Rehabilitation Plan fulfil the requirements of the Mining Operation Plan (which will become the rehabilitation and Environmental Management Plan (REMP) once the Mining Act amendments have commenced).	Section 2.4.1

Ref	Regulator	Issue	Where Addressed
136.	DRE	Extraction Plan DRE requires the inclusion of the preparation of an Extraction Plan that must take into consideration likely impacts that activities may have on Old Bulli Pillar Workings within the area and on key natural features and public infrastructures; such as angled voltage transmission towers, Mount Ousley Road, the Illawarra Escarpment and Cataract Creek/Cataract Reservoir. 1. The proponent must undertake Geotechnical Investigations prior to the submission of an extraction plan 2. The extraction plan must: a. Give consideration to impacts of old workings and include a detailed investigation of overlying old Bulli Pillar workings in consultation with DRE, which: • Assess the stability of remnant coal pillars in the former Bulli Seam workings; • Includes revised subsidence predictions for the second working areas • Recommends final design of the second workings panels and any necessary adaptive management measures; b. Includes a Built features Management Plan prepared in consultation with DRE, which: • Address in appropriate detail all items of key public infrastructure, other public infrastructure and all other built features; • Has been prepared following appropriate consultation with the owner/s of potentially affected features; • Recommends appropriate remedial measures and includes commitments to mitigate, repair, replace or compensate all predicted impacts on potentially affected built features in a timely manner; c. Includes a Public Safety Management Plan, which has been prepared in consultation with DRE; and d. Includes a Subsidence Monitoring Program, which has been prepared in consultation with DRE.	Section 2.4.2
137.	DRE	First Workings First working on site, other that in accordance with an approved Extraction Plan, may be carried out provided DRE is satisfied that the first workings are designed to remain long term stable and non-subsiding, except insofar as they may be impacted by an approved second working.	Section 2.4.3
138.	Dams Safety Committee (DSC)	The DSC's submission on NRE #1's Environmental Assessment for an Underground Expansion Project, contained 15 concerns. The Preferred Project has addressed 12 of these concerns to the satisfaction of the Committee. The three remaining concerns (i.e. Nos. 12, 13 & 14)) deal with the Groundwater Model. The Committee awaits confirmation that NRE will revise the Groundwater Model for the Preferred Project to address the issues raised by the DSC.	Groundwater discussion provided in Appendix C

Ref	Regulator	Issue	Where Addressed
139.	EPA	The Environment Protection Authority (EPA) has reviewed the Submissions Report and believes that its comments on pit top operations have been substantially addressed.	No response required
140.	Heritage Council	In the Preferred Project and Response to Submissions Report the Applicant has stated that the proposed Statement of Commitments above are unnecessary because "NRE has an existing approved Heritage Management Plan for the Pit Top that incorporates these measures and meets the requirements of the Preliminary Works Pt3A. This plan is updated at the end of each approved longwall and resubmitted for approval for the following longwall". As Delegate of the Heritage Council this is not considered adequate. This is particularly the case as a number of issues were identified with the draft Heritage Management Plan when it was reviewed by the Heritage Branch of OEH in September 2012. As the plan was never resubmitted for comment, it is unclear whether these issues were dealt with and whether any actions relating to the Applicants original six statement of commitments were included within that plan. Therefore, it is recommended that if the proposed project is approved, the six original statement of commitments (as listed above), should form part of the approval conditions.	Heritage discussion provided in Appendix H
141.	NSW Office of Environment & Heritage (OEH)	OEH notes that the PPR addresses a number of issues previously identified by OEH, particularly through the modification of the longwall layout to reduce impacts on upland swamps and streams. However, OEH does not consider that the PPR fully addresses the issues previously identified and therefore recommends the mining plan should be modified further to avoid impacts to these significant natural features (see Attachment A for further detail).	Section 2.8.1
142.	OEH	OEH's principal concerns in relation to the PPR are: • impacts to the Coastal Upland Swamps endangered ecological community (EEC), particularly to swamps of 'special significance' • potential loss of surface water to deeper storage via mining induced fracture networks • impacts to threatened species	Biodiversity discussion provided in Appendix G
143.	OEH	OEH also notes that further surface and groundwater behaviour/characteristics modelling is yet to be completed. In the absence of this information, OEH requests an opportunity to comment when the additional information is provided.	Groundwater discussion provided in Appendix C

Ref	Regulator	Issue	Where Addressed
144.	OEH	**Upland Swamps** **Impacts to Coastal Upland Swamps endangered ecological community** OEH supports the proponent's identification of upland swamps of 'special significance' in the project area in line with the methodology contained in OEH's draft *Upland Swamp Environmental Assessment Guidelines.* OEH notes that the PPR has modified the longwall layout in the Wonga East domain with the intent of reducing undermining of significant streams and areas of Coastal Upland Swamp endangered ecological community (EEC).	No response required
145.	OEH	OEH has consistently stated that longwall mining under the Sydney Catchment Authority Special Areas of the Woronora Plateau must meet a performance measure for swamps of special significance of no **negative environmental outcomes, or negligible environmental consequence.** OEH considers that all swamps recognised to be of special significance should be protected from the impacts of mining.	No response required
146.	OEH	Results of monitoring by both BHP Billiton Illawarra Coal (BHPBIC) and OEH in upland swamps undermined by longwall mining in Dendrobium mine on the Woronora Plateau has demonstrated that mining resulted in the fracturing of bedrock beneath a swamp causing: • A loss of the perched aquifer in the swamps (determined by piezometer monitoring of shallow groundwater levels) • A loss of water flow at the base of the swamp (determined by V-notch weir monitoring); and • A loss of soil moisture within the swamp (determined by soil moisture probes)	No response required
147.	OEH	Impacts of these types alter the ecological function of the upland swamp with a high likelihood of eventual loss of the vegetation communities and habitats that characterise this EEC.	Biodiversity discussion provided in Appendix G

Ref	Regulator	Issue	Where Addressed
148.	OEH	In the response to submissions, Gujarat states that the modified layout will result in an overall reduced risk of impact for upland swamps across the project area. However, OEH notes that all swamps in the Wonga East area, with the exception of CCUS10, have greater predicted maximum strains and tilts compared to the original EA (Table 29, pg 82, PPR). Of the seven swamps identified as "of special significance" the PPR proposes to directly undermine swamps CCUS4 and CRUS1. Gujarat's risk assessment identifies the maximum tensile and compressive strains and maximum tilts predicted for each swamp (valley closure is not included and would be informative). The Bulli Seam PAC (2010) identified subsidence criteria above which swamps may be at risk of negative environmental outcomes. The risk assessment for Wonga East indicates that swamps CCUS4 and CRUS1 will undergo maximum tensile and compressive strains and tilts of between 5 and 18 times these thresholds for all 3 parameters. A further four swamps (CCUS1, CCUS5, CCUS10, CRUS1) will undergo maximum tensile and compressive strains and tilts at least 3 times greater than these thresholds for all 3 parameters.	Biodiversity discussion provided in Appendix G
149.	OEH	As a result OEH believes that the amended mining plan will not meet a performance measure of negligible environmental consequence for swamps of special significance, and that significant impacts to multiple upland swamps in the Wonga East domain are likely. Further amendments to the mining layout should be considered to enable negligible impact criteria to be met.	Biodiversity discussion provided in Appendix G Performance measures for swamps are discussed in Appendix E
150.	OEH	Although the overall risk to upland swamps may be lower as a result of the removal of the Wonga West domain from the PPR, OEH notes that **none** of the upland swamp EECs in Wonga West are protected from future mining developments.	Biodiversity discussion provided in Appendix G
151.	OEH	**Flow Accumulation** OEH maintains that Biosis has over emphasised the impact of tilt and flow accumulation modelling when developing risk rankings for upland swamps. The types and level of impacts most frequently observed and of concern for upland swamps in the Southern Coalfields, including bedrock fracturing, is more closely related to physical stresses, strains and upsidence than tilt	Biodiversity discussion provided in Appendix G

Ref	Regulator	Issue	Where Addressed
152.	OEH	OEH accepts that use of additional information in a multi-criteria analysis may be useful, but has serious concerns that the outcome of subsequent risk assessment is affected by the weightings applied in such a multi-criteria analysis. For example, if flow accumulation is given equal weight to bedrock fracturing in such an analysis, a low flow accumulation criteria could artificially deflate the calculated risk to a particular swamp when the subsidence· predictions (both incremental and cumulative) exceed PAC thresholds for bedrock fracturing.	Biodiversity discussion provided in Appendix G
153.	OEH	OEH agrees with Biosis that some of these swamps may already have been impacted by previous mining in the area but notes that a comprehensive monitoring and measurement program was not undertaken prior to mining. A more detailed analysis of these potentially impacted swamps is required to gauge both likelihood and consequence (and therefore risk} for upland swamp EECs above the proposed mine plan. OEH suggests that close attention should be paid to piezometer responses at PCc2, PCc5A, PCc6 and PCc3 and that these should be contrasted with piezometer levels in swamps entirely unaffected by mining (ie reference swamps). Although not certain, this experimental data may be sufficient to resolve the question of potential past impacts.	Biodiversity discussion provided in Appendix G
154.	OEH	**Surface Water** **Potential loss of surface catchment water to deeper storage** There appears to be a common, widespread perception in the coal mining industry in the Southern Coalfields that a surface to seam connection, as a result of fracturing, creating a flow path for surface water into deeper storage within the mine, will not or can not occur. There is mounting scientific evidence to suggest that surface and rain water is indeed being lost from upland swamps and streams that supply Sydney's drinking water supply as a result of mining and is potentially making its way into Southern Coalfield mines or lower aquifers. The independent review commissioned by Department of Planning and Infrastructure into this proposal (Coffey 2013) is the latest report to highlight the risk of a surface to seam connection. Other evidence includes Ziegler and Middleton's (2011) analysis of algae in mine and tritium levels in mine inflow water, Heritage Computing's (2012) study of the correlation between rainfall and lagged inflows and Coffey Geotechnics' (2012) study of the potential complete drainage of aquifers above the longwalls, all of which suggest a loss of surface water to the mine network. BHPBIC have recently suggested that approximately 3.2% of total precipitation has moved into "deep storage", which suggests that this too can move into the mine if their deep storage equates to or is connected to the highly fractured goaf areas.	Leakage due to groundwater depressurisation is assessed in Appendix C. Impact on streams due to cracking is assessed in Appendix F.

Ref	Regulator	Issue	Where Addressed
155.	OEH	OEH is concerned that the general lack of investigation into the phenomenon in NSW may have led to insufficient consideration of the potential risks in recent mining proposals. There has not been any quantitative scientific evidence to support the claim that water returns to the surface at an unknown area downstream or into a reservoir. OEH has previously suggested that the loss of perched aquifers in upland swamp EECs, the consequent loss of baseflow to their connected streams and the alteration of groundwater aquifer levels has serious implications for the continued existence of these threatened ecological communities and the threatened species that rely on these habitats. Threatened species of particular concern in these areas are Littlejohn's Treefrog, Giant Burrowing Frog and the Giant Dragonfly. This situation also clearly has the potential to affect catchment yields.	Biodiversity discussion provided in Appendix G Loss and re-emergence of stream flow is discussed in Appendix E
156.	OEH	OEH believes a reanalysis of the potential surface to seam fracturing and complete aquifer drainage is required for the PPR since: • Longwalls 1-3 have increased panel widths (the largest change being for longwall 3 which is increased from 105m to 150m wide- a 43% increase) • Longwalls 6 to 10 have the pillar widths reduced from 60m to 45m • Longwall 11 has the pillar width reduced from 60m to 40m.	Groundwater discussion provided in Appendix C. Groundwater modelling has used the amended mine plan.
157.	OEH	All these changes (Table 4 of the PPR) are likely to lead to greater subsidence in some areas of the modified mine plan for Wonga East, although OEH acknowledges that subsidence will be lower in some areas as a result of the elimination of other longwalls. How these changes in mine layout interact with upland swamp EECs and potential aquifer draining have not been fully considered in the PPR.	Biodiversity discussion provided in Appendix G Groundwater discussion provided in Appendix C

Ref	Regulator	Issue	Where Addressed
158.	OEH	**Cataract Creek and its tributaries** Alteration of the natural flow regimes of streams is recognised as a major factor contributing to loss of biological diversity and ecological function in aquatic ecosystems (NSW Scientific Committee 2002). The PPR states (2.2.9.3) in regard to current mining beneath a Cataract Creek tributary that that NRE *"will continue to monitor CT1 tributary flow, water levels and water chemistry as LW5 passes beneath the tributary to clearly identify impacts that mine subsidence may have. There may be some effects on surface flow volumes but little impact on discharge into Cataract Creek'.* No evidence is presented to support this hypothesis and OEH contends that it is possible that some of the surface water will not re-emerge downstream.	Impact of groundwater depressurisation on stream flow is assessed in Appendix C. Impact of cracking on stream flow is assessed in Appendix F. Re-emergence of stream flow is discussed in Appendix E.
159.	OEH	Longwalls 1-3 will also undermine tributaries of Cataract Creek, one of which is predicted to experience valley closure between 350-650mm (Table 48). The PPR states that valley closures are likely to result in bedrock cracking and surface flow diversion and that this may result in decreased inflow in Cataract Creek and an increase in iron seepage. OEH considers Cataract Creek to be of special significance due to its ecological and biodiversity values, including as habitat to a number of threatened species. Given the interconnected nature of a creek and its tributaries, and the potential for impacts to extend up or downstream of the initial impact area, impacts to water quantity and quality along the entire stretch need to be assessed as a whole.	Water quality impacts due to cracking are assessed in Appendix C
160.	OEH	The PPR states that *"previous experience of mining under the Bald Hill Claystone outcrop in Cataract Creek indicates that there have not been any significant long term effects on the bed of the creek or the character of the creek despite LW11 in the Balgownie* Seam *causing the creek bed to subside 1.4m".* OEH is not aware of any baseline monitoring that was undertaken prior to mining in the area to support this claim.	Subsidence discussion provided in Appendix B
161.	OEH	In relation to this issue it is worth reflecting on the following points that were made by the Bulli Seam PAC on the issue of impacts of longwall mining to streams.	No response required

Ref	Regulator	Issue	Where Addressed
162.	OEH	*1. **The Panel does not subscribe to streams being represented as a series of discrete features in the landscape.** Streams form a connected linear network. Many stream values depend on the recognition of the stream system as a continuum with the value of any segment heavily dependent on what happens up and downstream and in higher and lower order components of the system. Protecting the values of streams from impacts that are broad in scale will rarely require intervention only at a series of discrete locations - it is more likely to require some form of intervention or control throughout the interconnected linear network.*	No response required
163.	OEH	2. ***In the remote areas of sandstone gorges to the east and south of the Study Area, the Panel's assessment finds that much of the value of the stream network is closely associated with its natural characteristics and its pristine setting.*** *Values relying on 'naturalness' have two distinguishing traits:* • *Even small impacts can have major consequences for naturalness values. The response is non linear with a major threshold at very low levels of impact.* • *Even with appropriate remediation, recovery of naturalness values has a long hysteresis and may in fact be irreversible. Reliance on remediation as a primaty risk management option does not recognise this trait*	No response required
164.	OEH	**Threatened Species** **Fish Monitoring** OEH previously recommended that a monitoring and management program be developed with Fisheries NSW in regard to Macquarie Perch, Trout Cod and Murray Cod in Cataract Creek. This has not been addressed in the PPR or response to submissions.	Section 2.8.2
165.	OEH	**Giant Dragonfly** OEH previously recommended that survey for the threatened Giant Dragonfly *(Petalura gigantea)* be undertaken. This has not occurred. In the Response to Submissions, CRUS1 was identified as likely habitat for this species and that the alteration of Wonga East longwalls has removed the threat to this species, OEH does not agree with this statement. Despite the revised mine plan, CRUS 1 is still predicted to experience levels of subsidence which will have the potential to result in bedrock fracturing and loss of shallow groundwater. OEH believes that the species may occur in other swamps and targeted surveys are appropriate to understand the spatial distribution of the species in the area so that impacts can be identified and avoided.	Biodiversity discussion provided in Appendix G

Ref	Regulator	Issue	Where Addressed
166.	RMS	RMS has reviewed the submitted information and is unable to make an informed comment on the proposal. In this regard, RMS provides the following comments: • RMS notes that a revision of the impact assessment is currently being carried out to account for the amendments made to the subject proposal including the reduced life of the project from 18 years to 5 years. RMS will review this report when it is provided. An electronic copy of the SIDRA analysis should be forwarded to RMS for review.	Traffic & Transport Impact Assessment is provided in Appendix I. RMS' response is provided in Appendix J.
167.	RMS	• RMS requests that the proponent provide information regarding the truck configurations to be used, including axle loadings and the additional equivalent standard axle loadings	Traffic & Transport Impact Assessment is provided in Appendix I. RMS' response is provided in Appendix J.
168.	Sydney Catchment Authority (SCA)	The SCA has reviewed the PPR and its submission is attached. In summary, while the current proposal has addressed some of the SCA's concerns, significant issues remain. **We object to the proposal as it currently stands, particularly with regard to its incursion into the Dams Safety Committee Notification Area surrounding Cataract Reservoir.**	No response required
169.	SCA	The SCA notes that the PPR proposes changes to the original proposal including: 1. Wonga east longwall layout has been modified. 2. Wonga west longwalls have been removed and are proposed to be revised and resubmitted as a separate application at a later date. 3. Wonga Mains driveage is proposed not to extend northwards under the south arm of the Cataract Reservoir through the known geological feature (in the Bulli seam). 4. The western Balgownie and western Bulli seam first workings have been removed from this application.	No response required
170.	SCA	The PPR proposes to mine Wonga east longwalls only with changes to the longwall (LW) lengths, widths, position and/or alignment and LW8 has been removed. The SCA notes that the changes to Wonga east mine layout include a reduction in the length of longwall panels in both mining areas, an increase in the panel width of Area 1 longwalls and a reduction in the main gate pillar width in Area 2.	No response required

Ref	Regulator	Issue	Where Addressed
171.	SCA	The PPR provides a revised assessment on subsidence, biodiversity and geological structures. The PPR states that the ground and surface water impacts will be determined on the outcome of surface and ground water re-modelling currently being undertaken. It further states that the ground and surface water impacts will vary due to the modification to the Wonga east layout.	Groundwater modelling discussed in Appendix C. Surface water modelling discussed in Appendix F.
172.	SCA	The SCA has adopted a set of principles that underpin its decision making in relation to mining activities in the Special Areas. These have been communicated to Gujarat NRE and to Department of Planning and Infrastructure on previous occasions and are repeated in the attached submission. The SCA has also developed performance measures for natural and built features of interest to the SCA for this project which is included in our submission. The SCA has assessed the proposed mining proposal and associated information contained in the PPR against its mining and coal seam gas principles and performance measures.	No response required
173.	SCA	The SCA has major concerns about the lack of detailed geological investigations. The SCA also has major concerns with regards to induced leakage from the Cataract Reservoir and longwall mining within the Cataract Dam Safety Committee (DSC) notification area. These concerns were highlighted in our earlier submission on the project and in subsequent correspondence.	Additional geological investigations discussed in Appendix K. Leakage from the reservoir is assessed in Appendix C.
174.	SCA	While the proposal has been modified, and some further information is available, the preferred project does not fully address the issues raised by the SCA. We therefore continue to object to the proposal in its current form.	No response required

Ref	Regulator	Issue	Where Addressed
175.	SCA	The SCA's primary concerns, based on revised information on geological structures and subsidence assessment and as outlined in this submission, relate to the potential impacts on Cataract Reservoir, Cataract River, Cataract Creek and associated tributaries, swamps and cliffs. Of particular concern is: • The potential loss of stored waters from Cataract Reservoir to underground mine workings at the upper arm of Cataract Reservoir as a result of mining induced leakage. • The impact on the environment of Cataract Creek and associated tributaries, swamps and dependent ecosystems as a result of the loss of stream flow, reduction in base flows, increased acidification and iron precipitation, and the reduction in shallow water tables affecting swamp vegetation and significant impacts to the *"Special Significance"* upland swamp CCUS4.	Leakage due to groundwater depressurisation is discussed in Appendix C. Impacts on Cataract Creek are discussed in Appendix E and Appendix F. Impacts on biodiversity are discussed in Appendix G.
176.	SCA	In light of our objection to the revised proposal, the SCA recommends: 1. The DSC Notification Area around Cataract Reservoir be adopted as an Exclusion Zone where no longwall mining is permitted (the SCA is in particular concerned about the significant extension of Longwall 7 into the DSC notification area). 2. The proposed adaptive management approach proposed for mining activities not be used due to the lag time for mining-related impacts to manifest and changes required to be implemented. 3. The SCA's performance criteria developed for the proposed mining area to be adopted.	Section 2.10.1
177.	SCA	It should also be noted that the SCA may have further comments on the PPR depending upon the findings of the yet to be completed ground and surface water assessments. As such, the SCA requests the opportunity to continue to be involved in any ongoing assessment of the application.	No response required
178.	NSW Fisheries	Fisheries NSW advises that issues raised previously have been addressed by the proponent, but remains concerned about potential impacts of mining in this area.	No response required

Appendix B

UPDATE TO SUBSIDENCE ASSESSMENT OF WOLLONGONG COAL PREFERRED PROJECT REPORT RUSSELL VALE NO 1 COLLIERY

Strata Control Technology

REPORT TO:

WOLLONGONG COAL

Update of Subsidence Assessment for Wollongong Coal Preferred Project Report Russell Vale No 1 Colliery

WCRV4263

Mining Research and Consulting Group
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REPORT TO	David Clarkson Group Environment & Approvals Manager Wollongong Coal PO Box 281 FAIRY MEADOW NSW 2519
SUBJECT	Update of Subsidence Assessment for Wollongong Coal Preferred Project Russell Vale No 1 Colliery
REPORT NO	WCRV4263
PREPARED BY	Ken Mills
DATE	18 June 2014

Ken Mills
Principal Geotechnical Engineer

SUMMARY

Wollongong Coal (WC) is proposing to mine eight additional longwall panels in an area approximately 9km north-north-west of Wollongong in New South Wales referred to as the Wonga East mining area. After consideration of submissions from the community and government agencies to its earlier Underground Expansion Project Part 3A (Pt3A) application, WC (then Gujarat NRE) significantly modified the application in a proposal referred to as the Preferred Project Report (PPR). In 2013, Gujarat NRE commissioned SCT Operations Pty Ltd (SCT) to predict the subsidence likely to be caused by the proposed longwall panels recognising the influence of previous mining in the area and to assess the likely subsidence impacts in the PPR mining area. Subsidence predictions and an impact assessment were presented in SCT Report NRE14123 dated 24 September 2013 (SCT 2013) based on the data was available at the time.

Since the completion of SCT Report NRE14123, Longwall 5 has finished, further subsidence monitoring data particularly in relation to valley closure measurements has become available, additional field studies have been undertaken, and the initial report has been peer reviewed. This current report is an update of the earlier report with the main changes being inclusion of subsidence monitoring results to the end of Longwall 5, revision of the valley closure estimates, and identification of a sandstone formation downstream of CCUS4. Changes and clarifications recommended in the peer review have also been included.

Our assessment indicates that the subsidence impacts associated with the proposed PPR mining layout can be managed to a level consistent with impacts from previous mining in the area. Continued monitoring and adaptive management strategies are considered appropriate to manage these impacts in a holistic sense, but changes in panel length may be required to completely protect individual natural features identified as ecologically or aesthetically significant depending on the balance that is struck by government between coal resource recovery and surface impacts. Mitigation measures will be required to manage the impacts on high voltage power transmission lines.

Site Description

The PPR Assessment Area is located entirely within the headwaters of Cataract River in the catchment of the Cataract Metropolitan Water Supply Reservoir and predominantly within the catchment of Cataract Creek. The surface is mainly undeveloped bushland. Surface features include sections of rain forest in the valleys, a variety of upland swamps located mainly on the valley sides and numerous sandstone rock formations on the upper slopes associated with Hawkesbury Sandstone. Some archaeological heritage sites are located within this outcrop. Several first order tributaries of Cataract Creek have formed waterfalls where they flow over Hawkesbury Sandstone formations. The surface is traversed by the Mount Ousley Road and four high voltage power transmission lines. A telecommunications installation

and the Illawarra Escarpment are located approximately 1km to the east of the proposed longwall mining area.

Coal has previously been mined in three seams at this site, the Bulli Seam, the Balgownie Seam 10m below, and the Wongawilli Seam a further 20m below that. The Bulli Seam was mined from the late nineteenth century through to the 1950's using a variety of mining systems including in the later stages mechanised pillar extraction. The Balgownie Seam was mined as one of the first longwall mining operations in Australia from 1970 through to 1982. The Wongawilli Seam has been mined by NRE with the first of two longwall panels commencing in April 2012. Within the PPR Assessment Area the overburden depth to the coal seams ranges 220-390m mainly as a result of variation in surface topography but also as a result of the strata dipping at between 1 in 25 and 1 in 30 to the west-north-west away from its outcrop on the Illawarra Escarpment.

The presence of this previous mining presents some challenges for future mining but also brings some advantages in terms of providing high confidence definition of the nature, location, and characteristics of geological structures, actual measurements of the subsidence behaviour of the overburden strata at the site during previous mining, and an extended baseline of some 60-100 years to study the recovery of natural features from previous subsidence impacts.

Prediction Methodology

The subsidence prediction methodology used in this assessment is based on previous subsidence monitoring experience at this site available from mining in the Bulli Seam (over longwall panels 6-8km to the west) and the Balgownie and Wongawilli Seams in the PPR Assessment Area. This data is considered to provide a strong basis for predicting subsidence above the proposed longwall panels, particularly when consideration is given to the mechanics of the subsidence processes involved, specifically the differences between sag subsidence over individual panels and elastic compression subsidence associated with elastic compression of the strata between panels. Tilts and strains are predicted using incremental subsidence and the approach forwarded by Holla and Barclay (2000). Maximum closure is predicted using the ACARP Method developed by Waddington and Kay (2002). Available monitoring data indicates that both approaches provide predictions that are conservative.

The approach to predicting subsidence movements that has been adopted is considered to be appropriate in the relatively complex mining environment that exists within the PPR Assessment Area especially now that there is actual subsidence data available from Longwalls 4 and 5 in the Wongawilli Seam to provide confirmation of behaviour when a third seam is mined.

The experience available from mining Longwalls 4 and 5 indicates that the subsidence behaviour is predictable albeit with somewhat different characteristics to subsidence over single seam mining operations. The main difference is that the overburden strata are more flexible as a result of the disturbance caused by previous mining. The bridging capacity across individual panels is reduced and sag subsidence in the middle of individual panels is thus greater than it would be above single seam operations.

Predicted Subsidence

Maximum subsidence over individual longwall panels in the Wongawilli Seam is predicted to range from 1.5m over the slightly narrower Longwall 7 through to 2.6m over Longwall 3 where the overburden depth is shallowest and there is overlying mining in both seams. Previous mining in the Bulli and Balgownie Seams is estimated to have caused up to about 1.9m of subsidence in some localised areas of the PPR east of the Mount Ousley Road but more generally cumulative subsidence in areas of previous mining has been in the range 0.3-1.3m.

There is considered to be some potential for pillar instability in the Bulli Seam to cause additional surface subsidence of up to about 0.5m in localised areas of marginally stable pillars when the proposed longwall panels are mined in the Wongawilli Seam. The area likely to be most affected by pillar instability is located at the northern end of Longwall 1 and although the area is relatively small compared to overburden depth, special consideration is required in this area to limit impacts on power transmission pylons located nearby.

Maximum tilts over individual longwall panels in the Wongawilli Seam are expected to range up to maxima of 24mm/m over Longwall 10 through to maxima of 51mm/m above Longwall 3. Although these maxima may occur anywhere in the panel, they are most likely to occur at panel edges in overlying seams and in areas of topographic change in gradient. More generally across the panel, systematic tilts are likely to be in the range 50-90% of the maximum values.

Maximum strains over individual longwall panels in the Wongawilli Seam are expected to range up maxima of 14mm/m over Longwall 10 to maxima of 31mm/m over Longwall 3. Although these maxima may occur anywhere within the panel, maximum tensile strains are most likely to occur at topographic high points and maximum compression strains are most likely to occur at topographic low points. More generally across the panel, systematic strains are likely to be 20-30% of the maximum values.

The predicted closures across Cataract Creek have been revised slightly from the earlier report. Total closures are predicted to range up to 300mm adjacent to the end of Longwall 5 and up to 290mm adjacent to the end of Longwalls 6 and 7. Closure across the second order southern branch of Cataract Creek upstream of the Mount Ousley Road crossing is predicted to reach 700mm. These closure estimates are recognised as being upper limit values because they are based on experience in deep gorges at high stress levels. Monitoring to date indicates closure movements of up to 49mm. These movements are less than 40% of the 135mm predicted for Longwall 5 only.

The following table summarises the subsidence that has occurred in the area of each longwall panel during mining in the Bulli Seam (estimated) and the Balgownie Seam (measured) as well as the subsidence that is predicted above each longwall panel from proposed mining in the Wongawilli Seam.

General Observations Above Individual Panels	Previous Bulli and Balgownie Seam Subsidence (m)	Predicted Additional Subsidence for PPR Wongawilli Seam (m) and Measured (in bold)	Predicted Tilt for PPR Wongawilli Seam (mm/m) and Measured (in bold)	Predicted Tensile Strain for PPR Wongawilli Seam (mm/m) and Measured (in bold)	Predicted Compressive Strain for PPR Wongawilli Seam (mm/m) and Measured (in bold)	Predicted Maximum Closure on Cataract Creek (mm) (Southern Tributary in Brackets – LW1-3)
Longwall 1	1.3	2.1	40	12	24	N/A (700)
Longwall 2	1.1	2.1	40	12	24	N/A (300)
Longwall 3	1.3	2.6	51	15	31	N/A (150)
Longwall 4	1.9	2.1 (**1.8**)	35 (**30**)	10.5 (**7.5**)	21 (**14**)	N/A
Longwall 5	0.9	1.9 (**1.8**)	36 (**16**)	10.8 (**6**)	22 (**12**)	300 (**49**)
Longwall 6	1.5	2.1	38	11	23	290
Longwall 7	1.2	1.5	28	8	17	290
Longwall 9	0.5	2.1	32	10	19	50
Longwall 10	0.6	1.6	24	7	14	30
Longwall 11	0.6	2.1	30	9	18	10

Movements outside the goaf edge (i.e. edge of each longwall panel) are expected to be similar to the movements observed beyond the goaf edges of Longwalls 4 and 5. Vertical movements of greater than 20mm are expected to be limited to within a distance of about 0.7 time overburden depth from the nearest goaf edge equivalent to an angle of draw of 35°. In areas where there is either solid coal or substantial coal pillars directly above the goaf edge, goaf edge subsidence is expected to be of the order of 100-200mm. In areas where there has been previous mining in both the overlying seams, vertical subsidence at the goaf edge is expected to increase up to 300-500mm and the goaf edge subsidence profile is expected to be more gradual outside the goaf edge and steeper directly over the panel.

Impact Assessment

The impacts of mining subsidence on surface features are considered in detail within the body of the report. These features include natural features such as Cataract Creek, Cataract River, upland swamps, sandstone cliff formations including the Illawarra Escarpment and some smaller sandstone outcrops where first order creeks have formed waterfalls, archaeological heritage features, and surface infrastructure including Mount Ousley Road, four high power transmission lines, Cataract Water Supply Reservoir, and a telecommunications installation on Brokers Nose.

Cataract Creek flows across the PPR Assessment Area. The PPR mine layout has been designed to avoid longwall extraction directly under the main channel of Cataract Creek and particularly the third and fourth order sections. An adaptive management strategy based on closure monitoring and cessation of longwall extraction if there is a likelihood of significant perceptible impacts becoming apparent is considered to be an effective method for managing the potential for subsidence impacts on Cataract Creek.

The valley closure measurements observed during mining of Longwall 5 are much less than predicted using the available methodology. The closure movements have occurred gradually and incrementally with mining allowing them to be predicted in advance with reasonable confidence. The more difficult challenge is determining the level of closure that is likely to cause impacts to the creek. Cataract Creek has previously been subsided up to 1.2m by mining Longwall 11 in the Balgownie Seam with closure of 350mm measured across Cataract Creek. This closure has not resulted in apparent impact, possibly because of the position of the creek in the stratigraphic section and the presence of Bald Hill Claystone in the base of the creek. There has been no perceptible impact from 49mm of closure associated with mining Longwall 5. An adaptive management scheme based on avoiding perceptible impacts is considered to be appropriate.

Cataract River is remote from the proposed mining in an area where there are not expected to be any perceptible impacts.

Biosis (2013) has mapped and described 33 separate upland swamps within the PPR Assessment Area. Many of these swamps have been previously mined under in both the Bulli Seam and Balgownie Seam. The proposed mining is not expected to cause significantly different impacts to those already experienced. It is considered that more work is required to determine the relationship between mining subsidence and the long term health of swamps. The extended baseline of subsidence impacts over 60-100 years in the Bulli Seam and 30-40 years in the Balgownie Seam provides a rare opportunity to study these effects. The development of a monitoring and review strategy involving relevant experts is recommended to manage mining impacts on these swamps. This process should include a review of the recovery of these features from previous impacts and the implication of this recovery for future swamp protection strategies.

CCUS4 has been identified as a significant swamp within the PPR mining area that drains via a first order watercourse. CCUS4 has previously been subsided 0.6-0.8m by mining in the Balgownie Seam without apparent impact. Proposed mining in the Wongawilli Seam is expected to cause up to 2.1m of additional subsidence. Impacts such as cracking of the sandstone base and surface water diversion are expected as a result of proposed mining.

There are numerous sandstone cliff formations located within the Hawkesbury Sandstone outcrop in the PPR Assessment Area. Most of these are less than 5m high. Some perceptible cracking on hard rock surfaces is expected to be apparent as a result of the proposed mining. Minor rock falls are expected on up to 5% of the length of sandstone cliff formations that are mined directly under. It is noted that there are a number of rock falls present across the site that can be attributed to previous mining impacts and others that have occurred naturally.

There are several locations where drainage lines and first order creeks flow over sandstone outcrops to form waterfalls following periods of heavy rain. Field inspections conducted since the previous report was prepared have identified the presence of several such features that were not apparent in original LiDAR surveys used to characterise the cliff formations because of their small size and the presence of downstream boulders.

Two of these features are approximately 7m high. However, only the feature at the downstream edge of CCUS4 is regarded as a semi-permanent waterfall. The others are either located on drainage lines that have no permanent flow or have been impacted by previous mining so that water emerges from the base of the rock formation during periods of low flow rather than flowing over it like a waterfall. Some impact from previous mining is apparent at each of these rock formations. Proposed mining is expected to cause further impacts including rock falls and cracking.

Nineteen Aboriginal heritage sites have been identified within the PPR Assessment Area. Some of these sites have potential to be impacted by rock falls caused by mining subsidence. A detailed assessment of these sites is presented in the body of the report and in Biosis (2013).

Mount Ousley Road is protected from direct mine subsidence by a horizontal distance from the nearest goaf edge equal to half overburden depth. Low levels of vertical subsidence of less than about 100mm in total are expected in the vicinity of Mount Ousley Road with up to approximately 40mm of this maximum having already occurred from mining Longwalls 4 and 5. These low level vertical movements are expected to be imperceptible for all practical purposes. Tensile cracking adjacent to the topographic high ground south of Cataract Creek and closure of up to a maximum of about 50mm is expected at the crossing of Cataract Creek. Some 11mm of closure was measured during mining of Longwall 5. There is considered to be no potential for significant horizontal movements to impact the Picton Road Interchange and no movements attributable to mining have been measured in the subsidence monitoring conducted to date.

There are four power transmission lines located in two corridors between Mount Ousley Road and the Illawarra Escarpment. All four lines were mined under by Longwalls 1 and 3 in the Balgownie Seam and potentially by late stage pillar extraction in the main heading pillars in the Bulli Seam although this latter mining may have preceded their construction. Subsidence movements predicted in the vicinity of four of the towers (two each on the 330kV and 132kV lines) are expected to be sufficient to require construction of cruciform bases to protect them from mining subsidence. T56 on the 330kV line will require a special design to accommodate the slight change in direction that occurs at this tower. Vertical subsidence of up to 2.1m and horizontal valley closure movements of up to 700mm are expected in the vicinity of some of the pylons.

The 33kV single and double pole structures are relatively tolerant of subsidence movements and because these structures are located more than 60m outside of the footprint of the longwall panels no protection measures are considered necessary, although a monitoring regime is nevertheless recommended.

The Cataract Water Storage Reservoir is not expected to be impacted by the proposed mining. The Full Supply Level (FSL) for the reservoir including the section that extends up Cataract Creek is protected from the nearest longwall goafs by a nominal horizontal distance of greater than 203m at 290m overburden depth (equivalent to 0.7 times overburden depth or an angle of draw of 35°). Vertical subsidence at the FSL is expected to be less than about 20mm.

Geological structures within the PPR Assessment Area are well defined because of the previous mining that has occurred in the overlying Bulli Seam over a large area and the overlying Balgownie Seam in a more limited area. The only geological structure that extends through to the proposed longwall panels in the PPR Assessment Area and the reservoir is Dyke D8. The horizontal distance along the dyke from the end of Longwall 10 to the FSL is approximately 560m at an overburden depth of 320m at the FSL. There is considered to be no potential for proposed mining to intersect the stored waters directly.

There are a number of small pre-existing Bulli Seam mining areas where, due to the legislative standards of the day, pillar extraction was permitted within the 0.7 times depth protection zone around the FSL. There does not appear to be any direct connection between the reservoir and the mining horizon through these mining areas. Although their presence appears to reduce the effectiveness of the 0.7 times depth barrier between the FSL and the proposed mining somewhat, particularly for mining of Longwalls 7 and 9, the pathway for seepage from the reservoir to the mine is likely to be predominantly along horizontal shear planes at or just below the level of the valley. This pathway is not expected to interact with the pre-existing Bulli Seam mining areas. As a result, there is not considered to be any potential for these existing Bulli Seam mining areas to significantly reduce the effectiveness of the 0.7 time depth barrier.

The Illawarra Escarpment at Brokers Nose and the telecommunications infrastructure located on it are protected by a horizontal distance of approximately 1km from the nearest point on Longwall 1. No ground movements or any perceptible impacts are expected in this area as a result of the proposed mining.

Management Strategies

The subsidence management strategies recommended include continuation of the upgrade to subsidence monitoring technique that has been ongoing since the start of Longwall 4. This upgrade has included measuring subsidence movements in three dimensions, increasing the resolution of valley closure monitoring, and establishing more reliable GPS based survey control points.

Ongoing management and review of subsidence impacts to Mount Ousley Road by a technical committee headed by the asset owner is considered suitable to manage the potential for any future impacts on the road and associated infrastructure. This approach was used successfully for managing the impacts from Longwalls 4 and 5. The half depth barrier used to substantially protect the road alignment provides a relatively high level of protection. Some consideration to remedial work to prevent water ingress into minor tension cracks that have formed is recommended to protect the road sub-base.

To manage potential impacts on the power transmission towers prior to mining Longwalls 1-3, it is recommended that a technical committee be formed with representatives from the colliery, the power utility companies, the Mine Subsidence Board, and government regulators. Several of the power transmission towers are likely to require the construction of cruciform bases to allow them to remain structurally stable during mining, a process that usually requires a significant lead time.

The Dams Safety Committee (DSC) is a statutory body with legal powers to manage mining to protect the stored waters in Cataract Reservoir. The colliery has been working with the DSC for many years and it is considered that the management process that has been adopted in the past continues to be appropriate. The 0.7 times depth (approximately 200m) stand-off from the FSL is the primary control for protecting the stored waters of Cataract Reservoir and this stand-off is expected to provide a high level of protection notwithstanding the presence of previous extraction in the Bulli Seam.

The detail of monitoring of swamps, cliff formations, heritage sites, and creek biota is beyond the scope of this report and has been addressed in other specialist's reports. However, it is recommended that one or more technical committees are formed to design monitoring programs that not only review the changes that may be associated with proposed mining but also take the opportunity to review the longer term impacts from previous mining in the same area. Ideally these technical committees would include external expertise from the community where appropriate so that monitoring programs are targeted, appropriate, can be ongoing, and are transparent to all stakeholders.

Response to Submissions to UEP Pt3A and Original PPR

A range of submissions were received in response to the Underground Expansion Project Pt3A (Pt3A). These submissions were received prior to the PPR amendments and while the PPR amendments have addressed many of the issues raised, a number of these issues are worth discussing in the context of the PPR design and how they have driven the changes that have been made to the design and the design process. There have also been submissions to the PPR itself. The response to this second group of submissions is included in an appendix to this report with the report itself updated to address the issues raised.

The subsidence prediction technique used in the original UEP Pt3A has been updated to reflect the subsidence monitoring data available from Longwalls 4 and 5. The revised approach is based on using the available data to provide insight into the subsidence mechanics and continuing to develop this understanding recognising the various subsidence processes involved. Although there is somewhat greater uncertainty for subsidence predictions in a multi-seam environment, the available data indicates that the behaviour observed is repeatable and consistent with the mechanics of the subsidence processes as currently understood.

There are a number of geological structures located in the general area of the proposed mining, but only one dyke (D8) is considered to be significant in the context of the proposed mining. The others are located away from the areas of mining and are not considered to have any significant potential to be affected by mining. A significant benefit of the previous mining activity is that the dykes and faults through the area are very well defined by previous mining activity.

The potential in the Bulli Seam for pillar instability and latent subsidence (where full subsidence has not occurred during previous mining) has been recognised as having some potential to cause additional subsidence at the northern end of Longwall 1 and this area is requires special consideration prior to mining Longwall 1. Other areas where there may be a similar potential are more difficult to identify because the mine records for the period of mining may be incomplete or inaccurate due to the survey and drafting standards of that time. The significance of any additional surface subsidence that may result is considered to be low, especially in terms of additional impacts to major surface infrastructure above the impacts expected.

The prediction of valley closure, upsidence, and far-field movements is recognised as being only approximate. Offsets that have been designed into the revised mine layout are aimed to avoid mining directly under the main channel of Cataract Creek to provide a buffer against closure related impacts and this protection is supported by Wollongong Coal's commitment to stop the longwalls short if closure movements become likely to cause unacceptable impacts.

There is considered to be no potential for the proposed mining to impact on the Illawarra Escarpment and in particular the section of Hawkesbury Sandstone outcrop at Brokers Nose. It should be recognised that there is always potential for cliff falls to occur naturally as part of the ongoing erosion processes.

The subsidence monitoring systems being used at Wollongong Coal have been upgraded from two dimensional surveying techniques used during the initial stages of mining Longwall 4 through to full three dimensional monitoring with an improved GPS survey control network.

Adaptive management strategies are being practiced by Wollongong Coal. Examples include the significant revision to the mine layout represented by the PPR and the use of closure monitoring across Cataract Creek to control the length of Longwalls 5, 6 and 7.

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1. INTRODUCTION

Wollongong Coal (WC) is proposing to mine eight additional longwall panels in an area approximately 9km north-north-west of Wollongong in New South Wales referred to as the Wonga East mining area. After consideration of submissions from the community and government agencies to its earlier Underground Expansion Project Part 3A (Pt3A) application, WC (then Gujarat NRE) significantly modified the application in a proposal referred to as the Preferred Project Report (PPR). In 2013, Gujarat NRE commissioned SCT Operations Pty Ltd (SCT) to predict the subsidence likely to be caused by the proposed longwall panels recognising the influence of previous mining in the area and to assess the likely subsidence impacts in the PPR mining area. Subsidence predictions and an impact assessment were presented in SCT Report NRE14123 dated 24 September 2013 (SCT 2013) based on the data was available at the time.

Since the completion of, Longwall 5 has finished, further subsidence monitoring data particularly in relation to valley closure measurements has become available, additional field studies have been undertaken and cliff formations identified, and the initial report has been peer reviewed. This current report is an update of the earlier report with the main changes being inclusion of subsidence monitoring results to the end of Longwall 5, revision of the valley closure estimates, and identification of several rock formations not identified in the original PPR assessment. Changes and clarifications recommended in the peer review have also been included.

The report is structured into three parts:

The first part, Section 2, describes the site, the background to the project and the rationale for the mining layout in the Preferred Project showing changes to the geometry compared to the earlier Pt3A application, the geological setting, and an overview of the surface features.

The second part, Sections 3 to 7, describes the previous mining activity, the past and future subsidence including available monitoring data from mining in one, two, and three overlying seams, a description of the subsidence prediction methodology and a discussion of the accuracy and level of confidence that can be placed in the predictions, estimates of subsidence for the proposed mining based on the data currently available, an assessment of likely subsidence impacts on each of the surface features including a review of past impacts and the threats that previous mining activity still has for unpredictable subsidence behaviour. In the last section, a range of strategies to manage the subsidence impacts expected are presented and discussed.

The third part, Section 8, presents a response to submissions to the earlier Part 3A application where these responses remain relevant to the PPR and a response to the more recent submissions provided for the initial PPR report.

2. SITE DESCRIPTION

This section is structured to provide an overview of the site, background to the PPR and the Assessment Area and changes since the Underground Expansion Project Pt3A application, a review of surface ownership, an overview of the main surface features and the geological setting.

This site description section is presented primarily to provide context for the subsidence assessment. More detail of specific aspects of various features such as the geological setting, the flora and fauna, surface features such as swamps and cliffs, archaeological and other heritage sites, and surface and groundwater interactions is presented in other specialist reports associated with the project.

2.1 Site Overview

Figure 1 shows the location of the PPR Assessment Area superimposed on a 1:25,000 topographic series map. Detail of the surface contour available from LiDAR (Laser Interferometric Detection and Ranging) imagery flown since the production of the 1:25,000 series topographic series map has been used to refine the location of surface watercourses, particularly Cataract Creek. These watercourses have been coloured on the basis of their stream order using the approach described in the Strategic Review into Impacts of Underground Coal Mining on Natural Features in the Southern Coalfields (NSW Department of Planning 2008). The longwall panels discussed in this report and shown in Figure 1 include Longwalls 4 and 5 in the Wongawilli Seam both of which have already been mined.

The Assessment Area is located entirely within the headwaters of Cataract River and the Cataract Reservoir and predominantly within the catchment of Cataract Creek. The surface is mainly undeveloped bushland. Surface features include sections of rain forest in the valleys, a variety of upland swamps located mainly on the valley sides and numerous sandstone rock formations on the upper slopes associated with Hawkesbury Sandstone outcrop. The surface is traversed by the Mount Ousley Road and four high voltage power transmission lines.

2.2 Project Background

Gujarat NRE purchased the colliery in December 2004. In February 2014, Gujarat NRE formally changed its name to Wollongong Coal. In this report, the company is referred to as Wollongong Coal (WC) except in relation to events that occurred prior to the formation of WC. Similarly the NRE No 1 Colliery has been renamed Russell Vale Colliery.

Russell Vale Colliery is located near Russell Vale in the Illawarra region of New South Wales (NSW). Extensive underground mining has been undertaken within the colliery holdings dating from the late nineteenth century. However, a substantial volume of high quality coking coal resources remains along with some potential thermal coal resources.

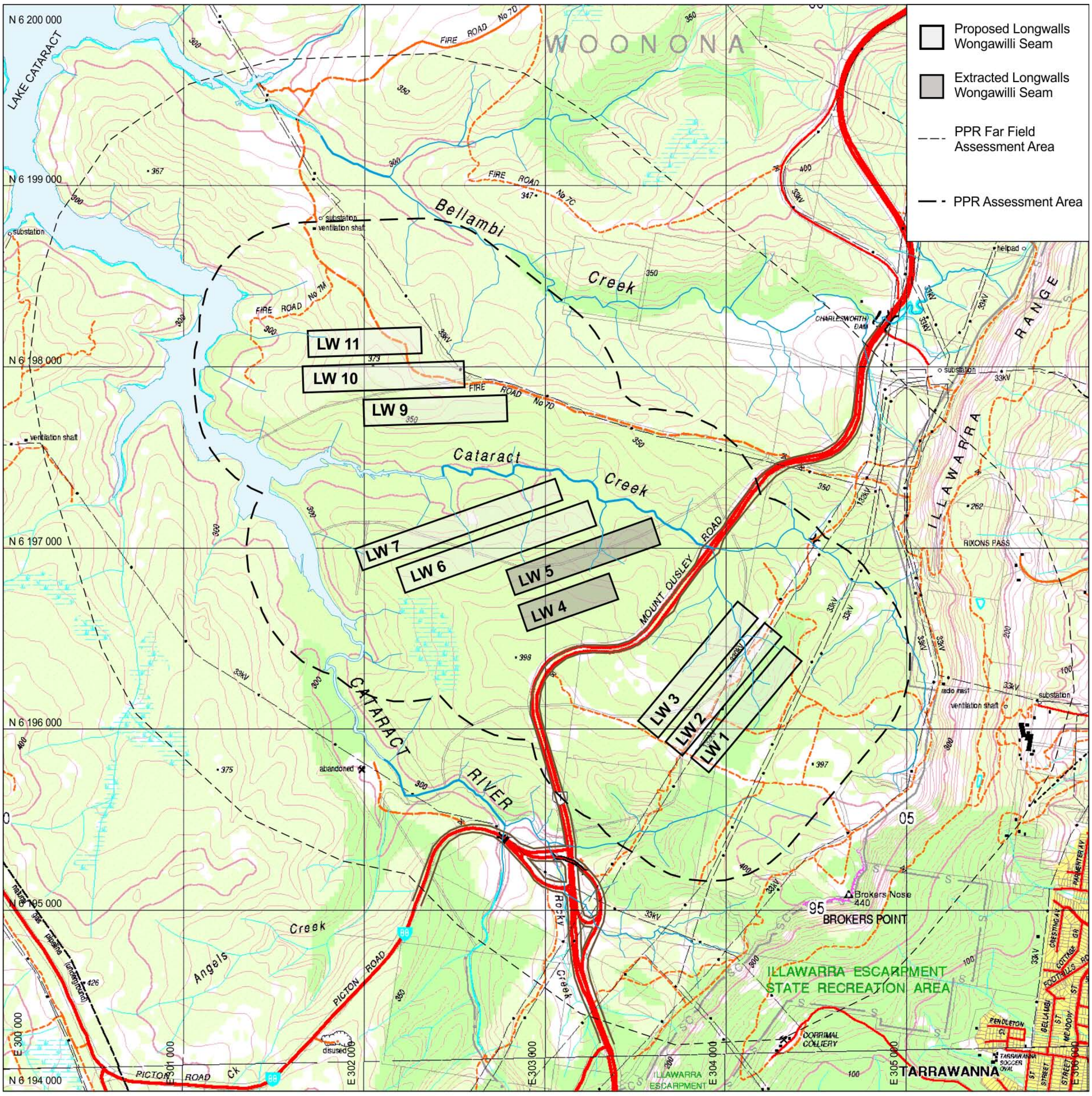


Figure 1: Plan showing location of PPR Assessment Area and proposed longwall panels superimposed onto a 1:25,000 topographic series map with creek alignments update based on LiDAR imaging of the ground surface.

The colliery holding includes a number of sub leases between WC and surrounding mine operators, including Consolidated Coal Lease (CCL) 745, Mining Purposes Lease (MPL) 271 and Mining Lease (ML) 1575 and covers a total area of approximately 6,973 hectares (ha).

Originally, NRE intended to expand its Wongawilli Seam operations in two stages. Stage 1 plans were included in the Preliminary Works Pt3A that was approved on 13 October 2011 allowing some first workings coal extraction and surface facility upgrades. On 24 December 2012, the Preliminary Works Part 3A was modified to allow the extraction of Longwalls 4 and 5 and the development of Maingate 6.

The original Stage 2 application known as the Underground Expansion Project Pt3A was lodged with the DPI on 12 August 2009 and contained an application to extract eleven longwalls in the Wonga East area and seven longwalls in the Wonga West area along with surface facilities upgrades to allow production of up to 3Mtpa for up to 20 years. Since that time the application has been progressing through the Major Project approvals process and was placed on Public Exhibition on 18 February 2013.

As a result of the submissions received on the application, NRE made the decision to substantially revise the application to facilitate the approval process and allow continuity in operations. Due to the scope of the changes, the New South Wales Department of Planning and Infrastructure (DPI) requested NRE to prepare a Preferred Project Report for the revised Underground Expansion Project Pt3A.

The Preferred Project report outlines the revised Underground Expansion Project which has been reduced to a 5 year interim stage project, with extraction of eight longwalls in the Wonga East area and upgrading of surface facilities to manage an extraction rate of up to 3Mtpa ROM coal per annum. The original Wonga West longwall extraction is planned to be reviewed and resubmitted to DPI as a separate application at a later time.

2.3 PPR Assessment Area

Taking account of the various submissions received, the longwall panels in the PPR have been designed recognising the following constraints:

- The constraints of the mine lease.
- Geological constraints including the Corrimal Fault in the south, dyke D8, silling (an igneous intrusion within the seam) in the north, and coal quality considerations and its impact on mining height.
- Mining constraints associated with the need for main headings in the north and the legacy of previous mining extent and geometry.
- Surface subsidence constraints including:

- o Avoiding longwall extraction within 0.7 times depth (equivalent of 35° angle of draw) of the full supply level (FSL) of Cataract Reservoir including the section of the reservoir that extends up Cataract Creek.

- o Avoiding mining directly under the third and fourth order sections of Cataract Creek.

- o Minimising impacts on Mount Ousley Road to tolerable levels by remaining beyond approximately half depth (equivalent to 26.5° angle of draw) from the road easement.

- o Significant upland swamps

These constraints are illustrated in Figure 2 together with the PPR layout and the original layout proposed for the Underground Expansion Project Pt3A application. In the PPR, Longwall 8 has been left out, most of the panels have been shortened, Longwall 7 has been narrowed, and six of the panels (Longwalls 1-3 and 9-11) have been rotated in order to remain within the constraints described above. The only constraints that were not able to be completely accommodated within the realignment were the upland swamp known as CCUS4 including a 7m high waterfall on the downstream edge of CCUS4 located on a first order tributary flowing from the swamp, a small part of upland swamp CRUS1 located above Longwall 6, and a small part of upland swamp CRUS5 located above Longwall 7.

The PPR Assessment Area has been defined as an area that extends to a horizontal distance of 600m from the outside edge of any of the proposed longwall panels including Longwalls 4 and 5 (NSW Department of Planning 2008). A second far field assessment area extending to 1.5km outside the proposed longwall panels has been used to include significant features such as the Illawarra Escarpment, the power pylons at changes of direction, and the bridges of the Picton Road Interchange that while remote from mining are within the area where far-field horizontal movements may occur.

Longwall 4 and 5 are included in the assessment area and this subsidence assessment because:

- Although they were mined under a different regulatory process, they are nevertheless within the purview of the current mining area and it is appropriate to assess their impacts in this context.

- The levels of subsidence measured were significantly higher than predicted using the single seam subsidence prediction methodology used for the original assessments and therefore reassessment is considered appropriate.

- The measured subsidence movements and impacts provide a gauge of the accuracy of the prediction methodology and impact assessments.

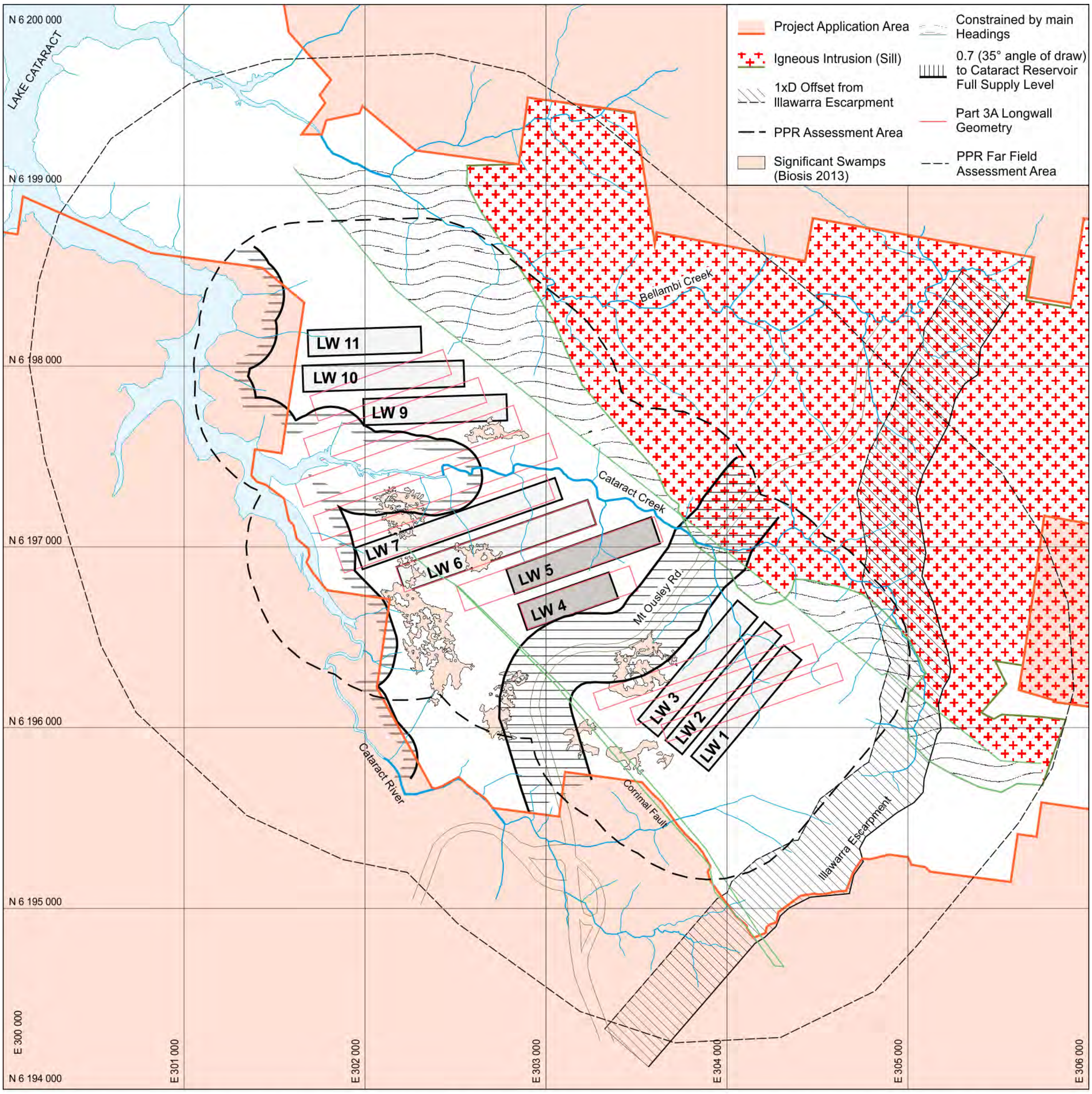


Figure 2: Plan showing the design constraints (lease, geological, mining, and surface protection) as the basis for the PPR mine layout design.

2.4 Surface Ownership

Figure 3 shows the surface ownership within the PPR Assessment Area. Most of the area is within the Metropolitan Special Area for Cataract Water Supply Reservoir. The surface area above the catchment is administered by the Sydney Catchment Authority (SCA). The stored waters of Cataract Reservoir are also administered by the Dams Safety Committee (DSC). A large part of the area to the east of Mount Ousley Road and small areas to the west are owned by WC. The easement for the Mount Ousley Road and an area northeast of the Picton Interchange within the Assessment Area is owned and administered by the Roads and Maritime Services (RMS).

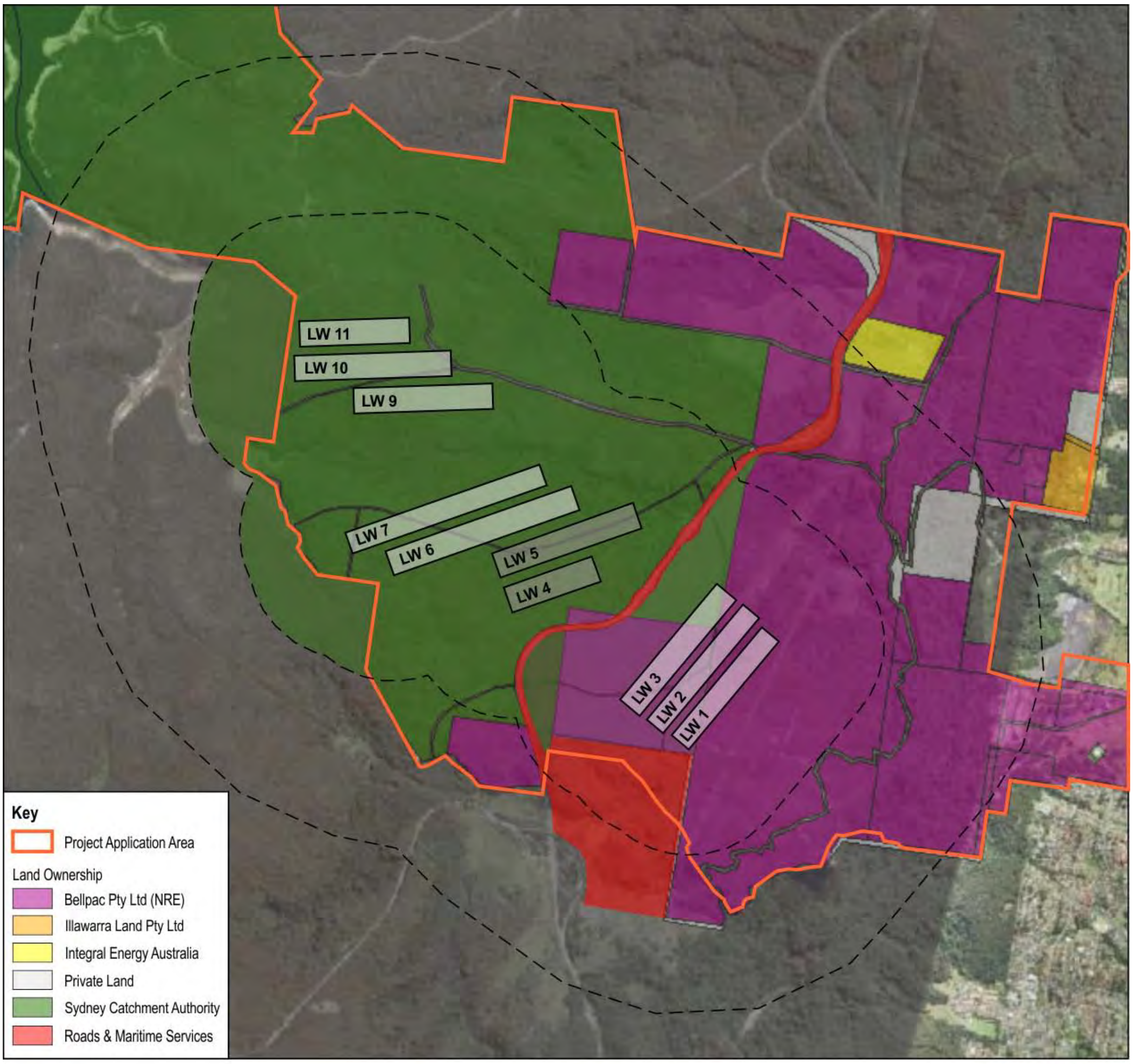


Figure 3: Plan showing land ownership within PPR Application Area. (Diagram modified from Figure 1.5 of EA from Environmental Resources Management Drawing Number 0079383s_EA_GIS013_RO.mxd dated 22/9/10).

2.5 Surface Infrastructure

Major infrastructure within the Assessment Area includes the Mount Ousley Road and four high voltage power lines to the east that cross the area. The location of this infrastructure is shown on the topographic map in Figure 1.

Mount Ousley Road (recently renamed the M1 Princes Motorway) is a major four lane highway connecting New South Wales largest and third largest cities. This road is administered by Roads and Maritime Services (RMS). The interchange with the Picton Road is located to the south outside the Assessment Area but within the 1.5km far field assessment area. This interchange includes a concrete bridge and several drainage culverts.

Mount Ousley Road was constructed as a defence route during 1942 with duplication of the highway commencing in 1965 reaching Picton Road from the south in 1979 (OzRoads 2012). A major deviation at Cataract Creek was opened in 1980. The northbound carriageway on Mount Ousley Road at Cataract Creek was last resurfaced in 2009 with the surface expected to last 10-12 years (Vecovski 2012). The southbound carriageway was last resurfaced in 2003 and resurfacing of this section is expected within 5-6 years.

There are four power transmission lines located within the Assessment Area, a 330kV transmission line owned and maintained by Transgrid, a 132kV transmission line located alongside that is owned and maintained by Endeavour Energy and two 33kV transmission lines and associated infrastructure owned and maintained by Endeavour Energy. There are also two more 33kV lines and sub-station infrastructure located outside the Assessment Area but within or just outside the 1.5km far field assessment area. One of these line services colliery infrastructure.

There is a telecommunications installation located adjacent to the Illawarra Escarpment at Brokers Nose. This facility is approximately 980m from the goaf edge of Longwall 1. The site is outside the PPR Assessment Area but within the far field assessment area.

2.6 Natural Features

Major natural features and natural resources in the area include the Illawarra Escarpment and the upper parts of Lake Cataract that forms part of the Sydney's water supply catchment. The Illawarra Escarpment is located some 800-900m east of proposed Longwall 1 and outside the PPR Assessment Area but within the far field assessment area. Approximately one third of the Assessment Area and sections of five longwall panels are located within the DSC Cataract Notification Area (revised in 2013).

There are numerous natural swamps identified within the Assessment Area. The nature and distribution of these swamps are described in detail in associated specialist reports (Biosis 2013).

There are numerous sandstone cliff formations located within the Hawkesbury Sandstone outcrop in the PPR Assessment Area. Most of these are less than 5m high. Some perceptible cracking on hard rock surfaces is expected to be apparent as a result of the proposed mining. Minor rock falls are expected on up to 5% of the length of sandstone cliff formations that are mined directly under. It is noted that there are a number of rock falls present across the site that can be attributed to previous mining impacts and others that have occurred naturally.

There are several locations where drainage lines and first order creeks flow over sandstone outcrops to form waterfalls following periods of heavy rain. Field inspections conducted since the previous PPR assessment was prepared have identified the presence of several such features that were not apparent in original LiDAR surveys used to characterise the cliff formations because of their small size and the presence of boulders immediately downstream.

Two of these features are approximately 7m high. However, only the feature at the downstream edge of CCUS4 is regarded as a semi-permanent waterfall on a first order watercourse. The others are either located on drainage lines that have no permanent flow or have been impacted by previous mining so that water emerges from the base of the rock formation during periods of low flow rather than flowing over it like a waterfall. Some impact from previous mining is apparent at each of these rock formations. Proposed mining is expected to cause further impacts including rock falls and cracking.

2.7 Heritage Features

Several Aboriginal heritage sites have been identified within the Assessment Area. These sites are mainly associated with rock shelters in sandstone cliff formations and grinding groove sites on upland sandstone outcrops. One of the shelter sites appears to have been impacted by instability of the associated sandstone overhang either as a result of previous mining in the Bulli Seam or as a result of tree root invasion and natural erosion processes.

2.8 Geological Setting

In this section, an overview of the geological setting is presented as context for the subsidence assessment. The geological setting is described in more detail in Clark (2013) but several of the key diagrams are reproduced here.

Within the Assessment Area, the strata dip at between 1 in 25 and 1 in 30 to the west-north-west from outcrop on the Illawarra Escarpment.

Figure 4 shows a plan of the geological formations that outcrop at the surface and the geological structure that exists at the Wongawilli Seam level and at the surface. Hawkesbury Sandstone is present on the surface over most of the Assessment Area. The Bald Hill Claystone that underlies the Hawkesbury Sandstone outcrops in Cataract Creek and its tributaries.

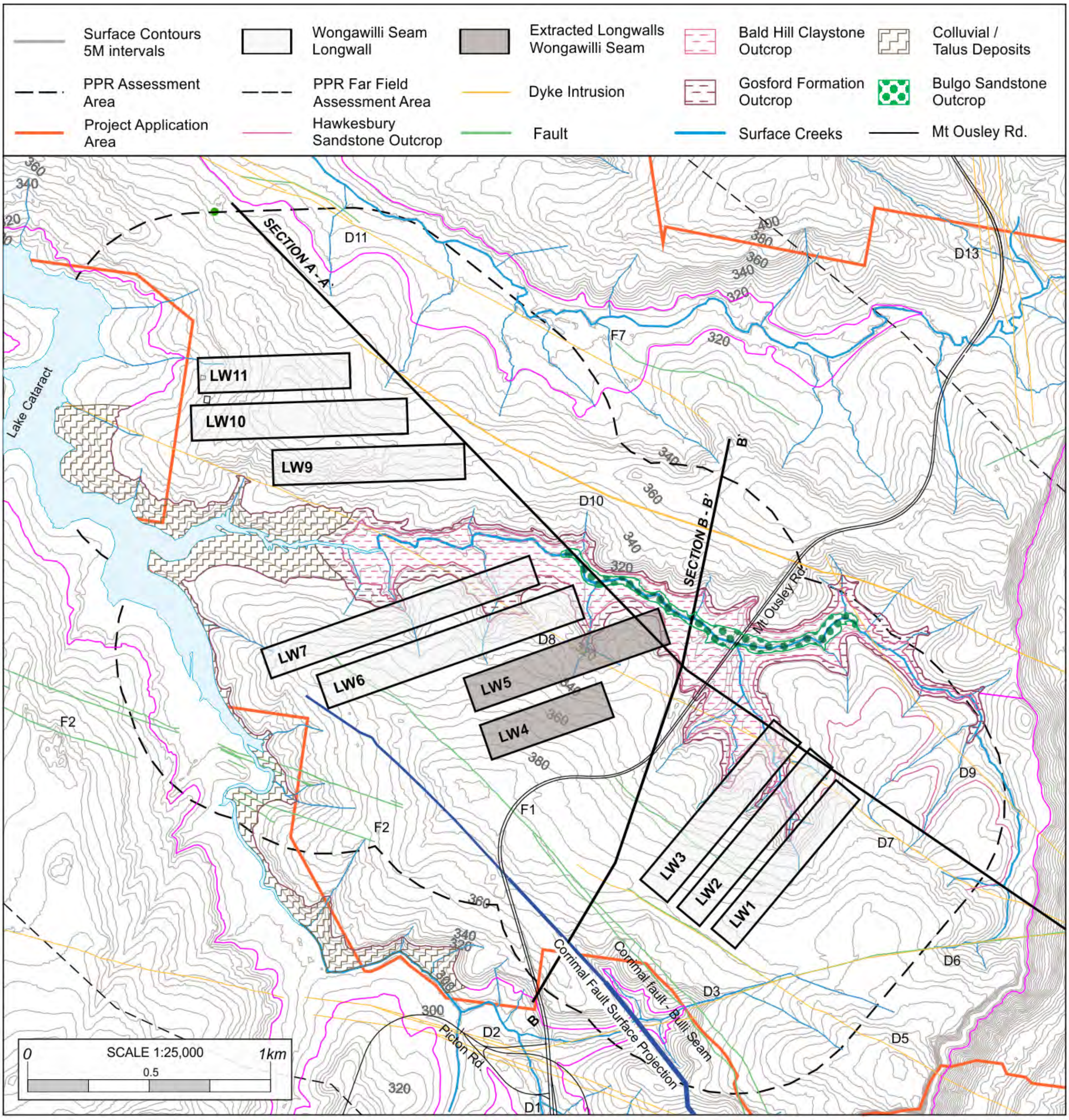


Figure 4: Plan showing geological outcrop at the surface and the location of major geological structures. (reproduced from Figure 11 of Clark 2013).

The Bulgo Sandstone that underlies the Bald Hill Claystone outcrops along the main channel of Cataract Creek on both sides of Mount Ousley Road.

Figure 5 shows a cross-section through the Assessment Area extending from south to north in the vicinity of Mount Ousley Road drawn at natural scale. This section shows how Cataract Creek has cut down through the stratigraphy near the top of the anticlinal structure (an upward or arch shaped fold in the geological strata) that exists in this area.

2.8.1 Coal Seams

The three coal seams that have been mined at the colliery are all located within the Illawarra Coal Measures.

The Bulli Seam is the uppermost of the three seams and averages about 2.2m in thickness across the Assessment Area. Figure 6 shows the layout of the Bulli Seam workings and the geological structure in the Bulli Seam (reproduced from Clark 2013).

The Balgownie Seam is located on average about 10m below the floor of the Bulli Seam ranging from 5m to 14m across the Assessment Area. Figure 7 shows the layout of the Balgownie Seam workings and the geological structure in the Balgownie Seam. The Balgownie Seam is approximately 1.2m thick, but anecdotal evidence from miners who worked the seam and subsidence monitoring indicates that the mining height may have been up to 1.5m on the longwall faces to accommodate the mining equipment. It is understood the additional height was gained by mining the immediate floor strata.

The Wongawilli Seam is located approximately 20m below the Balgownie Seam and ranges in thickness from 7.7m to 11.9m, but the lower 2.6-2.8m is the best quality. It is this section that is planned to be targeted by proposed longwall extraction. The development roadways are mined to a greater height for operational reasons. Figure 8 shows a plan of the geological structure at the Wongawilli Seam level reproduced from Clark (2013) and modified to include the Wongawilli Seam floor contours.

The floor of the Wongawilli Seam has an elevation of approximately RL 80mAHD at the north eastern corner of Longwall 1 and an elevation of approximately RL-25mAHD at the north western corner of Longwall 11. The dip of the seam between these two points is, for practical purposes, constant.

2.8.2 Geological Structures

The geological structure in each seam is shown in Figures 6-8. The major geological structures of interest in the area are igneous sills and dykes and the Corrimal fault. The vertically continuous structures are evident in the Bulli and Balgownie Seam and in the geomorphology on the surface. The position of these features is considered to be well defined as a result of the underground exposures.

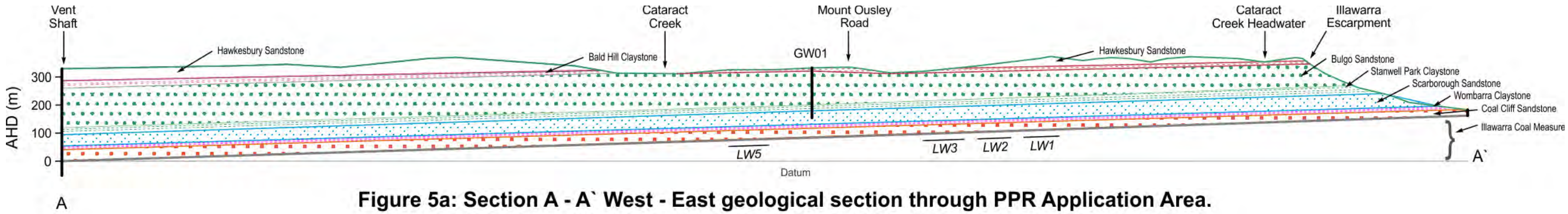


Figure 5a: Section A - A` West - East geological section through PPR Application Area.

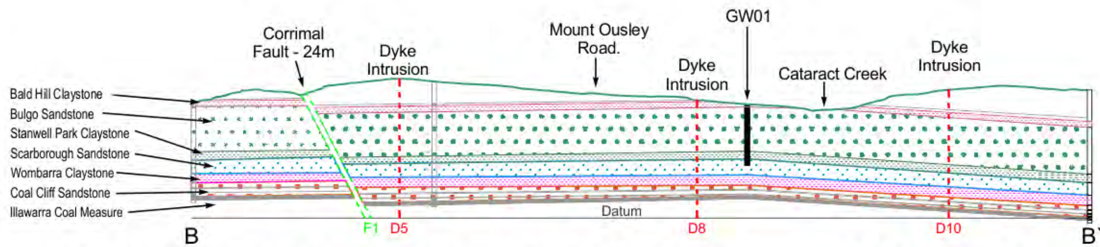


Figure 5b: Section B - B` South-North geological section through PPR Application Area. (reproduced from Figure 12 of Clark 2013).

Note: Vertical scale is the same as the horizontal scale.
Refer to Figure 4 for section locations.

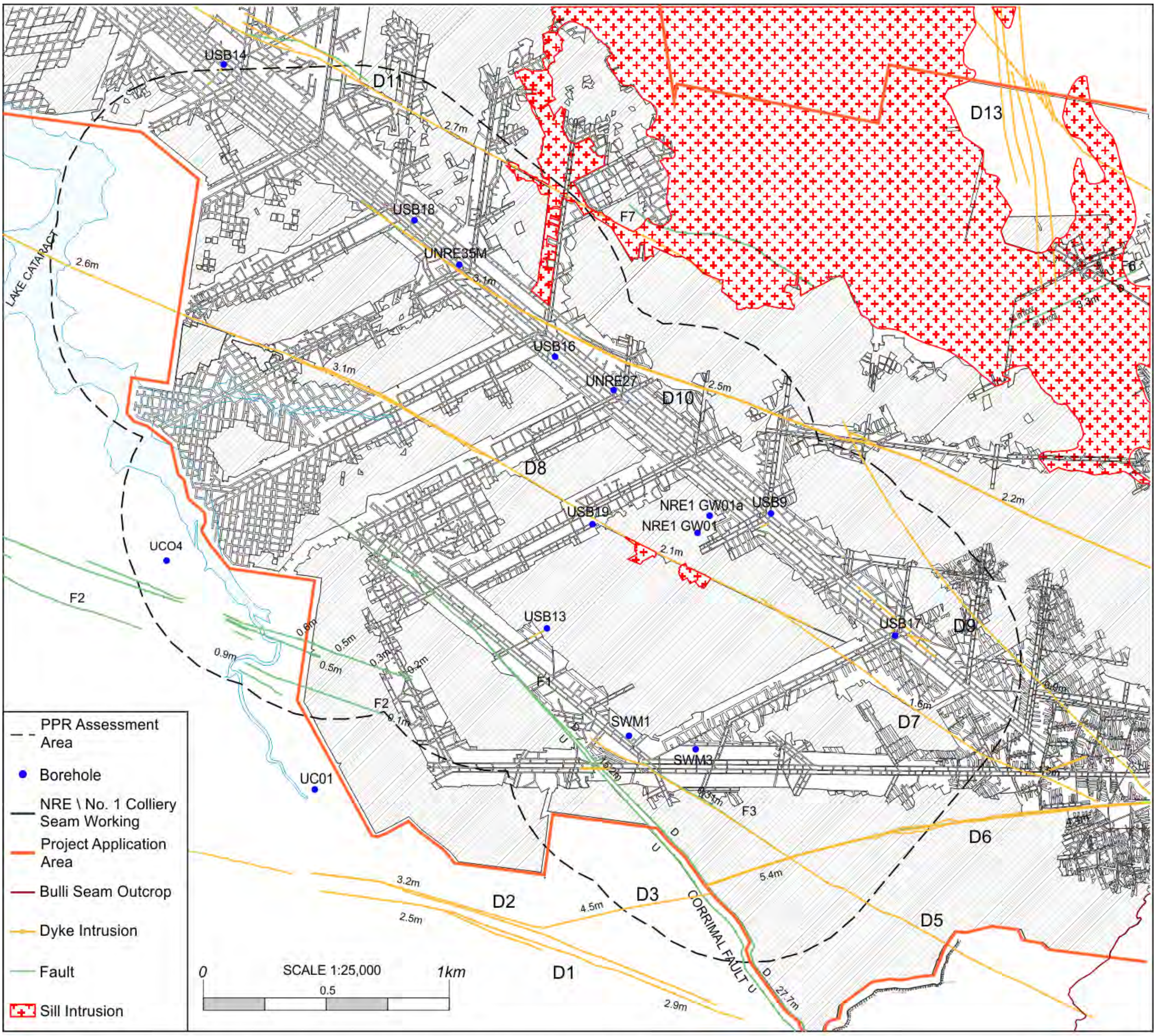


Figure 6: Plan showing geological structures and the extent of mining in the Bulli Seam level. (reproduced from Figure 14 of Clark 2013).

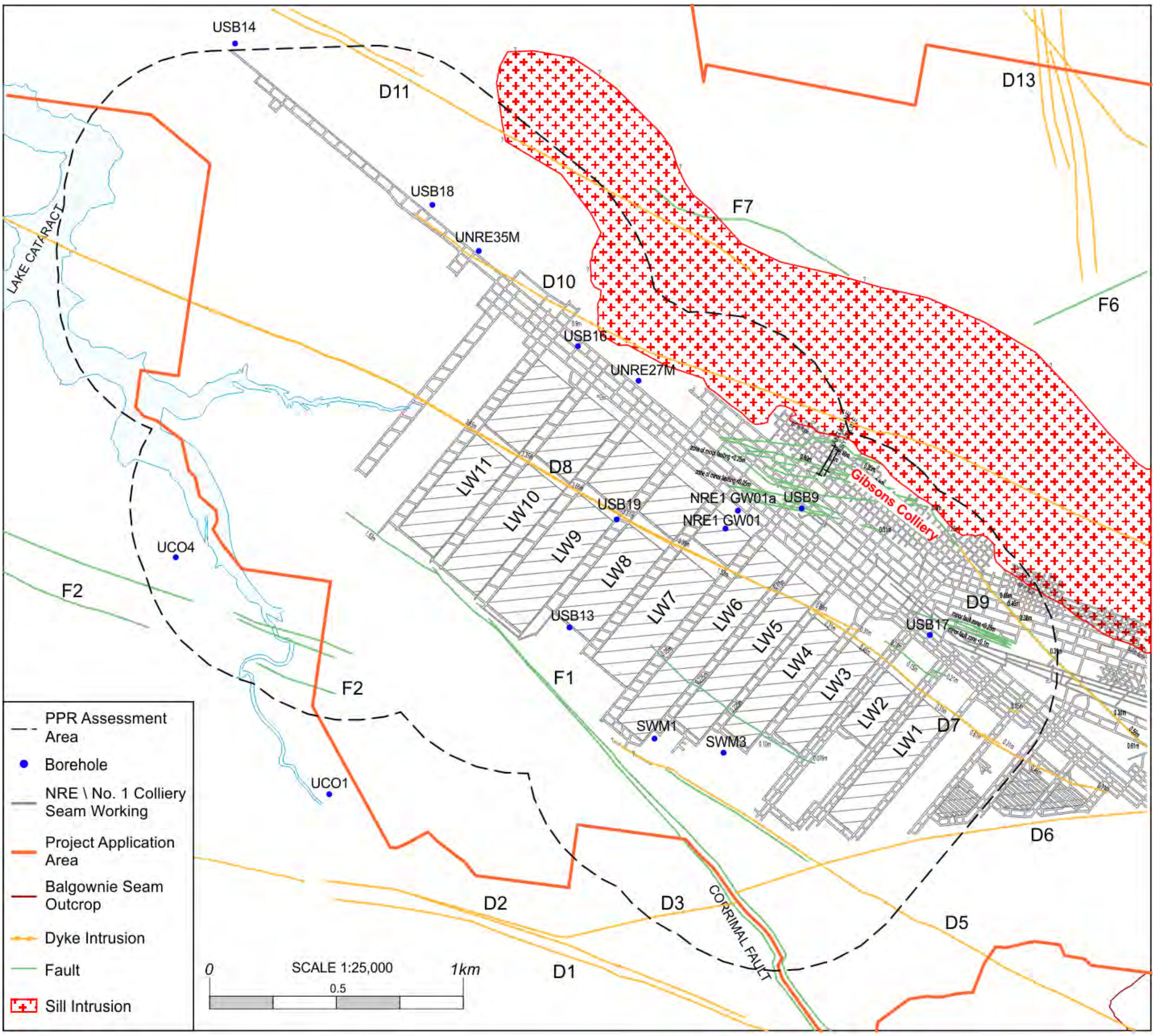


Figure 7: Plan showing geological structures and the extent of mining in the Balgownie Seam level. (reproduced from Figure 15 of Clark 2013)

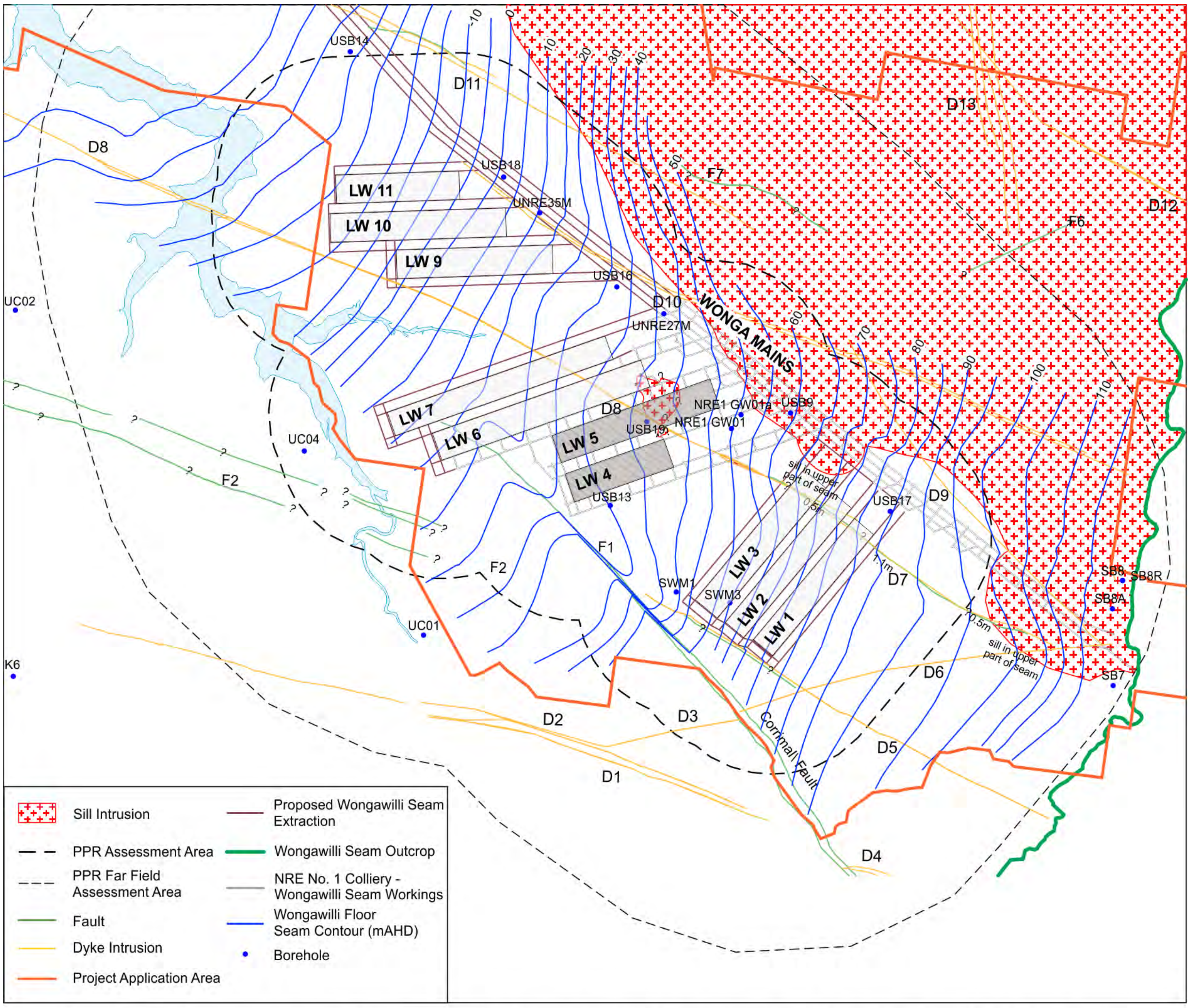


Figure 8: Plan showing geological structures in the Wongawilli Seam (reproduced from Figure 17 of Clark 2013) and floor contours of the Wongawilli Seam based on floor contours in the Bulli Seam.

An igneous sill has intruded into the Wongawilli Seam to the north of the main headings and the coal in this area is cindered and unsuitable to mine. A sill forms when molten igneous rock is injected under pressure into the host strata causing it to fracture hydraulically. When the in situ stresses at the time of injection are such that the lowest stress is vertical, the hydraulic fracture that forms is oriented horizontally. The injected rock then cools to form a horizontal layer of intruded rock within the host rock.

Several dykes exist within the Assessment Area with most having a west-north-west east-south-east orientation. Dykes are the vertical equivalent of sills and form when the lowest in situ stresses at the time of injection is one of the horizontal stresses. The resulting hydraulic fracture opens against this lowest stress cutting across the host strata to form an intrusion that is vertically and laterally continuous often for many kilometres in length. The dykes that have formed in the Southern Coalfield are generally less than a few tens of centimetres thick in the general strata but often increase in thickness at coal seam level where the in situ stresses are less. Dykes are usually hard to mine, dilute the coal product, cause damage to the mining equipment, and tend to be avoided where possible.

The site constraints within the Assessment Area mean that several of the proposed longwall panels will need to mine through Dyke D8. This dyke has been previously encountered in the Bulli Seam and Balgownie Seam workings and its trace is apparent in the geomorphology on the surface indicating that it is vertically continuous to the surface.

Figure 9 shows a photograph of Dyke D8 at Wongawilli Seam level where it was intersected on the longwall face at a shallow angle making it appear thicker than it actually is. Dyke D8 is approximately two metres thick in this area and fractured. Although the dyke appeared damp at the time of inspection (21/6/13), the coal seam to either side also appeared similarly damp. This dampness is considered likely to be a result of dust suppression water sprays on the longwall shearer. There did not appear to be any significant seepage flow emanating from the dyke consistent with experience at almost all other dyke intersections in the Southern Coalfield.

The only major geological fault within the Assessment Area is the Corrimal Fault (F1) which extends in a north-west south-east orientation in the southern part of the Assessment Area. This fault was intersected in the overlying Bulli Seam but the longwall panels in the Balgownie Seam did not extend far enough south, although some of the headings extended to the fault and the associated dyke D5. The fault is also apparent in the surface geomorphology and so its location and characteristics are well defined. The fault diminishes to the northwest and has become insignificant as a series of minor features with total displacement of about 1m where it is intersected by the gateroads for Longwall 6 in the Wongawilli Seam (Cartwright 2014).

Other faults in the general area, the Rixons Pass Fault, the Woonona Fault, and F2 are remote from the proposed mining and are not considered likely to affect mining or to be affected in any significant way by the proposed mining.

Figure 9: Dyke D8 exposed in the face of Longwall 5 on 21 June 2013. (Note this dyke was intersected at a shallow angle so the dyke appears thicker than it is).

2.8.3 Overburden Depth

Figure 10 shows a plan of the overburden depth to the Wongawilli Seam. The overburden depth ranges from 250m above Longwalls 2 and 3 in the northern part below the southern tributary of Cataract Creek through to 390m above the central part of Longwalls 10 and 11.

The overburden depth range for individual longwall panels is shown in Table 1. The ratios of panel width to depth range from 0.37 to 0.60. In previously unmined terrain, low levels of subsidence would be expected above each individual panel with the overall maximum subsidence controlled by elastic compression of the chain pillars between panels. However, subsidence monitoring data from the recently mined Longwalls 4 and 5 and from the Balgownie Seam longwall panels indicates that the presence of overlying mine workings has the effect of softening the overburden strata so that its bridging capacity (shear stiffness) is reduced thereby increasing the maximum subsidence above each individual panel to the higher magnitudes of subsidence that have been observed. This effect is discussed in more detail in the following sections.

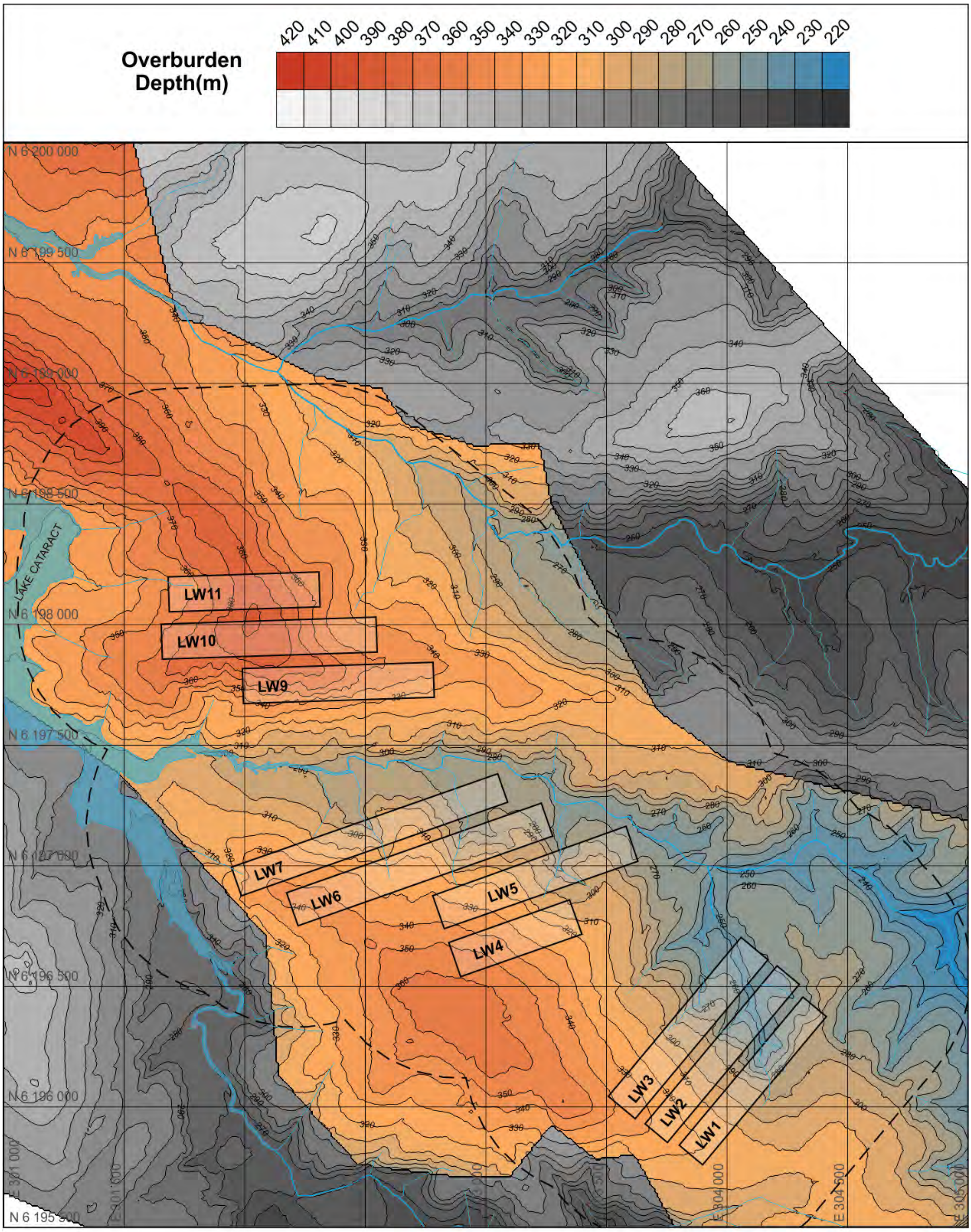


Figure 10: Depth of Overburden to the Wongawilli Seam.

Table 1: Overburden Depth Range

Longwall Panel	Panel Width (m)	Overburden Depth Range (m)	Width on Depth Ratio
1	131	255-320	0.41-0.51
2	125	255-330	0.37-0.49
3	150	250-340	0.44-0.60
4	150	300-360	0.42-0.50
5	150	265-345	0.43-0.57
6	150	270-345	0.43-0.55
7	131	270-340	0.39-0.49
9	150	330-380	0.39-0.45
10	150	335-390	0.38-0.45
11	150	350-385	0.39-0.43

3. PREVIOUS MINING ACTIVITY

A unique characteristic of the PPR Assessment Area is the presence of previous mining activity in two other seams in geometries that are unrelated to proposed mining in the third seam. Figure 11 and Figures 6-8 show the extent of previous mining in the Bulli Seam and Balgownie Seam within the PPR Assessment Area.

This previous mining provides a number of opportunities that are not usually available in single seam mining applications but also brings a number of differences as well. Geological structure and seam contour are much better known as a result of previous mining activity than would normally be possible for single seam mining.

Previous mining activity provides an opportunity to examine the mining impacts over timeframes of 50-100 years for the Bulli Seam and 30-40 year for the Balgownie Seam mining. The subsidence movements associated with the earlier mining have been estimated for the Bulli Seam and measured for the Balgownie Seam providing a baseline of impact experience and recovery that is not typically available.

The ongoing nature of the mining operation at NRE No 1 Colliery provides the opportunity to inspect the mine workings in the Bulli Seam and the Balgownie Seam to better understand the nature of the potential interactions between seams and the potential for pillar instability particularly in the Bulli Seam to cause unexpected additional subsidence. In preparation for this report, a site visit was made on 21 June 2013 to inspect the workings in all three seams.

Subsidence monitoring data available from mining in the Balgownie Seam and more recently from two longwall panels in the Wongawilli Seam is available and this provides a basis for predicting future subsidence behaviour. This data indicates that while there are some significant differences in behaviour compared to single seam mining, the multi-seam behaviour is predictable and occurs predominantly within the bounds of the panel being mined and the chain pillar to the previous panel. This data and observations of previous impacts indicate that the impacts of future mining are likely to be similar in nature to the impacts that have already occurred.

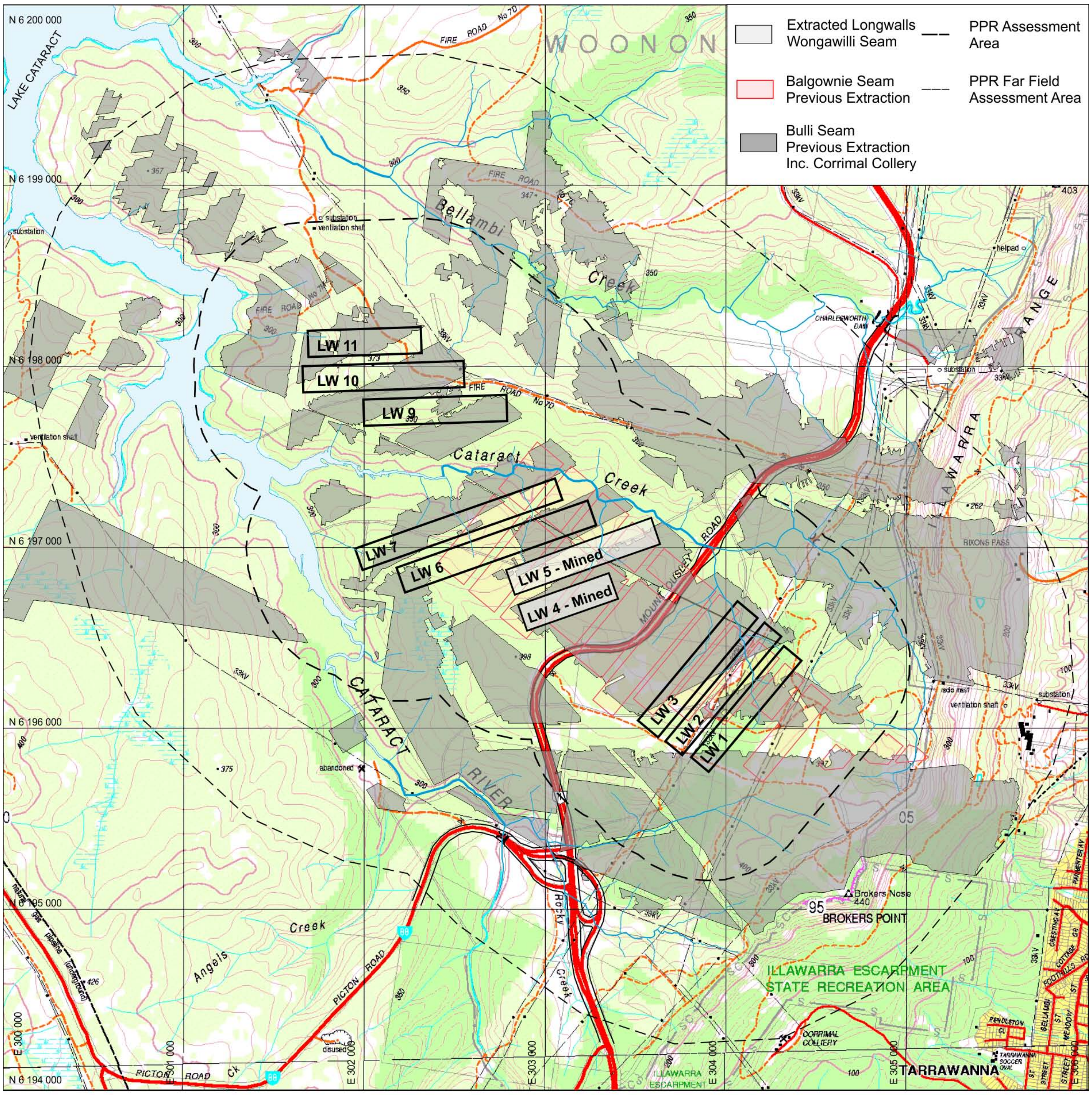


Figure 11: Plan showing extent of previous extraction in Bulli Seam (black) and Balgownie Seam (red) in the PPR Application Area.

The available subsidence monitoring data indicates that there is some softening of the goaf edge subsidence in areas where overlying seams have been mined but the effect is a second order effect and of relatively little significance in terms of subsidence impacts.

3.1 Bulli Seam Workings and Associated Subsidence

The Bulli Seam was mined initially using hand bord and pillar mining techniques from the 1890's through until pillar extraction became possible with improvements in mining technique and the arrival of mechanised mining. Some of the standing pillars associated with the main headings and original mining areas were extracted during the later stages of retreat. Mining in the Bulli Seam within the PPR Assessment Area had effectively finished by the 1950's. Areas of pillar extraction in Corrimal Colliery immediately to the south are also included in the estimation of subsidence from the Bulli Seam because they fall within the Assessment Area.

There are no known records of subsidence monitoring for the period of mining in the Bulli Seam. However, it is possible to estimate the levels of subsidence that are likely to have occurred given the geometry of the panels mined and estimating the likely extraction ratios.

Figure 12 shows contours of the surface subsidence interpreted as being caused by pillar extraction operations in the Bulli Seam. This subsidence has been estimated based on subsidence monitoring results and subsidence profiles from mining in the Bulli Seam further to the west above the T and W (200 and 300 series) longwall panels at South Bulli and subsequent pillar extraction operations.

An underground site inspection conducted on 21 June 2013 showed that there are existing bord and pillar workings alongside the Bulli Seam main headings that are likely to be destabilised if mined directly under in the Wongawilli Seam. Similar workings were directly mined under by the Balgownie Seam longwall panels and it is clear from the underground inspection that these overlying pillars were destabilised in the area directly above the Balgownie Seam longwall goaf as shown in Figure 13. There did not appear to be any evidence that the footprint of instability extended significantly beyond the footprint of the underlying goaf, but it is considered possible that this potential may exist in some places where there are localised areas of standing pillars.

Where large areas have been shaded (cross-hatched) to represent the completion of mining, the detail of the Bulli Seam extraction is not available. These areas are likely to include different levels of mining ranging from solid coal, large standing pillars, standing pillars associated with Welsh bords, and goaf areas where there has been pillar extraction or the pillars have previously collapsed.

The downward movements that occurred during Balgownie Seam mining and were observed on the surface as subsidence provide a basis to differentiate these shaded areas where they have been directly mined under by the Balgownie Seam longwall panels. Small pillars that have been mined under by the Balgownie Seam longwall panels are considered to have almost certainly

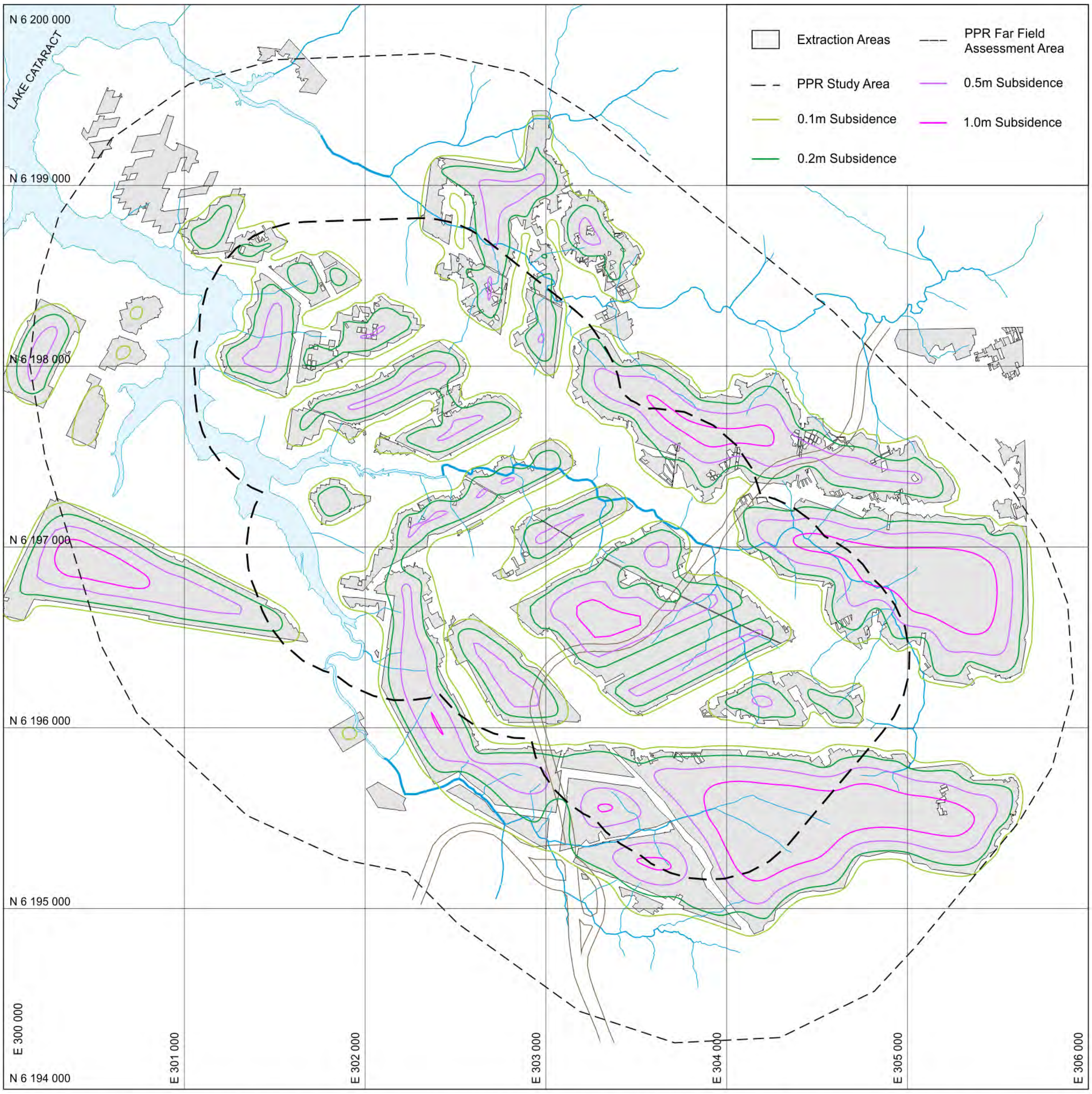


Figure 12: Plan showing estimated subsidence movements likely to have been associated with pillar extraction operations in the Bulli Seam.

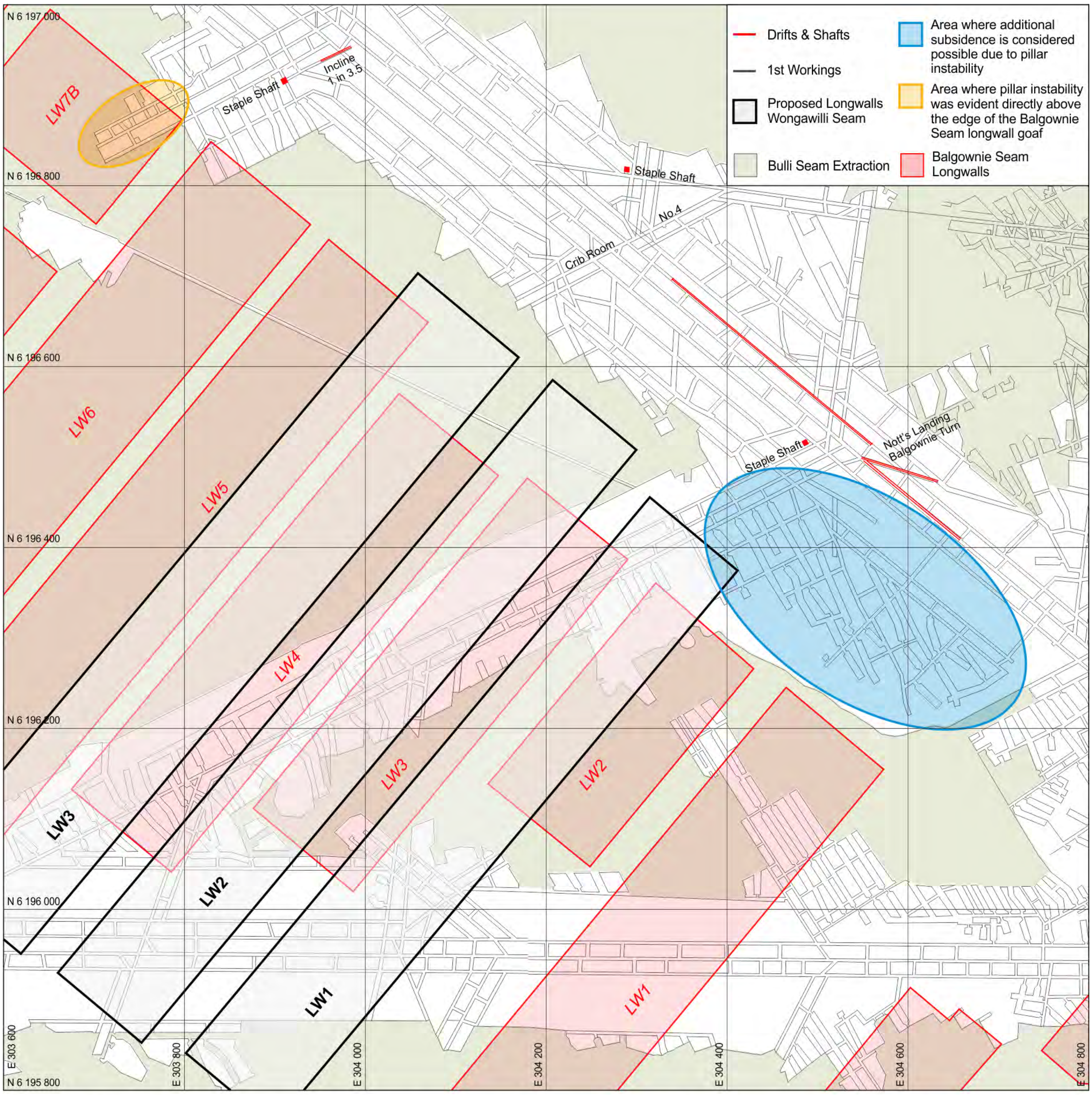


Figure 13: Plan showing areas of pillar instability in overlaying Bulli seam caused or possibly caused by mining in seams below.

been destabilised during the 1-1.5m downward movement that would have occurred as the pillars were mined under. Subsidence monitoring above the Balgownie Seam longwall panels shows areas where there has been some additional subsidence consistent with pillar instability, areas where there has been additional consolidation of an existing Bulli Seam goaf, and areas where there has been either no mining in the Bulli Seam or the Bulli Seam pillars are large enough to behave like solid coal.

The Bulli Seam subsidence estimates shown in Figure 12 include refinements based on the ground behaviour observed during longwall mining in the Balgownie Seam. Although it is not possible to interpret the characteristics of some of the other large Bulli Seam goaf areas that have not been directly mined under in the Balgownie Seam, these other large goaf areas are remote from the areas where the PPR longwall panels are proposed.

The detail of the Bulli Seam pillars is available in some areas close to the main headings as shown in Figure 13. The site visit to this area indicated that additional subsidence due to pillar instability would be possible in the area shown if Longwall 1 was extended to its full length although surface subsidence may be relatively small given the narrowness of the panel at an overburden depth of 270m. Any additional subsidence would have potential to impact on pylons on the two 33kV power transmission lines and this potential is addressed in the impact assessment for these structures.

The issue of a "pillar run" in the Bulli Seam was raised in the Pt3A submissions. As indicated above, there is considered to be potential for a classical "pillar run" associated with pillar instability, but the geometries in the Bulli Seam and the evidence from previous mining in the Balgownie Seam make it unlikely that such an event would extend more than a few hundred metres from the goaf edge (i.e. the extent of the panel of standing pillars). The subsidence from such an event would be limited to low levels of less than a few hundred millimetres maximum due to the narrow panel width of standing pillars small enough to be destabilised and would be limited to only those areas where there are small standing pillars that have not previously been mined under in the Balgownie Seam.

The terms "pillar run" and "pillar creep" have been used in some of the submissions to describe the phenomenon that is perhaps better described as "stress redistribution" because of the relatively smaller ground movements involved, typically less than 100mm. As one area is subsided, pillars become more heavily loaded, and compress slightly causing lateral migration of low level subsidence movements well beyond the limits of subsidence normally associated with single seam mining. This phenomenon is particularly common where panels are relatively narrow compared with overburden depth and surface subsidence is controlled mainly by elastic compression of the pillars between panels.

A similar process can also occur for horizontal movements as horizontal stresses are redistributed and dilation of subsiding strata causes horizontal movement in a downslope direction. Again the ground movements tend to be small second order movements that may cause perceptible low level cracking on hard surfaces such as sealed roads especially adjacent to topographic high points, but such movements are usually not significant because they tend to be of small magnitude and occur over large areas.

3.2 Balgownie Seam Workings and Associated Subsidence

Figure 7 shows the extent of the Balgownie Seam workings. There are eleven longwall panels extending to the south of the main headings. Apart from development headings, the remaining coal was recovered from three small areas of pillar extraction in the east and more recently as a panel of pillars formed up as first workings against the sill in the north.

Longwall mining in the Balgownie Seam started in September 1970 at Longwall 1 and finished on 27 May 1982 at Longwall 11. The first six panels were located east of the current Mount Ousley Road alignment and ranged in width from 141m to 145m. The last five panels were located west of Mount Ousley Road and ranged in width from 185m to 189m. These later panels were split into two parts either side of the D8 Dyke. These longwalls mined directly below the road alignment.

3.2.1 Vertical Subsidence

Surface subsidence was monitored along the centreline of each of the eleven longwall panels and on three cross-lines. The vertical subsidence was monitored at regular intervals during panel retreat above the initial panels and less frequently during mining of the last few panels. Surface strains were also measured during the last panel.

Figure 14 shows an example of the subsidence measured on the second cross-line that extends from the centre of Longwall 5 to the solid coal west of Longwall 11. The characteristics of the subsidence measured that are of relevance to this assessment are:

- The chain pillars are clearly evident in the subsidence profile with 0.5m to 0.75m of subsidence directly over these pillars.
- Coal left in the Balgownie Seam around the dyke is clearly evident as reduced surface subsidence.
- The maximum sag subsidence in the centre of each panel is reduced in areas where the panels are narrower (0.2m in narrow panels compared to 0.5m above the wide panels).
- The sag subsidence is more in areas where the Bulli Seam has been extracted.
- The subsidence is greatest (1.42m) over Longwall 10 in an area on the fringe of Bulli Seam goaf where full subsidence during mining of the Bulli Seam was prevented by the presence of solid abutment coal or marginally stable pillars were destabilised.
- Surface subsidence occurred primarily within the geometry of the Balgownie Seam longwall panels.

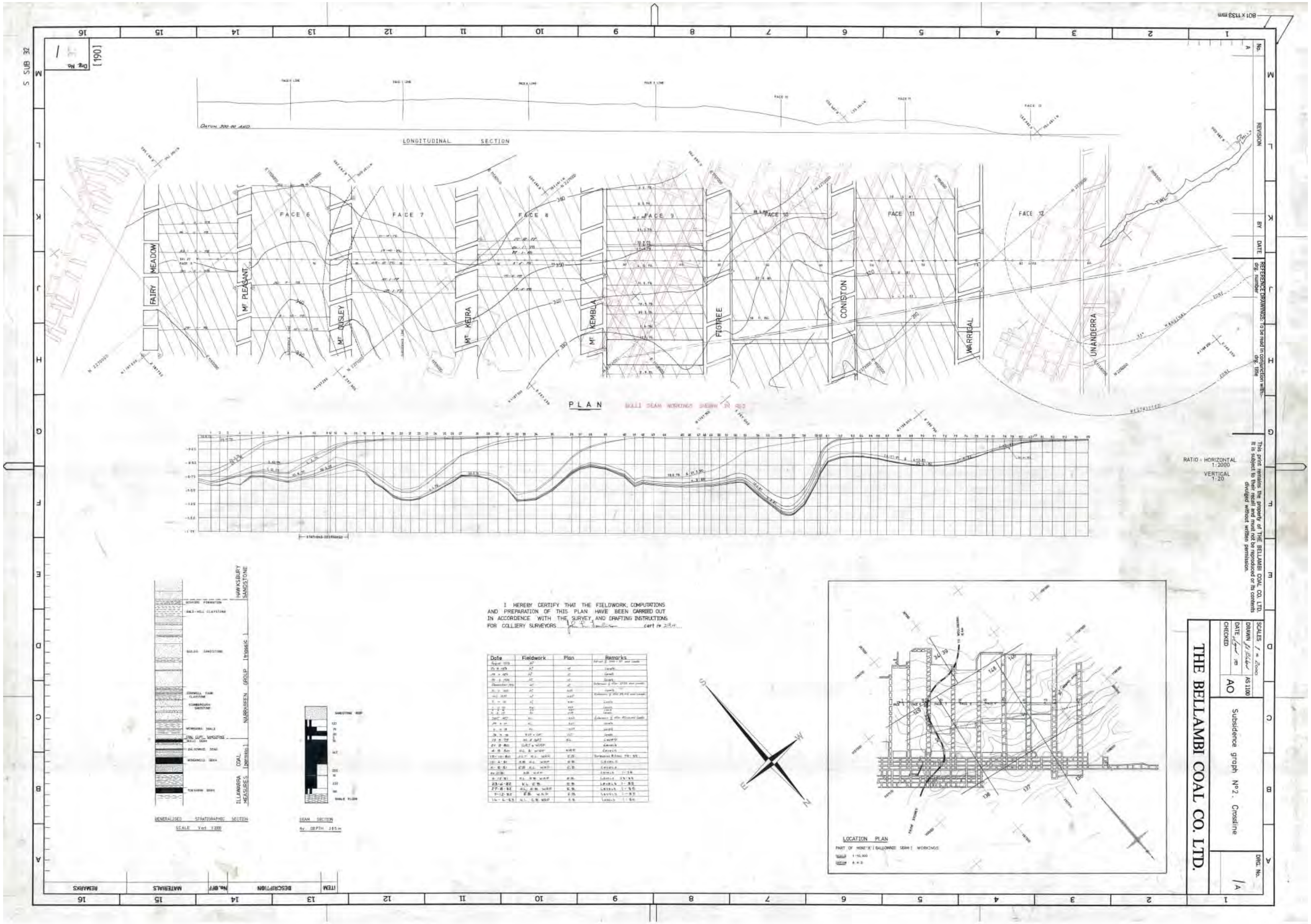


Figure 14: Example of subsidence monitoring of Balgownie Seam longwall panels.

- The goaf edge subsidence is greater and extends further when there is overlying Bulli goaf, but this effect is a second order effect.

These different characteristic behaviours have been considered for each of the subsidence lines and the maximum subsidence observed is able to be used to characterise the condition of the Bulli Seam goaf above.

Figure 15 shows the maximum subsidence observed for each of the longwall panels. The different areas can be divided up as shown in Table 2 based on where there are pillars and goaf in the two seams.

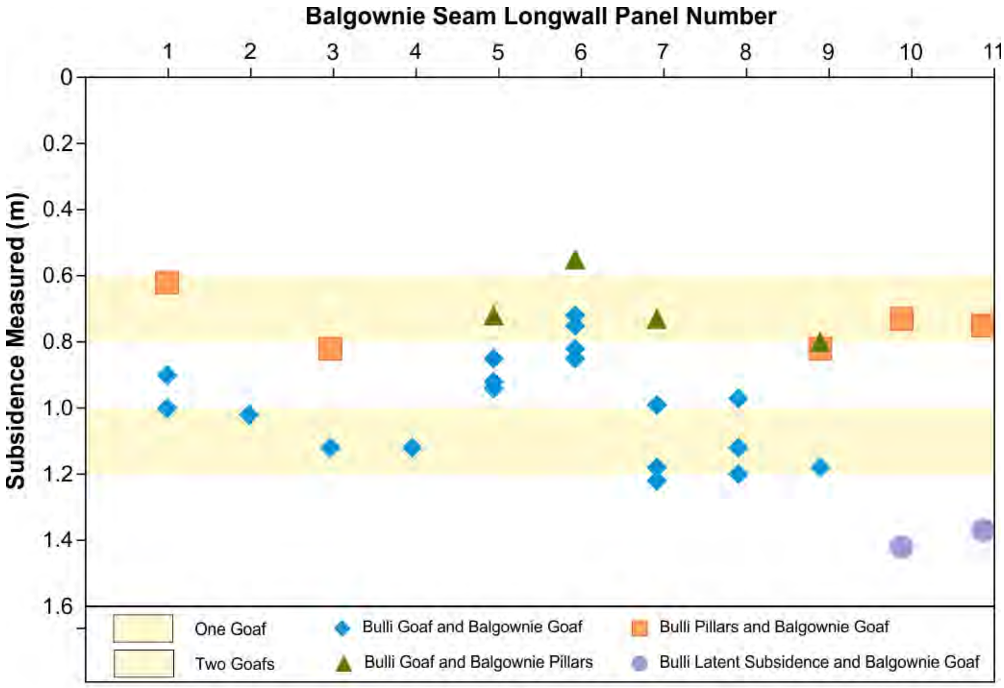


Figure 15: Maximum subsidence observed for each longwall panel in the Balgownie Seam.

Table 2: Subsidence Observed in Different Conditions

	Bulli Seam Pillars	Bulli Seam Goaf	Unstable Bulli Pillars
Balgownie Seam Pillars	Low level subsidence (<0.2m)	0.6-0.8m	Low level (<0.2m)
Balgownie Seam Goaf	0.6-0.8m	1.0-1.2m	1.4m

In areas where there are Balgownie chain pillars and pillars in the Bulli Seam, the subsidence directly over the chain pillars is less than 0.2m. In areas where there are pillars in one seam and extraction in the other seam, surface subsidence is between 0.6m and 0.8m. Where there has been extraction in both seams, the maximum incremental subsidence is in the range 1.0m to 1.2m – i.e. approaching 80% of the nominal mining height of the second seam mind.

In areas where there is clearly potential for either latent subsidence because the Bulli Seam goaf is narrow and bridging (such as the zone of high subsidence associated with mining Longwall 11 in the Balgownie Seam) or along a goaf edge where full subsidence has not been able to develop during mining the first seam (such as the high subsidence zone associated with mining Longwall 10 in the Balgownie Seam), the incremental subsidence reaches 1.4m and is of the order of 100% of the mining height of the second seam mined.

The 1.4m of subsidence observed in these circumstances is likely to have a component of destabilisation of standing pillars in the Bulli Seam caused by mining in the Balgownie Seam. Up to 0.7m of subsidence would be expected from mining below pillars in the Bulli Seam plus an additional 0.8m subsidence in the Bulli Seam of about 30% of the 2.2m mining height given an extraction ratio of about 30%. The total subsidence would therefore be about 1.5m and of the same magnitude as the subsidence observed.

Figure 16 shows the subsidence measured during mining the Balgownie Seam based on interpolation of the subsidence monitoring data. This data represents the incremental subsidence associated with mining the Balgownie Seam given that all the Bulli Seam subsidence had already occurred prior to the subsidence pegs being installed.

Maximum subsidence is 1.42m and 1.33m over Longwalls 10 and 11 respectively but in most of the areas, subsidence over the longwall goafs is in the range 0.6m to 1.2m.

3.2.2 Horizontal Strains and Tilts

Maximum strains measured over Longwall 11 ranged from 3-4mm/m along the panel to peaks of 14mm/m in compression across the topographic low point of Cataract Creek and 9mm/m in tension on the slope beyond. For the maximum subsidence of 1.4m and an overburden depth to the Balgownie Seam of 260m at this location, the strain peaks measured indicate a relationship between maximum strain and maximum subsidence of:

$E_{max} = 500\ S_{max} / D$ for systematic strains and

$E_{max} = 1500\text{-}2500\ S_{max} / D$ for non-systematic strains associated with valley closure and steep topography.

These compare reasonably with the peak strain subsidence relationships presented by Holla and Barclay (2000) for the Southern Coalfield which indicate:

$E_{max\ tensile} = 1500\ S_{max} / D$
$E_{max\ compressive} = 3000\ S_{max} / D$
$Tilt_{max} = 5000\ S_{max} / D$

for peak strains and tilts that include non-systematic strains and tilts associated with valley closure and steep topography. The peak compressive strains tend to be apparent in topographic low points and the tensile strains tend to be more apparent at the start of panels in ground sloping in the same direction as mining, and along topographic high points such as ridges.

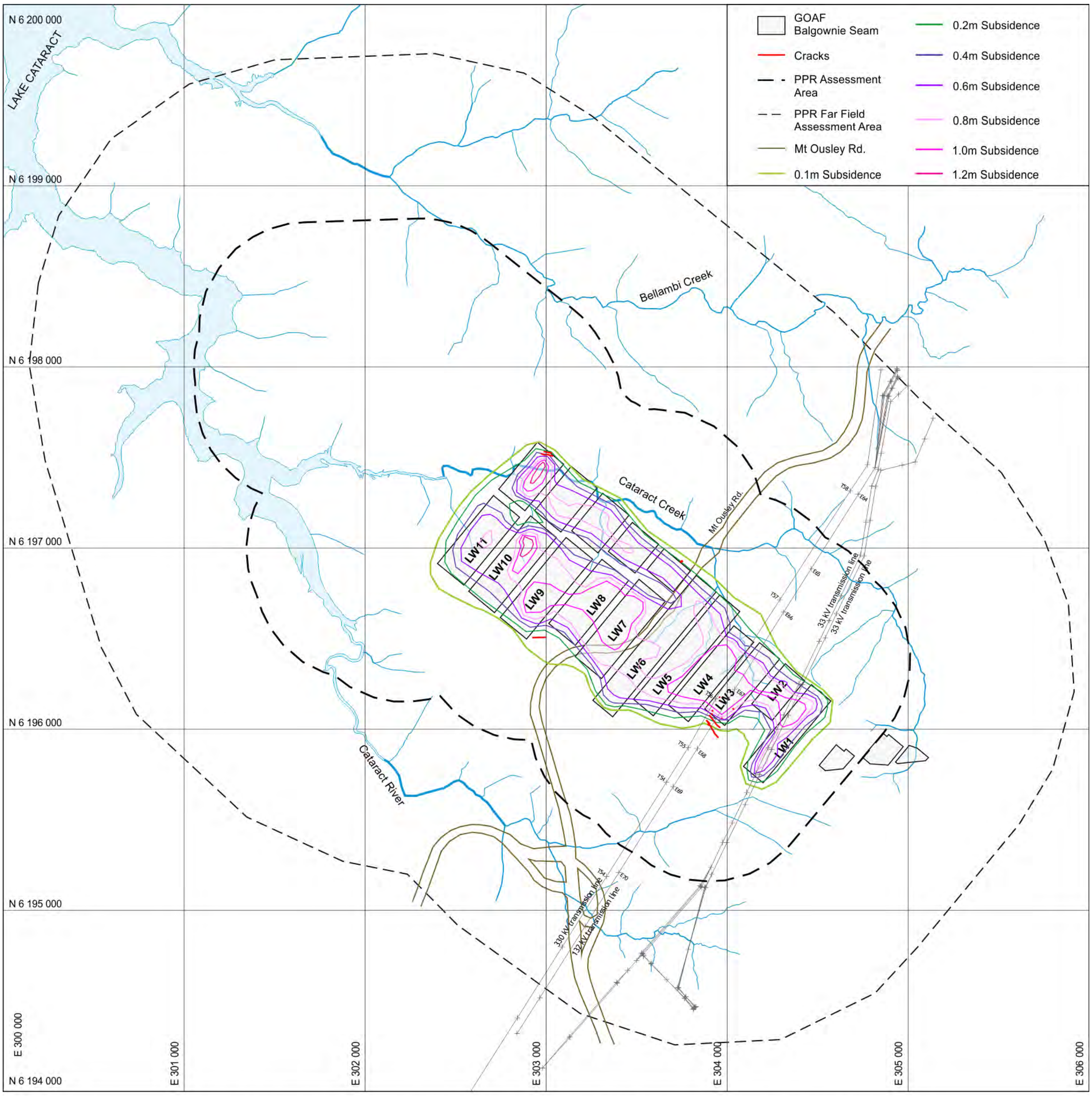


Figure 16: Contours of subsidence measured above the Balgownie Seam longwall panels.

Table 3: Comparison of Measured and Calculated Upsidence

Balgownie Longwall Panel	Distance from End of Panel (m) (positive over goaf)	Incremental Upsidence Indicated (mm) (not necessarily peak)	Overburden Depth (m)	Maximum Subsidence (m)	Calculated Upsidence for each panel individually (mm)
3	170	130	230	1.1	70
4	30	210	230	1.1	100
5	0	80	230	0.8	100
6	-75	30	240	0.8	120
8	-106	80	240	0.9	130
9	-30	120	250	0.9	110
10	20	100	260	0.9	100
11	116	100	260	1.4	90

3.2.3 Valley Closure and Upsidence

The 14mm/m compressive strain peak measured across Cataract Creek on the centreline of Longwall 11 was measured between pegs spaced 18m apart. Compressive strain of 4mm/m was measured between the next two pegs spaced 15m apart. These measurements imply a total closure across the creek of about 310mm.

The ACARP method for estimating valley closure developed by Waddington and Kay (2002) indicates the incremental valley closure for Longwall 11 as being of the order of 200-300mm and is therefore consistent with the closure measured during mining of Longwall 11. The agreement is relatively close between measured and calculated even though the geometry associated with the short longwall panels is irregular and well outside the database of experience on which the ACARP method is based.

Valley closure at other locations is also evident as upsidence in the subsidence profiles that extend across Cataract Creek. Table 3 summarises the upsidence measured as well as the incremental upsidence calculated for each longwall panel to allow direct comparison with the upsidence measured for each longwall panel during mining of that panel.

Upsidence measurements shown in Table 3 are made at the peg locations. The pegs are 15-20m apart while the upsidence tends to peak over a distance of only a few metres. The location of the pegs may not necessarily coincide with the peak upsidence, so the measured upsidence is considered to be a lower bound estimate of the maximum upsidence that occurred. The measurements made during mining of the Balgownie Seam longwall panels indicate that Cataract Creek has already sustained upsidence in the range 100-200mm from this mining with some additional upsidence likely to have occurred during mining in the Bulli Seam.

The ACARP method for estimating upsidence for single seam mining operations indicates upsidence and valley closure that are consistent with the values measured. This method appears likely to still be relevant for estimating upper bound upsidence and valley closure for future mining activity in the Wongawilli Seam even in a multi-seam mining environment.

3.2.4 Total Cumulative Subsidence

Figure 17 shows the total cumulative subsidence estimated by adding together the estimated subsidence from the Bulli Seam and the measured subsidence from the Balgownie Seam using Surfer and a 10m by 10m grid spacing. The locations of surface features that have or may have been impacted by subsidence from this previous mining are also shown. The proposed and previously mined longwall panels in the Wongawilli Seam are also shown for reference purposes.

The total cumulative subsidence associated with mining both the Bulli Seam and Balgownie Seam is an estimate because the Bulli Seam subsidence was not measured. The total subsidence is nevertheless useful as an indicator of maximum subsidence when interpreting subsidence impacts from previous mining activity.

Maximum cumulative subsidence is approximately 1.9m in the area above Longwalls 7 and 8 in the Balgownie Seam just to the west of the Mount Ousley alignment on the slope to the south of Cataract Creek. More generally the cumulative subsidence is in the range 0.3-1.3m.

3.3 Historical Mining Impacts

While it is not possible to completely separate the impacts from previous mining in the Bulli Seam from the impacts associated with previous mining in the Balgownie Seam in areas where both have been mined, it is nevertheless helpful to review the impacts that have occurred previously as a basis for estimating the likely impacts of future mining.

These impacts are most evident as rock falls and surface cracking on hard rock surfaces and changes in the character of stream channels such as upsidence cracking, iron staining, and sediment infilling in areas where the stream bed has been subsided. Other features where evidence of impacts is not so apparent include Mount Ousley Road, the power transmission lines, and natural features such as swamps and other vegetation.

3.3.1 Surface Cracks

Surface cracking is documented on subsidence plans prepared during and after mining of the Balgownie Seam longwall panels. The cracks reported are mainly located near the start of Longwall 3 in the open terrain of the power transmission line easement.

These cracks are located near the start of the longwall panel on a topographic ridge in an area where the combination of systematic horizontal movements at the start of the panel and horizontal movements in a downslope direction would be expected and are commonly observed. Similar cracks are likely to have occurred at other locations but most of these would be in bushland locations where they would be difficult to detect.

For instance, a linear depression opened up near the southern corner of Longwall 4 in the Wongawilli Seam during mining of Longwall 5. This depression is considered to be associated with subsidence cracking. The

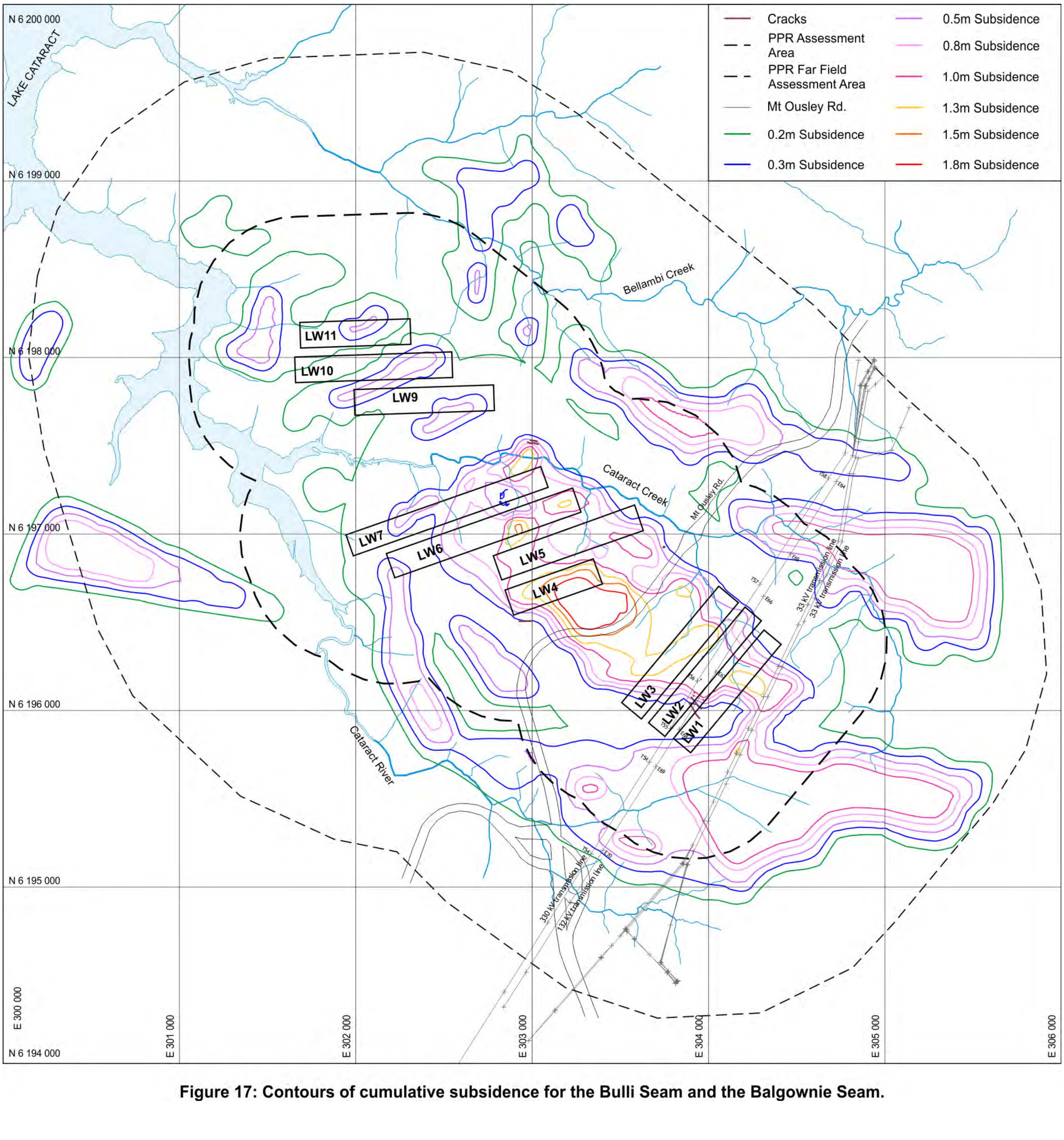


Figure 17: Contours of cumulative subsidence for the Bulli Seam and the Balgownie Seam.

depression and associated crack are located in an area where the goaf edges in all three seams are superimposed. The area is also near the top of the ridge between Cataract Creek and Cataract River where horizontal ground movements are expected to concentrate surface cracks. The ground displacement indicated by this crack is of the order of 700mm but subsidence monitoring indicates that only a small part of this movement occurred during recent mining of Longwall 5 when the crack was first noticed. The implication of these measurements is that the crack developed during previous mining but was disguised below the soil and had been substantially infilled by soil material over the period since it formed.

Inspections conducted in association with cracking on the Mount Ousley Road show that there are a series of tension cracks and minor sinkholes evident along the northern side of the ridgeline between Cataract River and Cataract Creek. These cracks are locally aligned with the direction of one of the principal joint directions in the Hawkesbury Sandstone

3.3.2 Rock Falls

An inspection of cliff formations across the PPR Assessment Area conducted during the original subsidence assessment program informed by LiDAR interpretation indicated that there are several rock falls that are considered to be attributable to mining subsidence from both Bulli Seam and Balgownie Seam mining activity. These rock falls are small in volume and are barely discernable from natural rock falls that have occurred in the general area over the period since mining was completed.

A recent inspection of sandstone cliff formations on the southern side of Cataract Creek indicated the presence of several rock falls and subsidence cracks associated with previous mining.

A sandstone formation immediately downstream of CCUS4 showed evidence of previous mining impacts in the form of cracking and a section of overhanging cliff that had toppled over. The nature of the fracturing is consistent with mining induced subsidence from the Balgownie Seam longwall panels.

A length of cliff formation associated with archaeological site 52-2-3941 appears to have been subjected to fracturing and resultant rock falls which are likely to have been caused by subsidence associated with mining activity in the Bulli Seam. The nature of the fracturing and the age of the rock weathering appear consistent with the rock fall having occurred many decades ago.

A small rock fall of only a few cubic metres of material was also observed above Longwall 10 in the Balgownie Seam. The rock fall is located at the head of a small gully where the horizontal compression movements have been concentrated as the strata has subsided.

A rock fall located over the proposed Longwall 11 in the Wongawilli Seam was observed during a recent surface inspection. This rock fall involving several tens of cubic metres appears to have occurred from natural causes over the last few years. The site is remote from recent mining activity and there is evidence of tree root invasion at the back of the fall.

There are numerous examples of much older natural rock falls along the slopes below most of the cliff formations. These isolated boulders are consistent with the natural processes of erosion. Similar boulders are observed in areas where there has been no mining.

3.3.3 Iron Staining

Water rich in iron is observed to be flowing into several watercourses from the base of the sandstone cliff formations at several locations on the slopes above the southern side of Cataract Creek. These watercourses are dry upstream of the sandstone outcrop and show signs of iron staining downstream of the point where water flows from the strata into the creek.

This phenomenon is consistent with horizontal shear movement at the base of the Hawkesbury Sandstone outcrop caused by mining subsidence. The sandstone strata that is fractured, both naturally and as a result of mining subsidence, appears to be acting as a sub-surface reservoir that delivers water into watercourses downstream of the outcrop of the shear horizon even when there is no overland flow from upstream.

More intense iron staining observed during site inspections appears likely to be a result of recent mining in the Wongawilli Seam.

3.3.4 Cataract Creek

Subsidence monitoring above Longwall 11 in the Balgownie Seam indicates that Cataract Creek was subsided by more than 0.4m over a 400m length of the creek with maximum subsidence of 1.3m over about 40m. The same length of creek is also estimated to have been subsided 0.2-0.4m during mining in the Bulli Seam.

Inspection of the bed of Cataract Creek indicates that there is almost no physical disturbance to the rock strata in the bed of the creek that is attributable to mining activity despite the indicated closure of 310mm. This level of closure would typically be apparent as surface cracking in Hawkesbury Sandstone strata.

Geological mapping presented in Figure 4 indicates that this section of the creek is located in outcrop of the Bald Hill Claystone and Newport/Garie Formations immediately below it. The presence of the Bald Hill Claystone is considered likely to have contributed to the lack of physical disturbance evident in the bed of Cataract Creek.

The presence of iron staining in the water of Cataract Creek is consistent with previous mining activity in the area causing disturbance to the overlying Hawkesbury Sandstone. Recent mining of Longwall 4 in the Wongawilli Seam appears to have increased the level of iron rich precipitate in the tributary leading down from the area above Longwall 4.

3.3.4 Power Transmission Towers

The power transmission towers T56 (on the 330kV line) and E57 (on the 132kV line) are located 100m and 200m respectively from the area of cracking at the start of Longwall 3 in the Wongawilli Seam and directly over Longwall 3 in the Balgownie Seam where there has been 1-1.2m of subsidence. The tower locations are noted on subsidence plans as T56 and T52 so it appears that they had been constructed prior to mining Longwall 3 in 1975. These towers do not appear to have been significantly impacted by previous mining and there does not appear to have been any mitigation or remediation.

3.3.5 Mount Ousley Road

The construction of the Mount Ousley Road on its current alignment appears to have taken place after mining directly below the alignment in the Bulli Seam and Balgownie Seams was complete. Bulli Seam mining was complete in the 1950's and by 1979 mining in the Balgownie Seam had progressed to Longwall 9 well to the west of the alignment.

There does not appear to have been any significant impact of historical mining on the operation of the highway despite up to approximately 1.0m of subsidence from Longwall 7 measured from 1976 to 1978 directly below the road alignment. The Cataract deviation was opened in 1980. Although recent mining in the Wongawilli Seam has caused minor cracking on the hard surface of the Mount Ousley Road that coincides with the goaf edges of previous mining activity in the Bulli and Balgownie Seams suggesting the possibility of remobilising pre-existing subsidence cracks.

4. SUBSIDENCE PREDICTION METHODOLOGY

In this section, the subsidence monitoring from Longwalls 4 and 5 in the Wongawilli Seam is reviewed as a basis for predicting future subsidence behaviour. The subsidence prediction methodology is described and the accuracy and sensitivity of the method are examined.

4.1 Review of Mining in the Wongawilli Seam

Two longwall panels have so far been mined in the Wongawilli Seam, both creating voids at the mining horizon that are 150m wide. Longwall 4 was extracted between 21 April and 21 September 2012. Longwall 5 was extracted between 15 January 2013 and early January 2014 although the panel was substantially complete by 18 December 2013.

The subsidence monitoring associated with the mining of these two panels provides insight into the incremental subsidence behaviour when multiple seams have already been mined, the magnitude of subsidence movements, and the nature of surface impacts. In this section, the results of recent subsidence monitoring in Longwalls 4 and 5 are reviewed.

It is convenient to discuss the surface subsidence as comprising two components. These two components are described in detail in Mills (1998).

The first component, called sag subsidence, is the subsidence that results from the overburden strata draping down into the void created by each longwall panel. Sag subsidence increases with increasing panel width up to a maximum at a distance referred to as critical width. Sag subsidence also increases as the overburden depth reduces, as the thickness of the coal seam mined increases, and with the presence of previous mining activity in the overlying seams. Sag subsidence is a measure of the capacity of the overburden strata to bridge across each longwall panel and in wide panels the vertical support able to be provided by the extracted goaf.

The second component, called strata compression subsidence, is the subsidence that results from compression of the chain pillar between panels and the rock strata above and below the chain pillar. The total strata compression is seen on the surface as subsidence. The increased load on rock strata above and below the chain pillar contributes almost all of the compression subsidence with compression of coal in the chain pillar contributing only a relatively small proportion of the total.

Strata compression subsidence increases with depth from less than 100mm when the overburden depth is less than 100m to 600-800mm at an overburden depth of 400m. Strata compression subsidence is function of the compression of the strata between panels and is largely independent of the sag subsidence and the capacity of the strata to bridge across each panel.

4.1.1 Vertical Subsidence

Figure 18 shows a summary of the results of subsidence monitoring over Longwall 4 and 5 on the two centreline subsidence lines and three cross-lines, including one short line, M Line, located across the chain pillar to measure strata compression above the chain pillar.

At the completion of Longwall 4, the maximum subsidence in the centre of the panel was 1.3m and this represents the sag subsidence for a single panel 150m wide and about 340m deep. When Longwall 5 had finished, centreline subsidence ranged from 1.1-1.8m and the centreline subsidence on Longwall 4 had increased to 1.6-1.8m consistent with strata compression at the intermediate chain pillar. Subsidence monitoring on M Line indicated that the total elastic chain pillar compression was approximately 0.7m based on superposition of the subsidence measured on M Line during Longwall 5 and goaf edge monitoring observed during mining of Longwall 4.

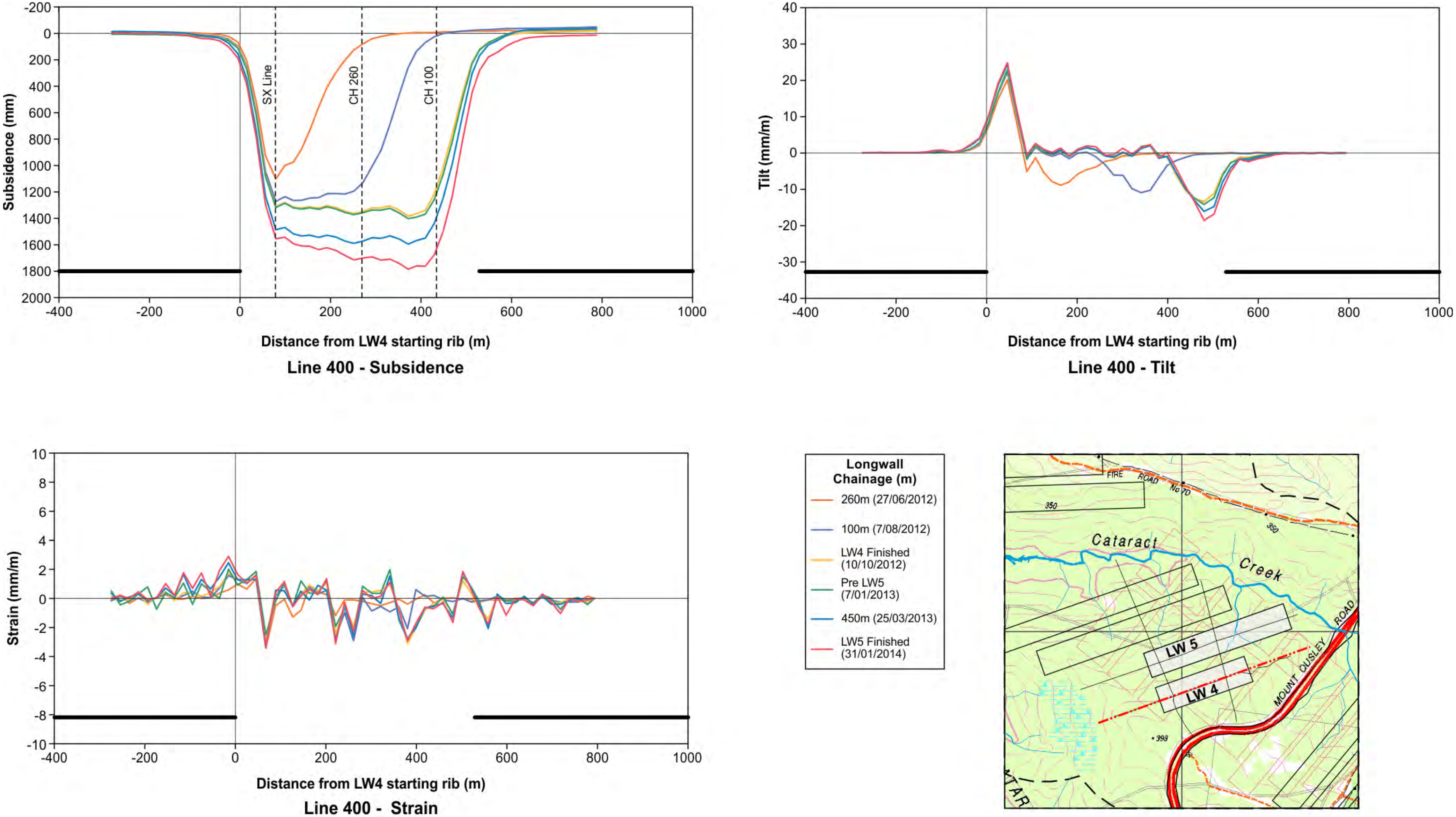


Figure 18a: Summary of Subsidence Monitoring Results from Longwalls 4 in the Wongawilli Seam.

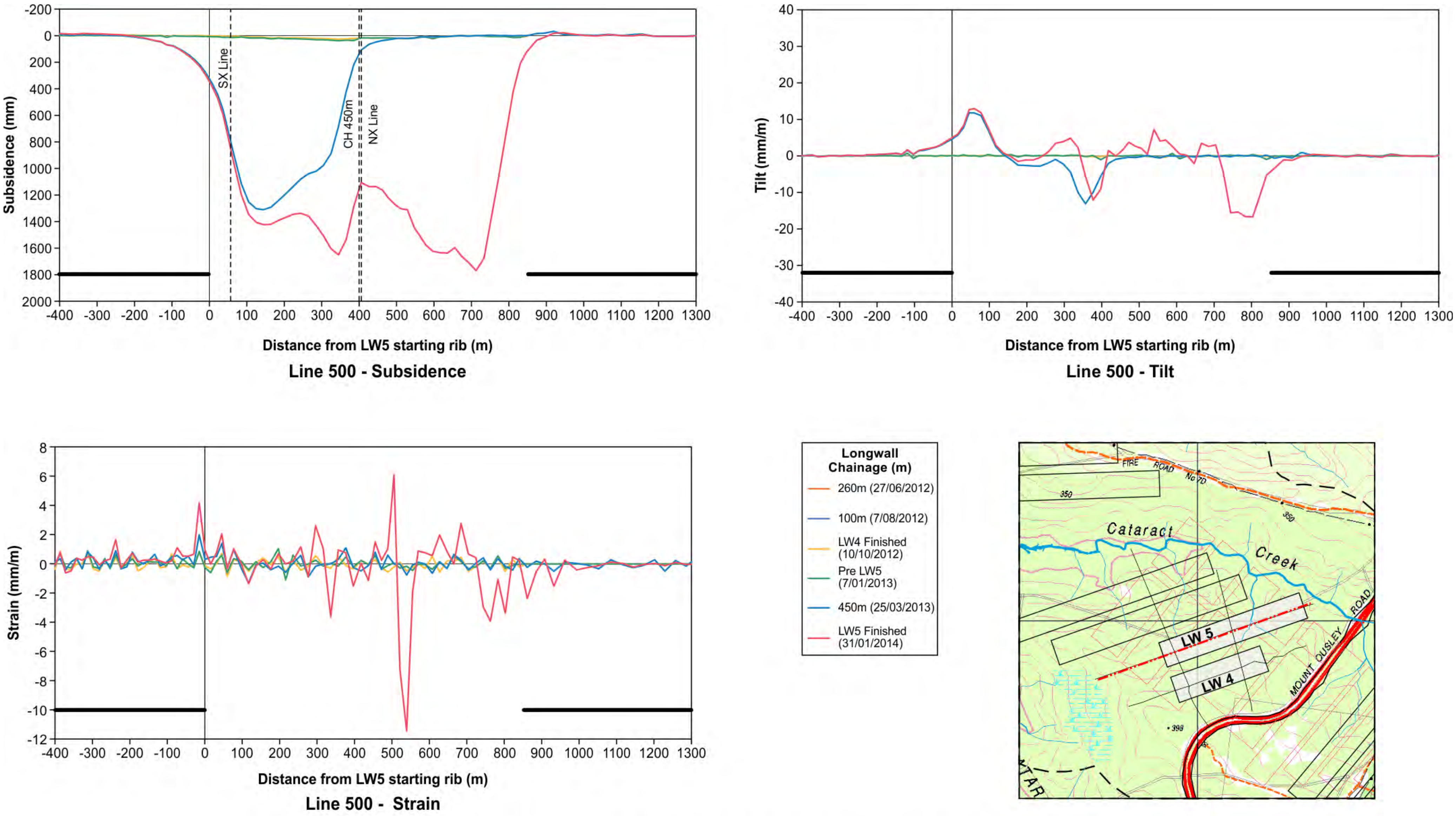


Figure 18b: Summary of Subsidence Monitoring Results from Longwall 5 in the Wongawilli Seam.

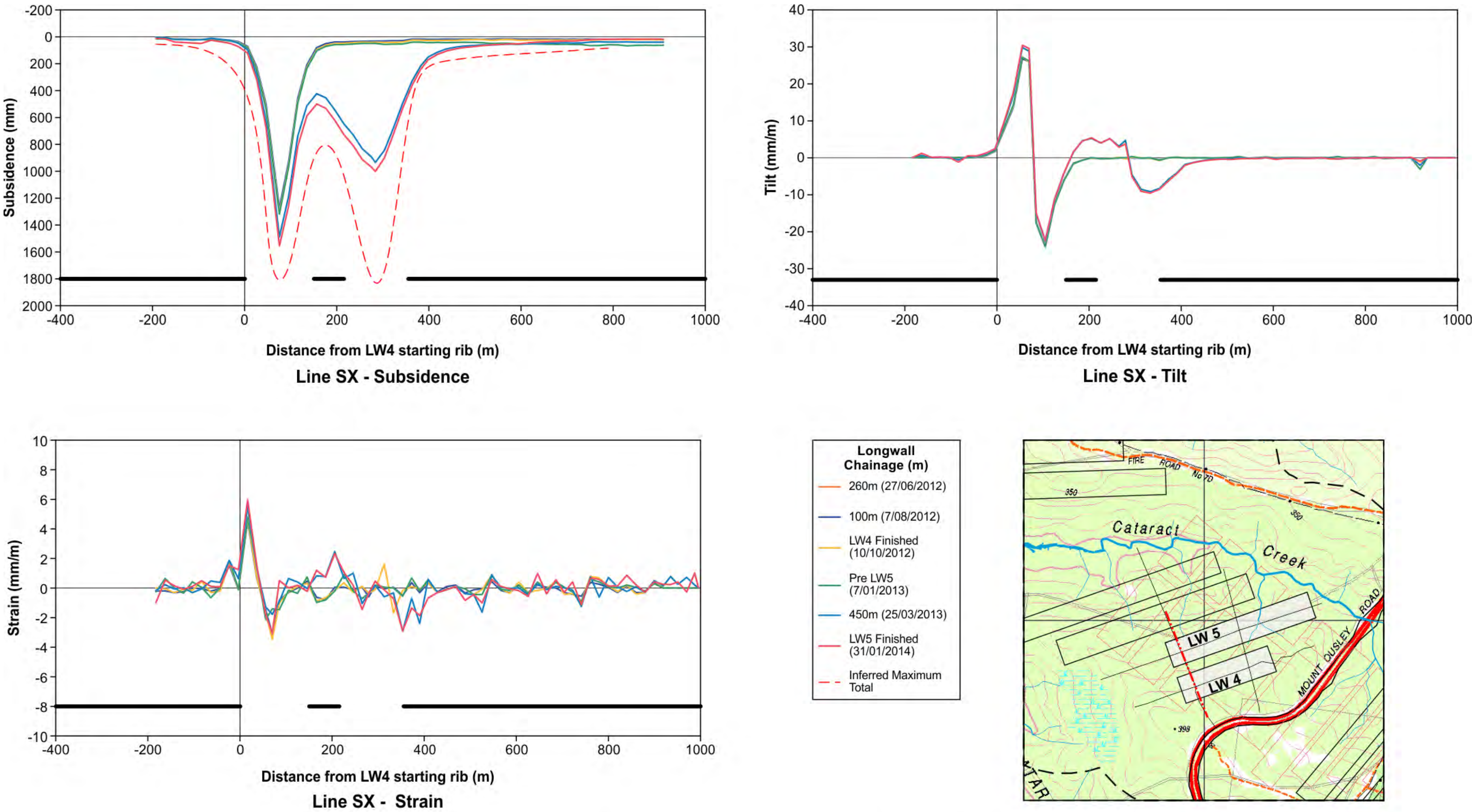


Figure 18c: Summary of Subsidence Monitoring on SX Cross Line – Longwalls 4 and 5 in Wongawilli Seam.

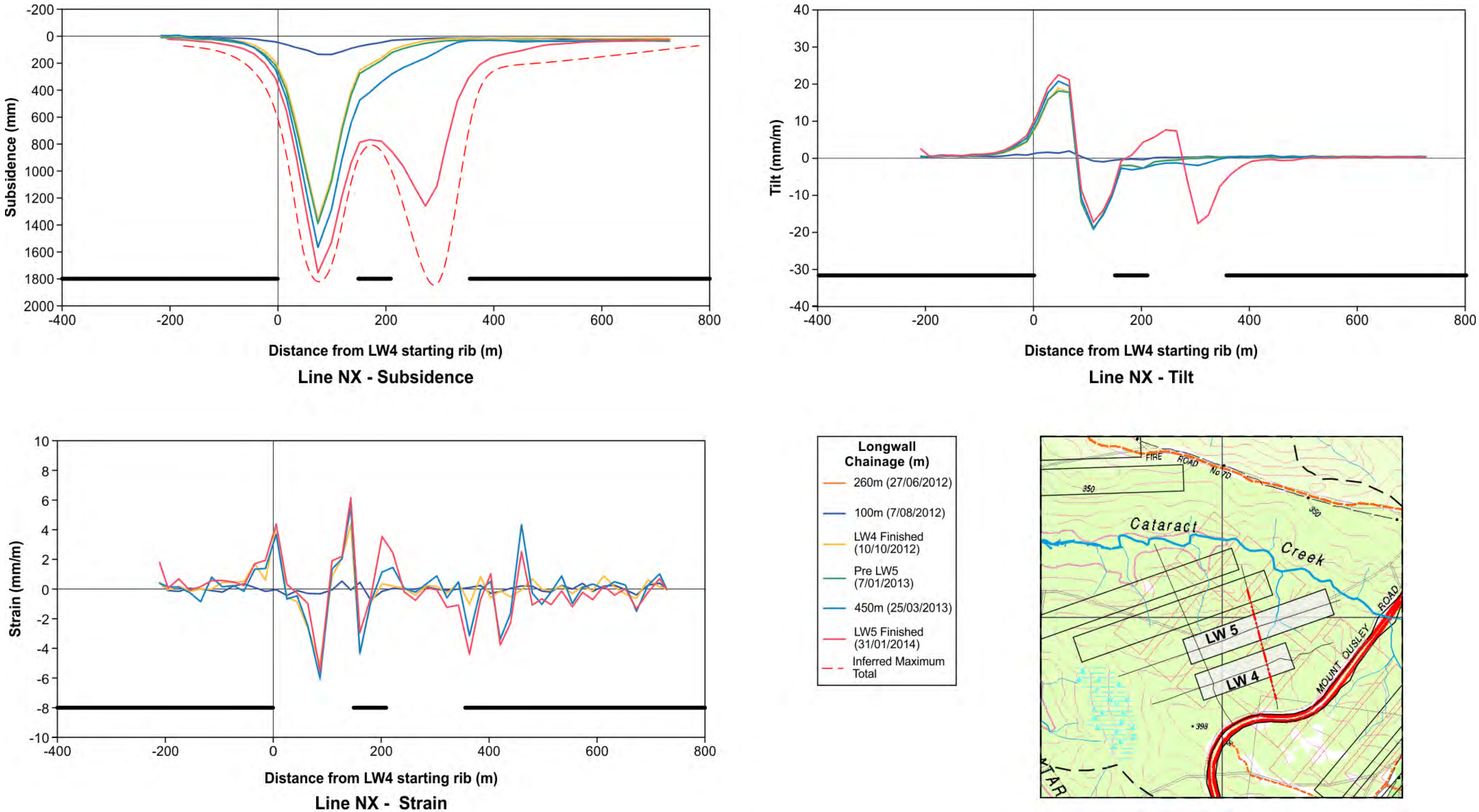
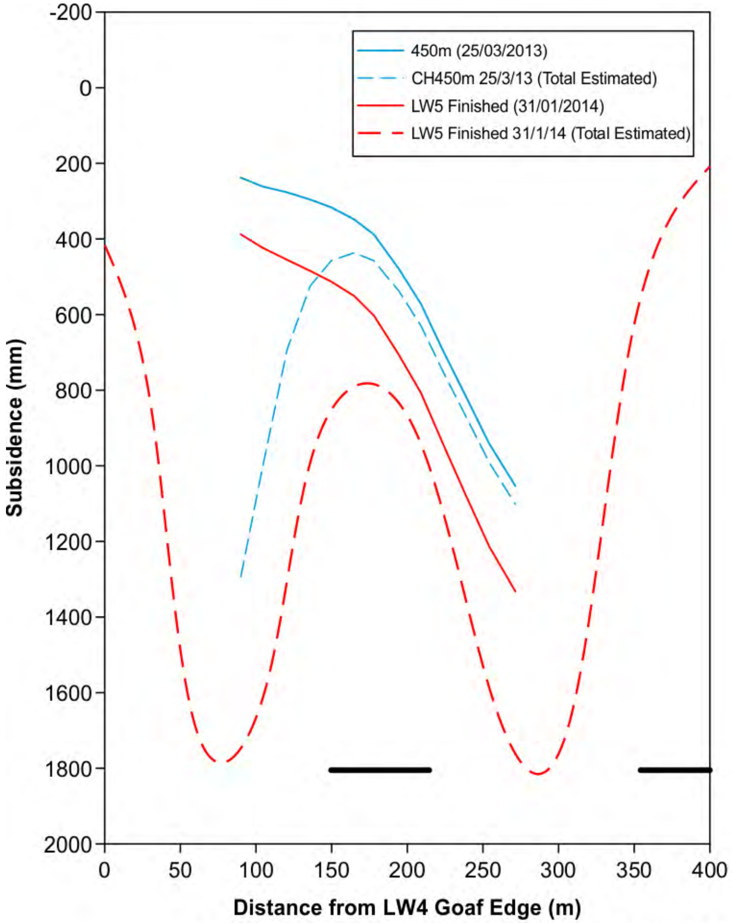


Figure 18d: Summary of Subsidence Monitoring on NX Cross Line – Longwalls 4 and 5 in Wongawilli Seam.



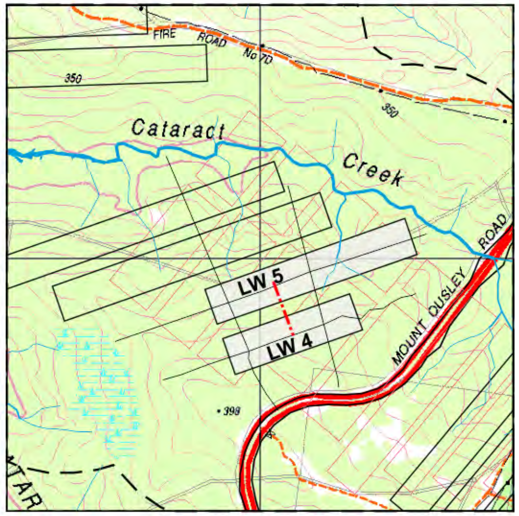


Figure 18e: Summary of Subsidence Monitoring on M Cross Line – Longwalls 4 and 5 in Wongawilli Seam.

The increase in Longwall 4 centreline subsidence from 1.3m at the completion of Longwall 4 to 1.7m when Longwall 5 had been substantially mined is consistent with strata compression above the chain pillar between the panels of about 0.8m causing the surface above one side of the panel to be lowered 0.8m and the surface above the centre of Longwall 4 to be lowered a further 0.4m. There has been no significant increase in sag subsidence over Longwall 4 as a result of mining Longwall 5. The additional subsidence is due to strata compression above the chain pillar between Longwalls 4 and 5.

The sag subsidence above Longwall 5 is of a similar magnitude to the sag subsidence above Longwall 4 although this does not show on the two cross-lines, SX and NX, because SX is too close to the end of the panel for full subsidence to develop and NX is located near the dyke pillar in the Balgownie Seam where subsidence is reduced. The presence of the full 1.8m of subsidence above Longwall 5 is apparent on the longitudinal 500 Line.

Figure 19 shows the sag subsidence plotted as a function of the panel width for Longwalls 4 and 5 and the sag subsidence that is commonly observed in undisturbed strata for a broad range of panel width to overburden depth ratios. Longwall 4 is mined in an area where there is both Bulli Seam goaf and Balgownie Seam goaf above most of the panel. Longwall 5 is mined in an area where there are Bulli Seam main heading pillars that have been partly mined and Balgownie Seam longwall goaf that has been completely extracted. The difference in disturbance to the overburden strata is clearly evident in the sag subsidence results plotted in Figure 19.

Above Longwall 5 where the Balgownie Seam has been fully extracted, the sag subsidence is significantly more than the sag subsidence that would be expected in previously undisturbed strata. Above Longwall 4, the Bulli Seam has also been mined, the sag subsidence is greater again consistent with the additional mining in the overlying Bulli Seam and the greater disturbance to the overburden strata that mining in both overlying seams has caused.

In narrow panels that depend on the overburden bridging to reduce the magnitude of surface subsidence as was the intention in the original Pt3A application, this reduction in the bridging capacity of the overburden strata has a profound effect on the maximum subsidence observed at the surface.

Another way to visualise the reduction in bridging capacity of overburden strata is through the goaf edge subsidence profiles. Figure 20 shows the range of goaf edge subsidence profiles observed in undisturbed strata compared to when one seam and two seams have been mined. These profiles show that as the number of seams mined increases and the disturbance to the overburden strata increases, the shear stiffness and rigidity of the overburden strata decreases.

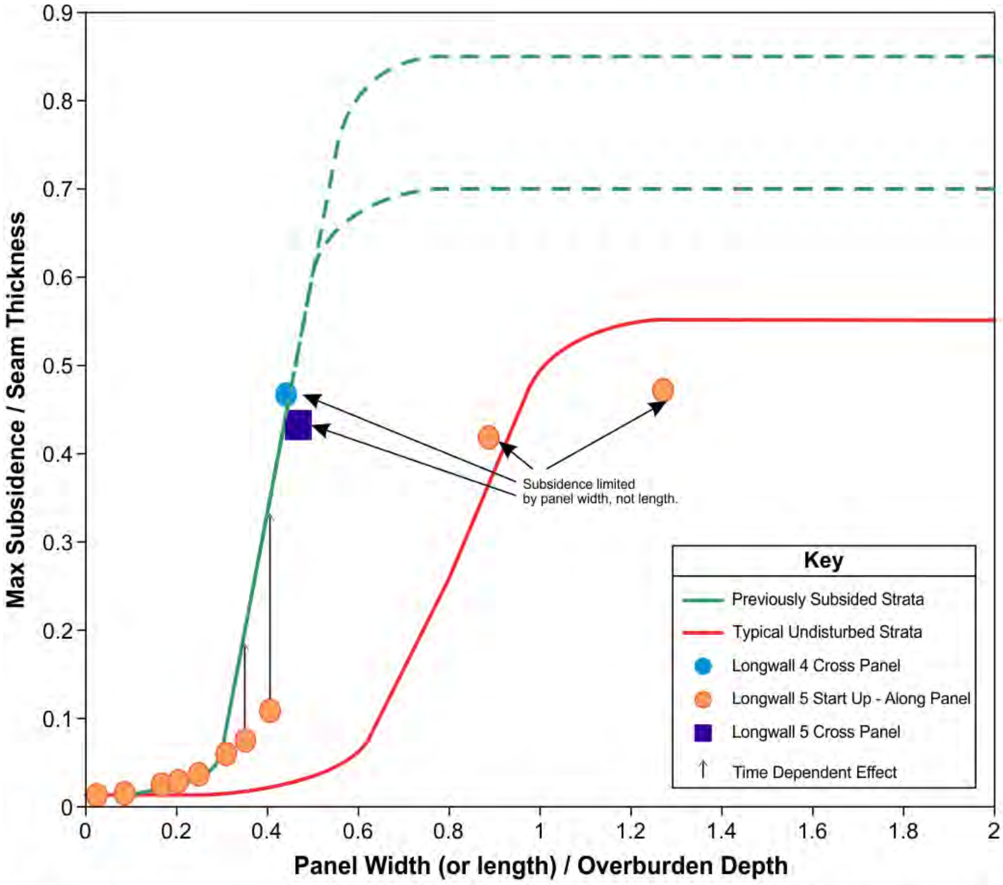


Figure 19: Summary of Sag Subsidence Measured at Start of Longwalls 4 and 5 in the Wongawilli Seam.

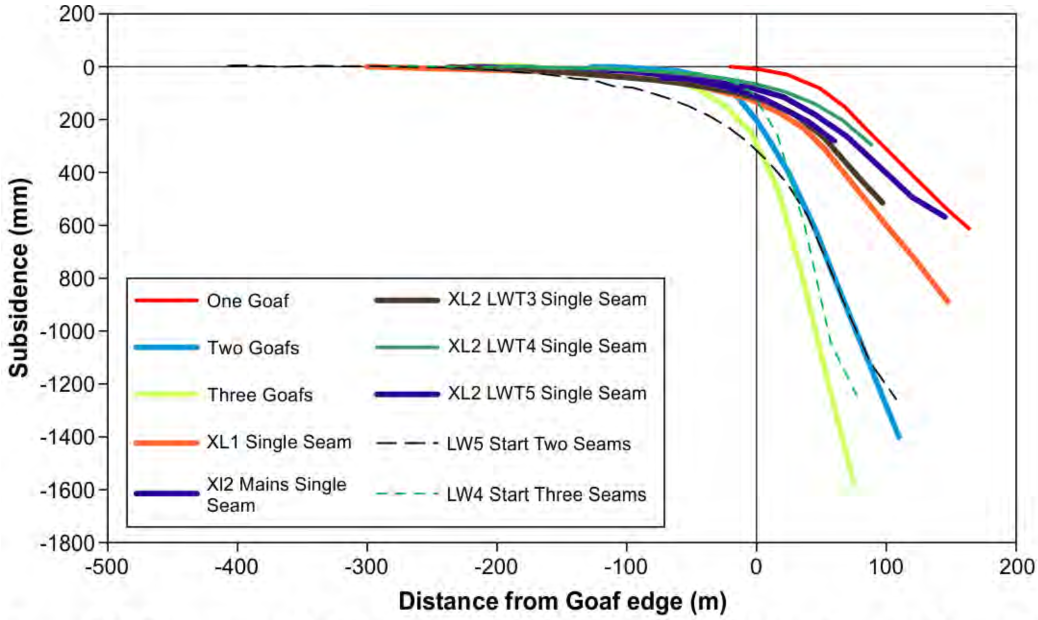


Figure 20: Summary of Goaf Edge Profiles for Mining in One, Two, and Three Seams.

The profiles in Figure 20 show that the sag subsidence behaviour above multiple goafs is consistent with subsidence behaviour observed over panels in single seam mining operations except that the shear stiffness or rigidity of the overburden strata is greatly diminished as a result of the previous mining activity. The reduced shear stiffness leads to reduced bridging capacity of the overburden strata and significantly increased maximum subsidence for the same overburden depth and longwall panel geometry.

In previously undisturbed overburden strata, the maximum subsidence above a 150m wide longwall panel at 300-360m would be of the order of 0.1-0.3m and barely perceptible for all practical purposes. The measured maximum sag subsidence has been 1.3m because softening of the overburden strata by previous mining has significantly increased the sag subsidence.

This phenomenon was also apparent in the Balgownie Seam longwall panels located below Bulli goaf compared to when the longwall panels were mined below solid pillars as summarised in Table 2 above.

Strata compression subsidence of 0.6-0.8m observed above the 60m wide chain pillar between Longwalls 4 and 5 is consistent with the level of strata compression subsidence that would be expected for the panel geometries at an overburden depth of 340m.

A significant characteristic of the subsidence observed over Longwalls 4 and 5 is that the additional sag subsidence caused by mining panels in the deeper seams is substantially limited to within the footprint of the panel, much the same as for single seam mining operations. This characteristic is clearly apparent despite the presence of an irregular overlying mining geometry. In some areas above Longwalls 4 and 5, there are overlying goafs in both seams, in others just one seam and not the other, and in other areas there are standing pillars. And yet, in all three circumstances, the surface subsidence is substantially limited to within the area that has been mined.

The form of the cross-panel subsidence profiles indicates that maximum subsidence in the centre of each panel is not being controlled by recompression of the strata directly above the longwall goaf but rather by the disturbance to the overburden strata from previous mining affecting the ability of the overburden strata to bridge.

There are subtle variations outside the goaf edge associated with previous mining in the overlying seams. More gradual subsidence profiles and greater goaf edge subsidence are evident where there are goaf areas in both the Bulli and Balgownie Seams as can be seen in Figure 21. Where there are goaf areas directly above the goaf edge in only one of the overlying seams, the subsidence profile is sharper and shows less subsidence outside the goaf. When there are no overlying goaf areas, the subsidence profile is sharpest and the subsidence profile beyond the goaf edge is the same as for single seam mining geometries.

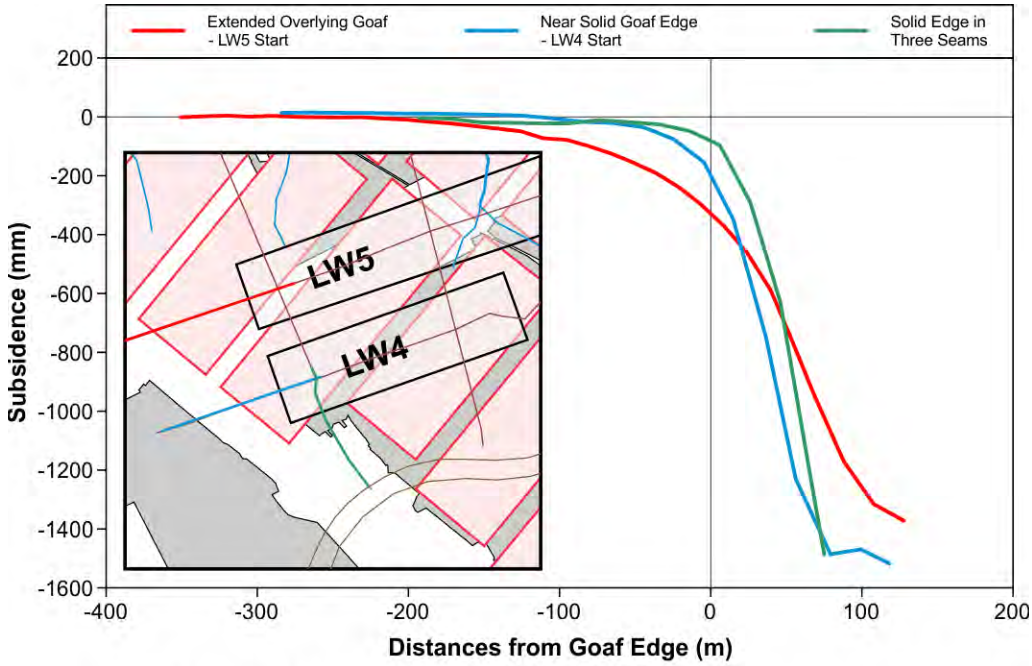


Figure 21: Goaf edge variations above Longwalls 4 and 5.

In areas where there are small standing pillars in the Bulli Seam above the goaf edge, there exists the possibility that mining in the Wongawilli Seam below will cause these pillars to be destabilised. If the pillars were destabilised, the resulting subsidence from the pillar destabilisation could then extend outside the Wongawilli Seam goaf edge to the edge of the overlying pillar panel in the Bulli Seam.

There has been no evidence of this type of behaviour so far from longwall mining in the Wongawilli Seam or in the Balgownie Seam but there is considered to be some opportunity for additional subsidence during mining of Longwall 1. A panel of Welsh bords was visited during the site inspection on 21 June 2012 in an area of the Bulli Seam immediately above and to the northeast of the end of Longwall 1 as shown in Figure 13.

If this area of pillars were to be destabilised, there would be potential for the surface subsidence to extend some 100m to the northeast of the panel and up to 300m east of the eastern corner of Longwall 1, but this subsidence would only occur if Longwall 1 was mined full length and the pillars in the Bulli Seam were destabilised. Maximum additional subsidence of a few hundred millimetres would be expected as a result of this instability. Special consideration is required in this area to manage this potential.

4.1.2 Extent of Vertical Subsidence Outside the Panel

Survey measurements conducted along the edge of the northbound lane of Mount Ousley Road have measured the influence of multi-seam mining based on the distance from the goaf edge providing evidence that vertical subsidence diminishes to low levels a short distance beyond the goaf edge.

Figure 22 shows a summary of the vertical subsidence measured along Mount Ousley Road during mining of Longwall 4 and the timing of the subsidence that developed at key points. The projections of adjacent goaf areas in the Bulli, Balgownie, and Wongawilli Seams are also shown. The subsidence observed is of low level reaching a maximum of approximately 40mm at the projected centre of Longwall 4 some 180m from the goaf edge at an overburden depth of 350m.

These measurements indicate the angle of draw to 20mm of subsidence is greater than 26.5° consistent with experience elsewhere in the Southern Coalfield at this overburden depth. At the projection of the north-eastern corner of Longwall 4 where both the Bulli Seam and the Balgownie Seam have been mined, subsidence at 230m from the goaf corner is 20mm at 320m deep indicates the angle of draw to 20mm off the corner of the panel is equal to 35°. At the south-eastern corner of Longwall 4, where the Balgownie Seam has not been mined but there are areas of mining in the Bulli Seam, the 14mm of subsidence at 225m at 360m overburden depth indicates an angle of draw off the corner of the panel of less than 32°. There does not appear to be any evidence of significant vertical subsidence outside the panel being mined associated with any type of pillar instability.

Other cross line measurements indicate the vertical subsidence is 50mm at between 20m and 100m from the goaf edge.

On the basis of these measurements, the angle of draw to 20mm of subsidence is considered likely to be slightly greater than 35° in areas where both overlying seams have been mined and slightly less than 35° where only one overlying seam has been mined. The angle of draw is therefore not significantly different to the angle of draw that would be expected for mining in a single seam at similar overburden depths. If pillar instability were to occur near the edge of a Wongawilli Seam longwall panel, it is possible that that low level subsidence may extend outside the panel edge and potentially increase the angle of draw slightly. However, the impact of any such increase is expected to be small.

4.1.3 Far-Field Horizontal Movements

There are several sources of far-field horizontal subsidence measurements available from mining Longwalls 4 and 5. The Mount Ousley Road P Line and Picton Road Interchange provide measurements of horizontal movements based on three dimensional GPS controlled surveying and the closure measurements across Cataract Creek provide an indication of the horizontal movement in the middle distance. Observations of cracks on Mount Ousley Road provide an indication of the horizontal distance that changes potentially associated with mining have been observed.

The GPS controlled surveying does not show any convincing evidence of far-field horizontal movements. The survey tolerance of the systems being used is ±20mm. The monitoring at Picton Road Interchange is approximately 1300m from the southern end of Longwall 4 and there is no evidence that there has been any differential or even total movement at the interchange associated with mining Longwalls 4 and 5.

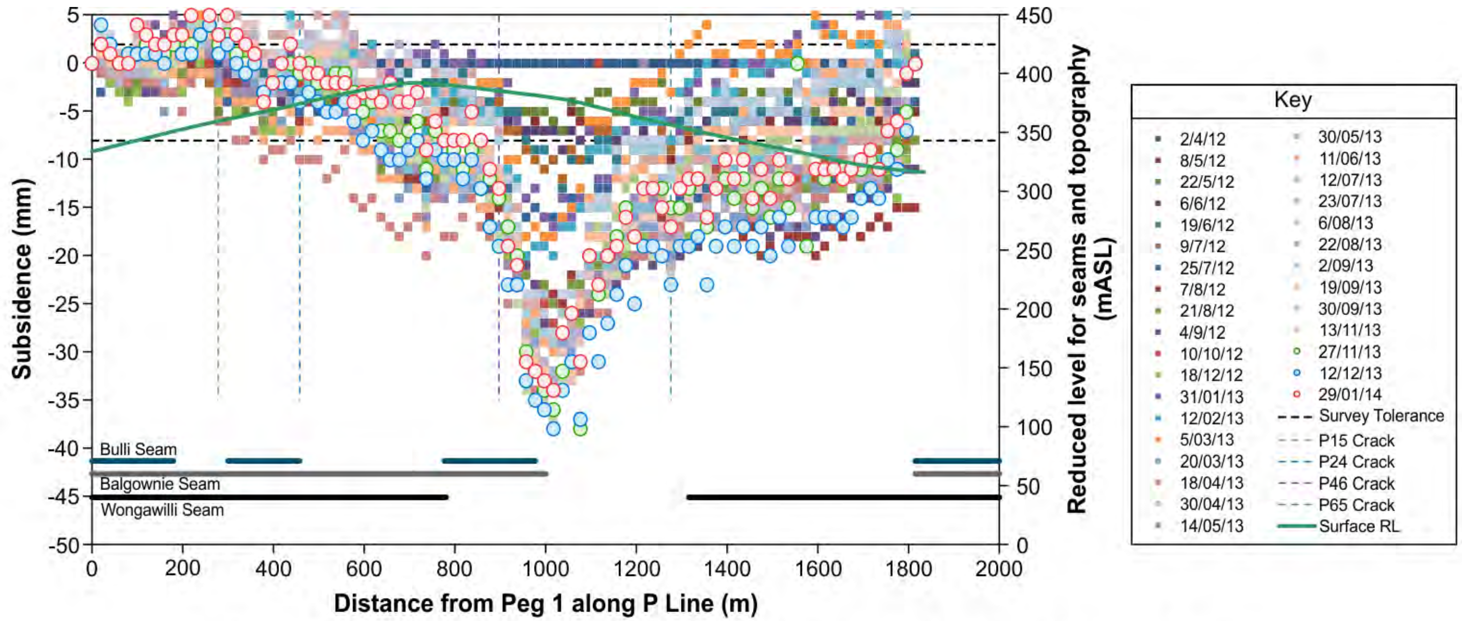
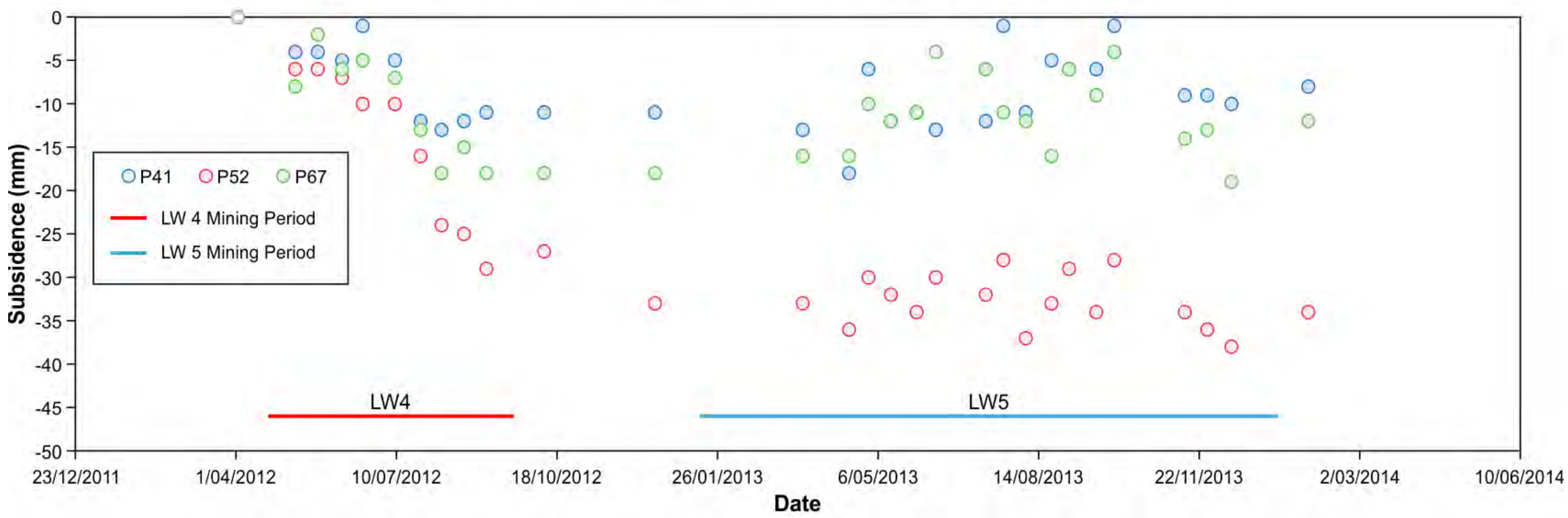


Figure 22a: Subsidence measured on P Line alongside Mount Ousley Road.



a) Development of P Line Subsidence over Time.

Figure 22b: Development of subsidence on P Line over time and as a function of longwall retreat.

Figure 23 shows the closure measurements on Cataract Creek observed during mining of Longwall 5. Closure measurements across Cataract Creek first became evident at three of the four measurement points when Longwall 5 was approximately 450m from the finishing end of the panel (i.e. at longwall chainage CH400m). The longwall face at this position was approximately 320m from CC4, 420m from CC2, 530m from CC1, and 700m from CC3.

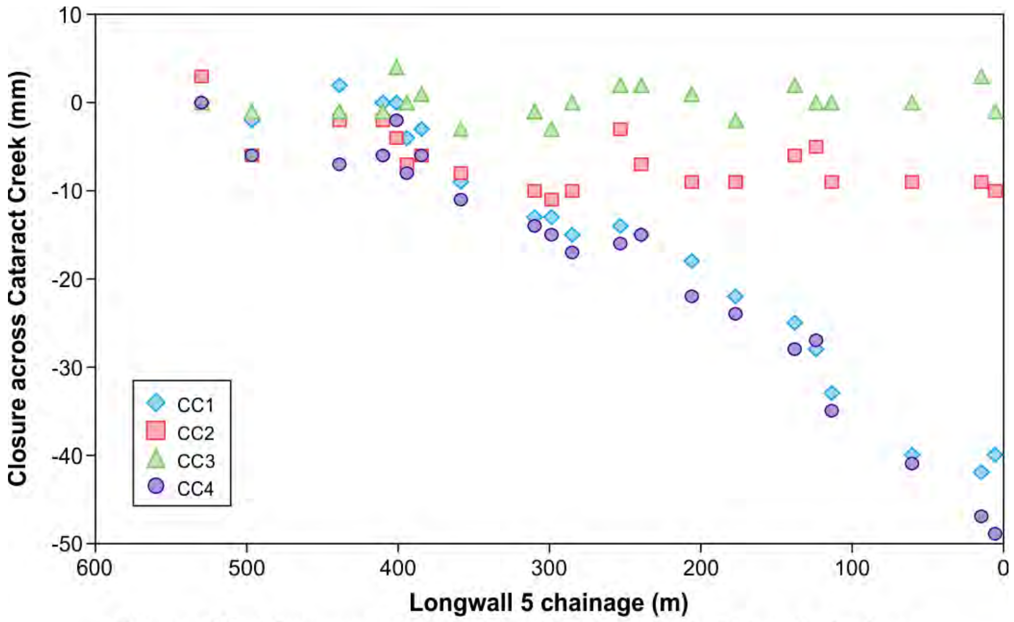


Figure 23: Closures observed across Cataract Creek during mining of Longwall 5.

At Cataract Creek where the measurement points are located, the overburden depth to the Wongawilli Seam is approximately 280m, so the horizontal closure movements have been observed out to a distance from the goaf edge equal to between 1.1 and 2.9 times depth.

The closure measured on the Cataract Creek closure lines has steadily increased as Longwall 5 has continued to retreat. These measurements indicate that far-field downslope movements have been evident to a distance of up to about 450m from the approaching longwall panel but increase linearly with longwall retreat so that the longwall retreat required to generate a set amount of closure can be estimated with confidence.

Relatively fresh cracks that have appeared on Mount Ousley Road at P24 and P25 are approximately 500m from the southern end of Longwall 4 at an overburden depth of about 360m, so there is some evidence of small horizontal movements to a distance of about 1.4 times overburden depth.

Small far-field movements are evident from the longwall mining conducted so far in the PPR Assessment Area but these movements are of low magnitude and decrease with distance from mining.

4.2 Subsidence Prediction Methodology

The subsidence prediction methodology used in this assessment is based on consideration of the mechanics of the subsidence processes involved, particularly the differences between the two components of subsidence, sag subsidence and strata compression subsidence and using measured subsidence profiles to characterise the subsidence behaviour and provide a basis for prediction of subsidence associated with future mining.

This approach is considered to be appropriate in the relatively complex mining environment that exists within the PPR Assessment Area especially now that there is actual subsidence data available from Longwalls 4 and 5.

The presence of mining in two other overlying seams makes the use of methods such as the Incremental Profile Method which relies on repeatable elastic superposition of goaf edge profiles and the Influence Function Method which assumes elastic strata behaviour less reliable because of the variable characteristics of the overburden strata.

The method used to estimate subsidence in all three seams is primarily based on existing monitoring data. Contours of subsidence for the Bulli Seam mining operations have been estimated using subsidence profiles measured in the 1990's over the longwall panels at South Bulli Colliery (now owned by NRE). These profiles have been adjusted for overburden depth and contours of subsidence have been drawn in AutoCAD relative to the edges of goaf areas indicated on mine record tracings.

The subsidence observed on the surface above the Balgownie Seam longwall panels also provides an indication of the status of the Bulli Seam mining. The Bulli Seam subsidence contours have been modified slightly to reflect this indicated status. The subsidence contours thus produced have then been converted into gridded model of subsidence values on a 10m by 10m grid using Golden Software's Surfer program.

Hard copies of measured subsidence from each of the Balgownie Seam longwall panels are available in the mine archives. These drawings have been scanned, scaled, and converted into a format that allows the final subsidence across all the panels to be contoured. The contours have then been converted to a 10m x 10m grid of subsidence using the same approach described above for the Bulli Seam subsidence.

Subsidence predictions for mining in the Wongawilli Seam are based on measured subsidence profiles from Longwalls 4 and 5. These profiles have been adjusted for panel width and overburden depth and allowances have been made for possible chain pillar interactions with the overlying Balgownie Seam longwall goafs above Longwalls 1-3. The contour plots generated have again been drawn in AutoCAD and then gridded in Surfer onto a 10m by 10m grid.

The combined subsidence from each seam or from combinations of seams has then been determined by adding together the components from each seam.

Contours of the surface topography have been generated from LiDAR data on the same 10m by 10m grid to allow the subsidence to be added and subtracted from the surface topography. Contours of the three coal seams have been developed from survey information of floor seam contours available in the Bulli Seam within the mine lease boundary.

The Balgownie and Wongawilli Seam floor contours have been estimated from the Bulli Seam floor contours assuming a separation of 10m and 30m to the Bulli Seam respectively. Overburden depth to the Wongawilli Seam has been determined as the difference in the Surfer model between the surface topography and the estimated Wongawilli Seam floor contours.

Estimates of strains and tilts presented in this assessment are based on measured values and the experience more broadly of monitoring in the Southern Coalfield reported by Holla and Barclay (2000). This broader experience is considered to provide a strong basis for predicting maximum surface strains and tilts. Based on the subsidence measurements that have been made over Longwalls 4 and 5 and previously above the Balgownie Seam longwall panels, the method described by Holla and Barclay (2000) appears to provide a reasonable and conservative basis to predict the incremental maximum strains and tilts even for multi-seam mining environments.

The strains and tilts are highly variable and are generally of a much lower magnitude than the maximum values. For prediction purposes, the maximum values have been determined to be conservative. The exact position of the maximum values is difficult to determine accurately, although it is recognised that maximum tensile strains are most likely to occur at topographic high points and at the start of panels, particularly in those areas where mining is proceeding in a downslope direction. Maximum compressive strains are most likely to occur in topographic low points or near the finishing end of the panel particularly when mining in a downslope direction.

The measurements of incremental tilts and strains made so far indicate that the background values of tilts are more generally of the order of 50-80% of the maximum values indicated by the approach presented by Holla and Barclay (2000). Similarly, background values of strains are more generally of the order of 20-30% of the maximum values indicated.

Closures across Cataract Creek have been estimated using the ACARP method developed by Waddington, Kay and Associates (2002). This method is recognised to be an upper limit prediction method based on a limited database. Nevertheless, the method provides a consistent approach to estimating closure that can be used to compare with measured values and provide a basis for extrapolation to give realistic closure estimates.

4.3 Accuracy and Sensitivity Assessment

The subsidence monitoring data available from eleven longwall panels in the Balgownie Seam mined 10m below the Bulli Seam and more recent subsidence data from Longwall 4 mining under two levels of previous mining and from Longwall 5 mining under Balgownie Seam goaf and Bulli Seam main heading pillars is considered to provide a strong basis to predict future subsidence.

The accuracy of the subsidence predictions is limited by the uncertainties that exist in a natural environment combined with additional uncertainties about the detail of mining geometries in the Bulli Seam and some aspects of subsidence behaviour in a multi-seam mining environment.

Available subsidence monitoring data from mining in the PPR Assessment Area indicates that the subsidence associated with multi-seam subsidence in this area is similar to the subsidence behaviour in a single seam mining environment except that the bridging capacity of the overburden strata is significantly reduced. The key observations are:

- Reduced bridging capacity affects the magnitude of the maximum sag subsidence over the centre of each longwall panel.
- Subsidence occurs predominantly within the footprint of the panel being mined except where there is potential for pillar instability as discussed separately below.
- Panel width can still be used to control the magnitude of maximum subsidence.
- Strata compression subsidence above the chain pillars between longwall panels is of a similar magnitude to that which occurs in single seam mining operations.
- Subsidence at the goaf edge is softened by previous mining activity in overlying seams, but the effect is small and of second order significance.
- The angle of draw to 20mm of subsidence is of the order of 35° and consistent with experience in single seam mining operations.

The uncertainties that remain from predicting subsidence behaviour in a multi-seam environment are offset somewhat by the benefits of having previous subsidence monitoring experience and the opportunity to review the longer term recovery of surface impacts associated with earlier mining activity. The ability to inspect all three levels of mining underground also improves confidence in the understanding of the mechanics involved at this site.

There exists some potential in areas where there are small standing pillars in the Bulli Seam above the goaf edge for these pillars to be destabilised by mining in the Wongawilli Seam below. This destabilisation is evident in the Bulli Seam beyond the end of Longwall 7 in the Balgownie Seam. If overlying pillars are destabilised at the goaf edge, the resulting subsidence from the pillar destabilisation could then extend outside the Wongawilli Seam goaf edge to the edge of the overlying pillar panel in the Bulli Seam. The magnitude of additional subsidence resulting from pillar instability is expected to be small. The only place where this type of behaviour appears likely is in an area beyond the northeast corner of Longwall 1 (see Figure 13).

The monitoring data indicates that maximum sag subsidence is able to be controlled by the width of individual panels. It is nevertheless helpful to have an indication of the maximum credible subsidence that might result. Li et al (2010) provide a summary of the experience of multi-seam mining subsidence that indicates maximum subsidence of up to 83% of the cumulative mining height for all seams compared to 65% for single seam mining. The maximum subsidence indicated by this approach provides an upper limit to the maximum subsidence.

The combined mining height for all three seams ranges 5.4-6.9m depending on how much the thickness of the Bulli Seam is discounted to allow for the realistic recovery rates of pillar extraction and bord and pillar mining. The maximum subsidence using 85% of this thickness would be 4.6-5.8m.

Maximum subsidence of up to 1.4m has so far been observed above the Balgownie Seam with an additional 0.5m estimated for the Bulli Seam to give a maximum of 1.9m of subsidence from previous mining. Using the Li et al approach would indicate maximum subsidence from mining in the Wongawilli Seam would be likely to be in the range 2.7m (allowing for the 1.9m that may have already occurred) to 5.8m (in areas of small standing pillars in the Bulli Seam that may be destabilised by further mining and are coincident with the goaf edge of Balgownie Seam longwall panels).

Above Longwalls 4 and 5, the maximum subsidence measured in the centre of the longwall panels ranges 1.3-1.8m and is therefore much less than the maximum subsidence that would be expected if these panels were wider. Although the bridging capacity of previously mined strata is less than the bridging capacity of previously undisturbed strata, the narrower panel widths of Longwalls 4 and 5 and the remaining longwalls proposed within the PPR are clearly still limiting maximum subsidence to well below the level that would be observed if the panels were wider and full subsidence could develop in the centre of each panel.

Strain and tilt values observed to date are within the range of predicted values using the approach presented by Holla and Barclay (2000). While it is possible that higher values of strain and tilt may be observed in isolated locations, the approach used for prediction is considered unlikely to significantly underestimate maximum strain and tilt values.

Small errors or tolerances in the data used in the assessment are not considered likely to significantly influence the accuracy of the subsidence predictions. The LiDAR surface data is expected to be accurate to a few tens of centimetres across the entire PPR Assessment Area. The Bulli Seam floor contours have been surveyed and are therefore likely to be accurate to about a metre.

The PPR Assessment Area extends beyond the mine lease boundary so the floor contours beyond the lease boundary have been extrapolated and are therefore of lower confidence, but are nevertheless considered suitable for the purposes of this assessment. There is considered to be potential for a 5-10m difference in seam separation across the PPR Assessment Area that will slightly affect the calculation of overburden depth, but not significantly.

5. PREDICTED SUBSIDENCE

In this section, the predicted subsidence parameters above the proposed Wongawilli Seam longwall panels are presented and discussed.

5.1 Vertical Subsidence

Figures 24a and 24b shows the contours of subsidence predicted above the proposed longwall panels in the PPR Assessment Area at the same scale as other diagrams (Figure 24a) and at a magnified scale (Figure 24b). The area is also shown where special consideration of the potential for pillar instability in the Bulli Seam is recommended. Table 4 presents a summary of the predicted subsidence movements for mining in the Wongawilli Seam, as well as estimated and measured subsidence in the Bulli Seam and Balgownie Seam in the area of each Wongawilli Seam longwall panel. Actual measurements from the Balgownie Seam longwalls and Longwalls 4 and 5 in the Wongawilli Seam are shown in brackets as a basis for comparison with the predictions.

Maximum subsidence over individual longwall panels in the Wongawilli Seam is predicted to range from 1.5m over the slightly narrower Longwall 7 through to 2.6m over Longwall 3 where the overburden depth is shallowest and there is overlying goaf in both seams.

5.2 Tilts and Strains

Maximum tilts over individual longwall panels in the Wongawilli Seam are expected to range up to maxima of 24mm/m over Longwall 10 through to maxima of 51mm/m above Longwall 3. Although these maxima may occur anywhere in the panel, they are most likely to occur at panel edges in overlying seams and in areas of topographic change in gradient. More generally across the panel, systematic tilts are likely to be in the range 50-90% of the maximum values.

Maximum strains over individual longwall panels in the Wongawilli Seam are expected to range up maxima of 14mm/m over Longwall 10 to maxima of 31mm/m over Longwall 3. Although these maxima may occur anywhere within the panel, maximum tensile strains are most likely to occur at

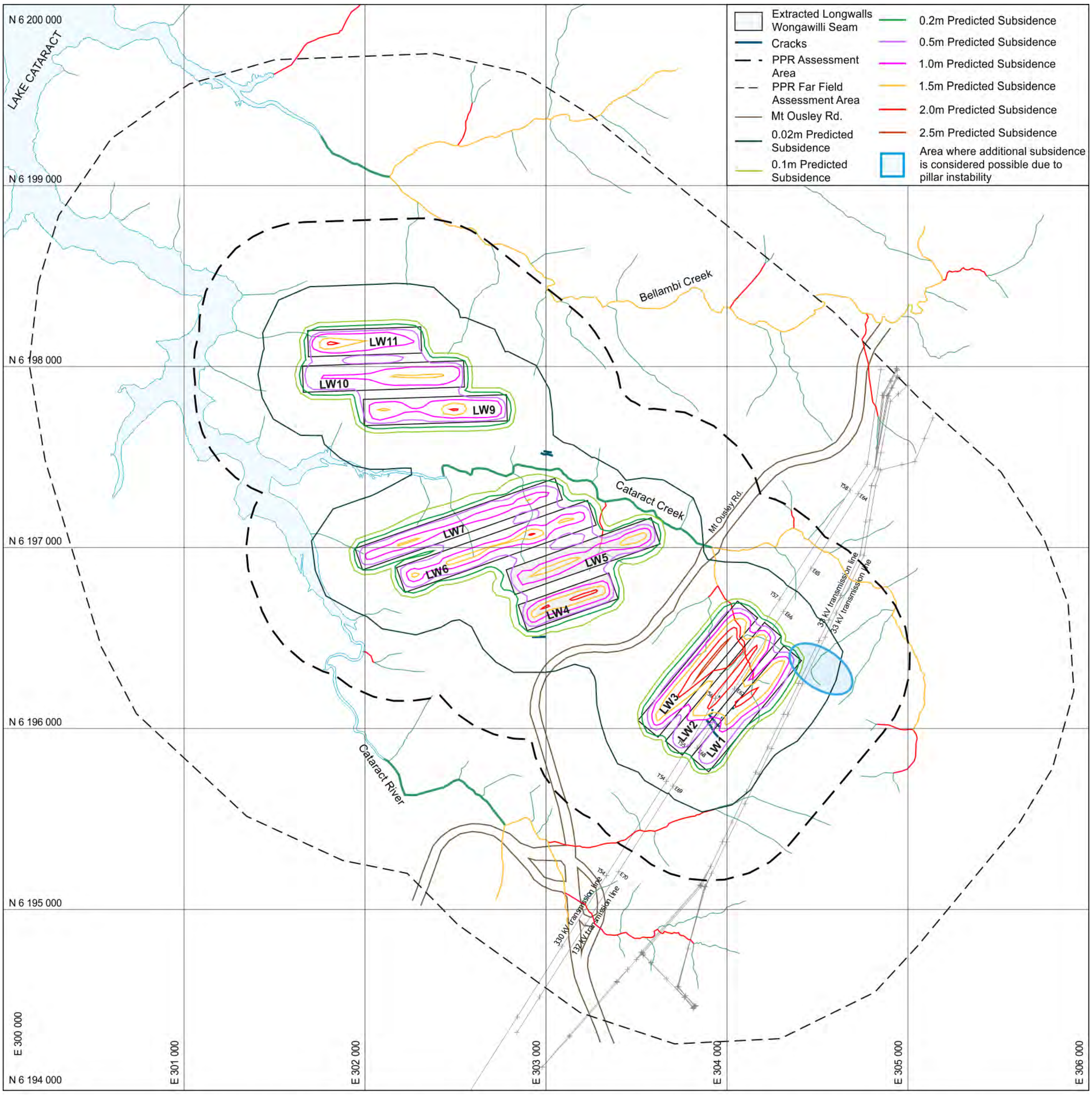


Figure 24a: Contours of predicted subsidence from the Wongawilli Seam (at same scale as previous diagrams).

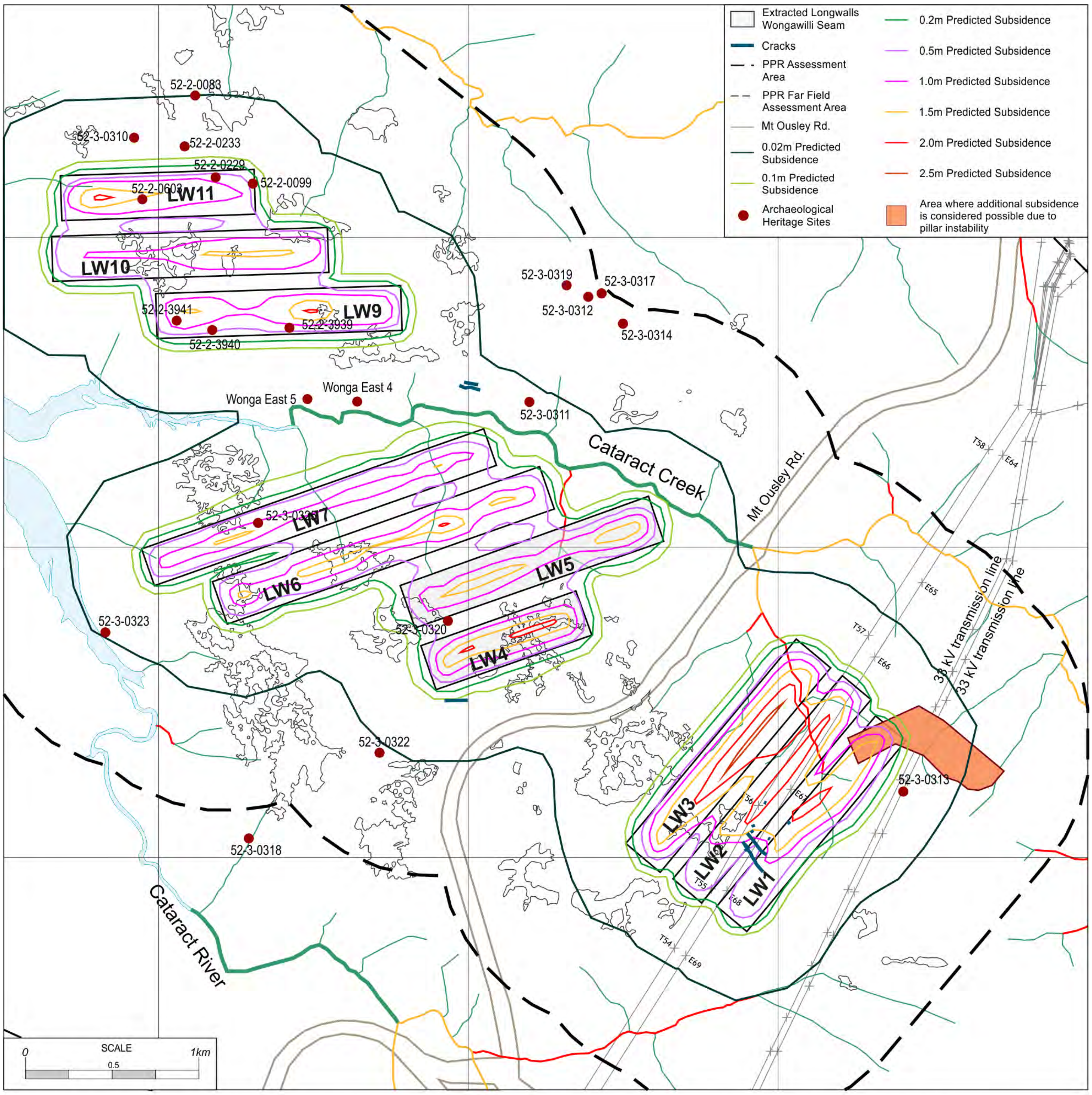


Figure 24b: Enlarged view showing contours of predicted subsidence from the Wongawilli Seam relative to surface features.

Table 4: Subsidence Predictions for PPR Assessment Area

General Observations Above Individual Panels	Overburden Depth to WWSM (m)	BUSM and BASM Subsidence (m)	WWSM Subsidence Predicted (m) and Measured (in bold)	BASM Tilt (mm/m)	Predicted WWSM Tilt (mm/m) and Measured (in bold)	BASM Max Tensile Strain (mm/m) and Typical (in brackets)	Predicted WWSM Tensile Strain (mm/m) and Measured (in bold)	BASM Max Compressive Strain (mm/m) and Typical (in brackets)	Predicted WWSM Compressive Strain (mm/m) and Measured (in bold)	Closure on Cataract Creek Observed Directly and Inferred from Upsidence (mm)	Closure on Cataract Creek (mm) (Southern Tributary in Brackets)
Longwall 1	260	1.3	2.1	19	40	N/A	12	N/A	24	N/A	N/A (700)
Longwall 2	260	1.1	2.1	19	40	N/A	12	N/A	24	N/A	N/A (300)
Longwall 3	255	1.3	2.6	13	51	N/A	15	N/A	31	N/A	N/A (150)
Longwall 4 (completed)	300	1.9	2.1 (**1.8**)	11	35 (**30**)	N/A	10.5 (**7.5**)	N/A	21 (**14**)	100	N/A
Longwall 5 (completed)	265	0.9	1.9 (**1.8**)	11	36 (**16**)	N/A	10.8 (**6**)	N/A	22 (**12**)	130	300 (**49**)
Longwall 6	280	1.5	2.1	18	38	7.5 (3)	11	14 (4)	23	310	290
Longwall 7	270	1.2	1.5	18	28	7.5 (3)	8	14 (4)	17	310	290
Longwall 9	330	0.5	2.1	N/A	32	N/A	10	N/A	19	N/A	50
Longwall 10	340	0.6	1.6	N/A	24	N/A	7	N/A	14	N/A	30
Longwall 11	350	0.6	2.1	N/A	30	N/A	9	N/A	18	N/A	10
SELECTED NATURAL FEATURES											
Threatened frog habitat CRUS2 Trib	300		0	5 estd	0	3	0	4	0		
Threatened frog habitat CRUS1 Trib1	320	0.5	0	5 estd	0	3	0	4	0		
Threatened frog habitat CRUS1 Trib2	320	0.5	0.02	11 estd	0	3	0	4	0		
CCUS4 Trib	270	0.9	1.5	18	28	7.5 (3)	8	14 (4)	17		
Cliffs over LW9	330	1.2	2.1	N/A	32	N/A	10	N/A	19		
Cataract Creek	260	0.5	0.1	15 estd	1	N/A	0	N/A	N/A		

topographic high points and maximum compression strains are most likely to occur at topographic low points. More generally across the panel, systematic strains are likely to be 20-30% of the maximum values.

5.3 Valley Closure

The upper limit of valley closure across Cataract Creek downstream of the Mount Ousley Road has been estimated using the 2002 ACARP Method. The predicted closures across Cataract Creek have been revised slightly from the earlier report. Total closures are predicted to range up to 300mm adjacent to the end of Longwall 5 and up to 290mm adjacent to the end of Longwalls 6 and 7. Closure across the second order southern branch of Cataract Creek upstream of the Mount Ousley Road crossing is predicted to reach 700mm. These closure estimates are recognised as being upper limit values because they are based on experience in deep gorges at high stress levels. Monitoring to date indicates closure movements of up to 49mm. These movements are less than 40% of the 135mm predicted for Longwall 5 only.

Closures of 700mm are predicted for the southern tributary of Cataract Creek above Longwalls 1-3. This section of the creek is a second order creek and perceptible impacts from the proposed mining are expected along this section. The northern tributary is the main channel of Cataract Creek. Some of this northern tributary is a third order stream but it is remote from the proposed mining and no significant closure movements are expected.

Cataract River is located to the south of the longwall panels. There is considered to be no potential for significant valley closure movements along the section of Cataract River adjacent to the start of Longwalls 6 and 7. These longwall panels are mainly located on the northern side of the ridge and any downslope horizontal movements are expected to occur mainly on the northern slope causing movement toward Cataract Creek.

There is considered to be potential for valley closure across numerous first, and second order creeks where longwall panels are located directly below the slopes that lead down to these creeks and the creeks are within about 300m of the longwall panel goaf edge.

5.4 Subsidence Movements Beyond the Goaf Edge

Movement outside the goaf edge are expected to be similar to the movements observed so far during mining of Longwalls 4 and 5. Vertical movements of greater than 20mm are expected to be limited to within a distance of 0.7 time overburden depth from the nearest goaf edge equivalent to an angle of draw of 35°. In areas where there has been previous mining in both the overlying seams, vertical subsidence at the goaf edge is expected to reach up to 300-500mm and the goaf edge subsidence profile is expected to be generally more gradual than elsewhere. In areas where there is either solid coal or substantial coal pillars directly above the goaf edge, goaf edge subsidence is expected to be of the order of 100-200mm.

The area of potential pillar instability adjacent to the end of Longwall 1 may cause additional vertical subsidence of up to about 0.7m over a limited area to a distance of about 300m from the goaf corner in an area where the overburden depth is about 270m.

Horizontal movements are also expected to be of low magnitude but may still be perceptible at up to 1.5-3 times overburden depth from the nearest goaf edge. These movements may be concentrated above previous goaf edges such as has been observed to date along the Mount Ousley Road. Horizontal downslope movements associated with valley closure have been observed at the site to extend ahead of mining in a downslope direction to distances ranging from 1 times overburden depth to 2.9 times overburden depth when mining below the slope.

6. SUBSIDENCE IMPACTS

In this section, the subsidence impacts on the range of surface features identified within the PPR Assessment Area and the far field assessment area are assessed.

6.1 Natural Features

The natural features considered in this section include Cataract Creek and its tributaries, Cataract River and its tributaries, swamps across the area identified and mapped by Biosis (2013), cliff formations associated with the Hawkesbury Sandstone outcrop, and the Illawarra Escarpment.

The stored waters of Cataract Reservoir are discussed in the surface infrastructure section.

6.1.1 Rivers and Creeks

Figure 24 shows the creeks across the PPR Assessment Area coloured to show their stream order. The creeks and their order are consistent with the approach used in the Southern Coalfields Inquiry (NSW Department of Planning Southern 2008). The location of the creeks has been adjusted to surface contours derived from LiDAR surveys.

6.1.1.1 Cataract Creek

Cataract Creek flows west across the PPR Assessment Area and is the major creek system within the assessment area. The creek starts as first order creeks west of the Illawarra Escarpment and becomes a fourth order creek from where it flows under Mount Ousley Road to where it joins Cataract Reservoir. There is no mining proposed directly under the third and fourth order sections of Cataract Creek. Second order sections of the southern branch of Cataract Creek are mined under by Longwalls 2 and 3 and a short section of another branch has been mined under by Longwall 5. First order tributaries are mined under by all but three of the panels.

Almost all the second and higher order sections of Cataract Creek that are either directly mined under or are close to longwall panels are flowing within the outcrop of the Bald Hill Claystone. Previous experience of mining under the Bald Hill Claystone outcrop in Cataract Creek indicates that there have not been any significant long term effects on the bed of the creek or the character of the creek despite Longwall 11 in the Balgownie Seam causing the creek bed to subside up to 1.4m.

A management approach based on monitoring closure and stopping the longwall panels if the closure reaches unacceptably high values is considered an appropriate method of managing the closures across Cataract Creek. Barbato et al (2014) report experience in Hawkesbury Sandstone river channels indicating that flow diversion and perceptible cracking in major river channels such as Cataract Creek has not been observed where valley closure is predicted to be less than 100mm with the proportion of pools impacted increasing linearly with closure to be 100% by 700mm of predicted closure. By adopting a TARP based system and adaptive management strategy for limiting closure, it is anticipated that the potential for flow diversion and perceptible impacts on Cataract Creek can be maintained at low levels. SCT understand that acceptable trigger levels will be set in management plans developed in consultation with regulatory authorities.

Figure 25 shows the stream bed profile of the southern branch of Cataract Creek located over Longwalls 1-3 and Cataract Creek downstream to Cataract Reservoir past the ends of Longwalls 4-7. This stream bed profile has been generated from the Surfer model derived from LiDAR imaging of the surface. The subsided profiles at the completion of mining in the Bulli Seam, Balgownie Seam, and Wongawilli Seam are shown. Variation in level associated with the gridding process used to generate the profile has been smoothed.

The vertical subsidence predicted mainly influences the creek profile in the second order section above Longwalls 1-3. In this area there is potential for up to 2.6m of subsidence below the creek alignment. Although there is potential for water to pool in this area, valley closure effects are expected to increase the potential for sub-surface flow so pooling may only be short lived during periods of heavy rain. Valley closures are expected to cause perceptible cracking and surface flow diversion in the upper reaches of the southern branch of Cataract Creek, particularly where it flows across Hawkesbury Sandstone outcrop above Longwall 1. Some loss of surface water and iron staining is expected in this area as a result.

Figure 25 also shows the closures predicted using the 2002 ACARP Method. These closure predictions are sensitive to the approach used to estimate valley depth.

Above Longwalls 2 and 3 and downstream of the crossing below Mount Ousley Road where the creek is not be directly mined under, the bed of the stream is located mainly in Bald Hill Claystone. Only low levels of perceptible impact are expected in this section based on previous experience. Iron staining and flow diversion into the surface strata are not expected to be so apparent in Bald Hill Claystone because of its finer grained nature and high levels of natural fracturing.

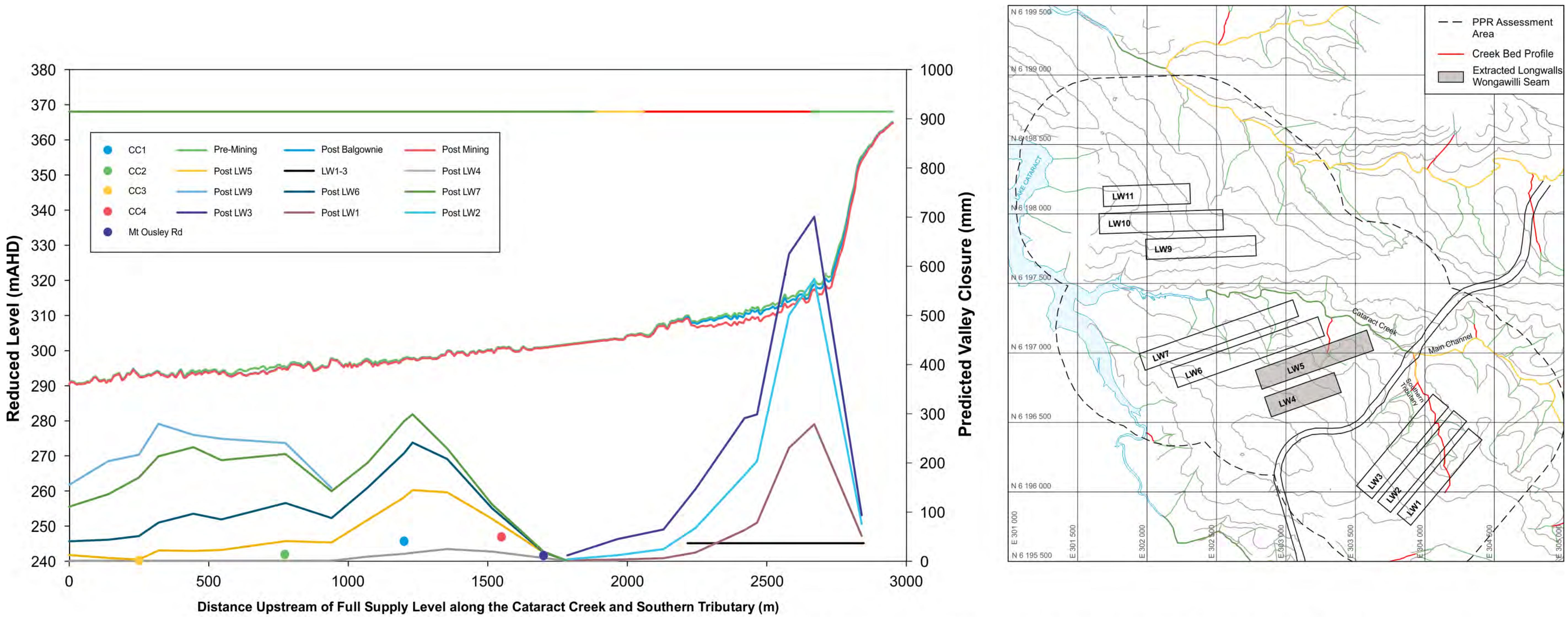


Figure 25: Thalweg profile (pre and post mining) and closure estimates for Cataract Creek from Southern Tributary Headwaters to the Full Supply Level of Cataract Reservoir.

A management strategy based on closure monitoring and cessation of mining if there is a likelihood of significant perceptible impacts becoming apparent is considered to be an effective method of managing the potential for subsidence impacts on Cataract Creek.

6.1.1.2 Cataract River

Cataract River is located on the southern side of the ridge that runs below the start of Longwalls 4-7. Only the southern ends of Longwalls 6 and 7 mine directly below the slopes that lead down to Cataract River and mining is in an upslope direction at the start of these panels. As a result, only very low levels of valley closure are expected across Cataract River from mining these two panels. The maximum valley closure indicated by the ACARP method is approximately 30mm and 40mm from Longwalls 6 and 7 respectively. The nature of the bed of Cataract River in this area is such that these low levels of closure will have no perceptible impact on Cataract River or the surface flows.

6.1.1.3 Cataract River Tributary

A second order tributary of Cataract River flows west-south-west and joins the river at Picton Road Interchange. This tributary flows off the Hawkesbury Sandstone outcrop at a point that is approximately 260m south of the start of Longwall 1. No significant valley closure or perceptible impacts are expected along this section of creek because Longwalls 1-3 do not mine under any significant part of the slope that leads down to this creek. Instead they start under the ridge and mine to the north so that downslope movements are expected to occur mainly on the northern slopes toward Cataract Creek.

6.1.2 Upland Swamps

Biosis (2013) has mapped and described 33 separate upland swamps within the PPR Assessment Area. Figure 26 shows the location of these swamps. Different swamps are differentiated on the basis of the creeks into which they flow and the nature of the swamp vegetation.

Many of these swamps have been previously mined under in both the Bulli Seam and Balgownie Seam. The proposed mining is not expected to cause significantly different impacts to those already experienced. The subsidence parameters estimated and measured for previous mining and predicted for proposed mining in the Wongawilli Seam are presented in Appendix 1.

Individual swamps cover large areas and may be somewhat discontinuous in nature. The prediction of relevant subsidence parameters is challenging because of the large area of some swamps and the relatively large change in subsidence parameters such as strain and tilt over short distances.

The approach taken has been to present the maximum subsidence parameters that are considered credible based on the experience presented in Holla and Barclay (2000) and recognise that these may only occur in one

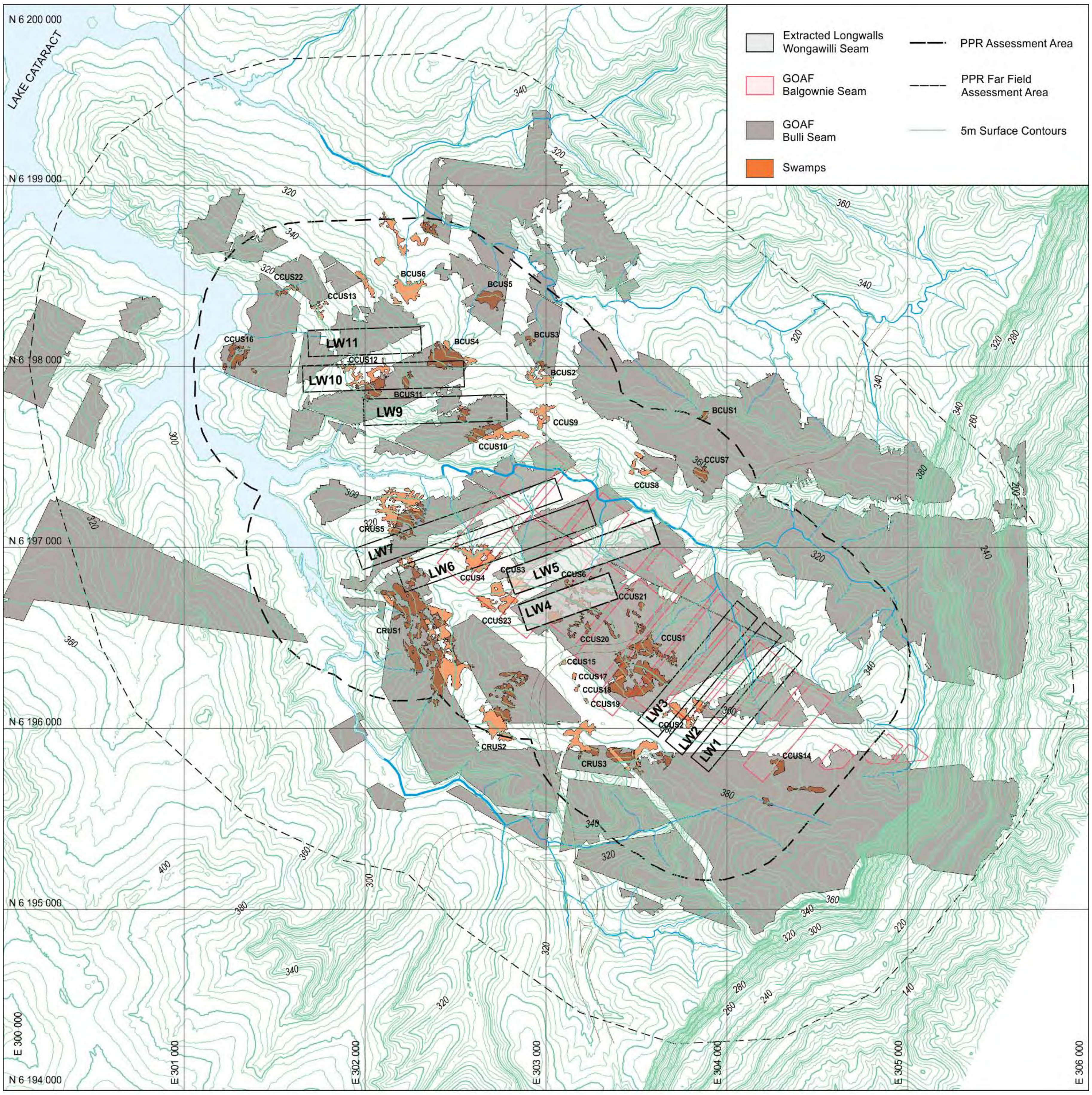


Figure 26: Location of Peat Swamps relative to historic mining and proposed longwall panels.

isolated area of a swamp, if at all. The subsidence parameters more likely to occur are in the order of 50-80% of the peak values for tilt and in the order of 20-30% of the peak values for horizontal strain.

Maximum subsidence within the bounds of the swamp may not necessarily be a good indicator of the maximum subsidence parameters of strain and tilt given that maximum strain and tilt typically occur on the fringes of a subsided area. The maximum strain and tilt values have been estimated based on the level of subsidence within the general proximity of a swamp that would contribute to maximum strains and tilts within the swamp boundary.

When strains are greater than about 1-2mm/m in tension and 2-3mm/m in compression, perceptible fracturing of the sandstone strata below swamps are expected.

It is unclear how sensitive swamps are to mining subsidence. There is a clear association between mining and short term loss of piezometric pressure after rain within the surface layers of some swamps. However, the swamps located within the PPR Assessment Area appear to be thriving despite having been previously subsided to levels that are of the same order as the subsidence expected above future longwall panels. This observation suggests that the drop in piezometric pressure observed when some swamps are mined under may not have had a significant impact on their long term condition.

More work is required to determine the relationship between mining subsidence and the long term health of swamps. The extended baseline of subsidence impacts over 60-100 years in the Bulli Seam and 30-40 years in the Balgownie Seam provides a rare opportunity to study these effects at this site. Proposed mining is expected to cause impacts to the rock strata and to surface and near surface water flows in the areas directly mined under, so it would be helpful to study how and if the wide range of swamps present above the site are significantly impacted by further mining.

6.1.3 Sandstone Cliff Formations and Steep Slopes

There are numerous sandstone cliff formations located within the Hawkesbury Sandstone outcrop in the PPR Assessment Area. Figure 27 shows the distribution of these cliff formations relative to the proposed longwall panels based on an interpretation of LiDAR data by Mine Subsidence Engineering Consultants (MSEC).

Many of these features have previously been mined directly beneath. The impacts of previous mining were able to be assessed during site visits to inspect the surface area.

The most significant cliff formations are those associated with Brokers Nose on the Illawarra Escarpment located some 900m east of the southern end of Longwall 1. Within the PPR Assessment Area, there are several short sections of cliffs between 3m and 10m high located on the northern side of

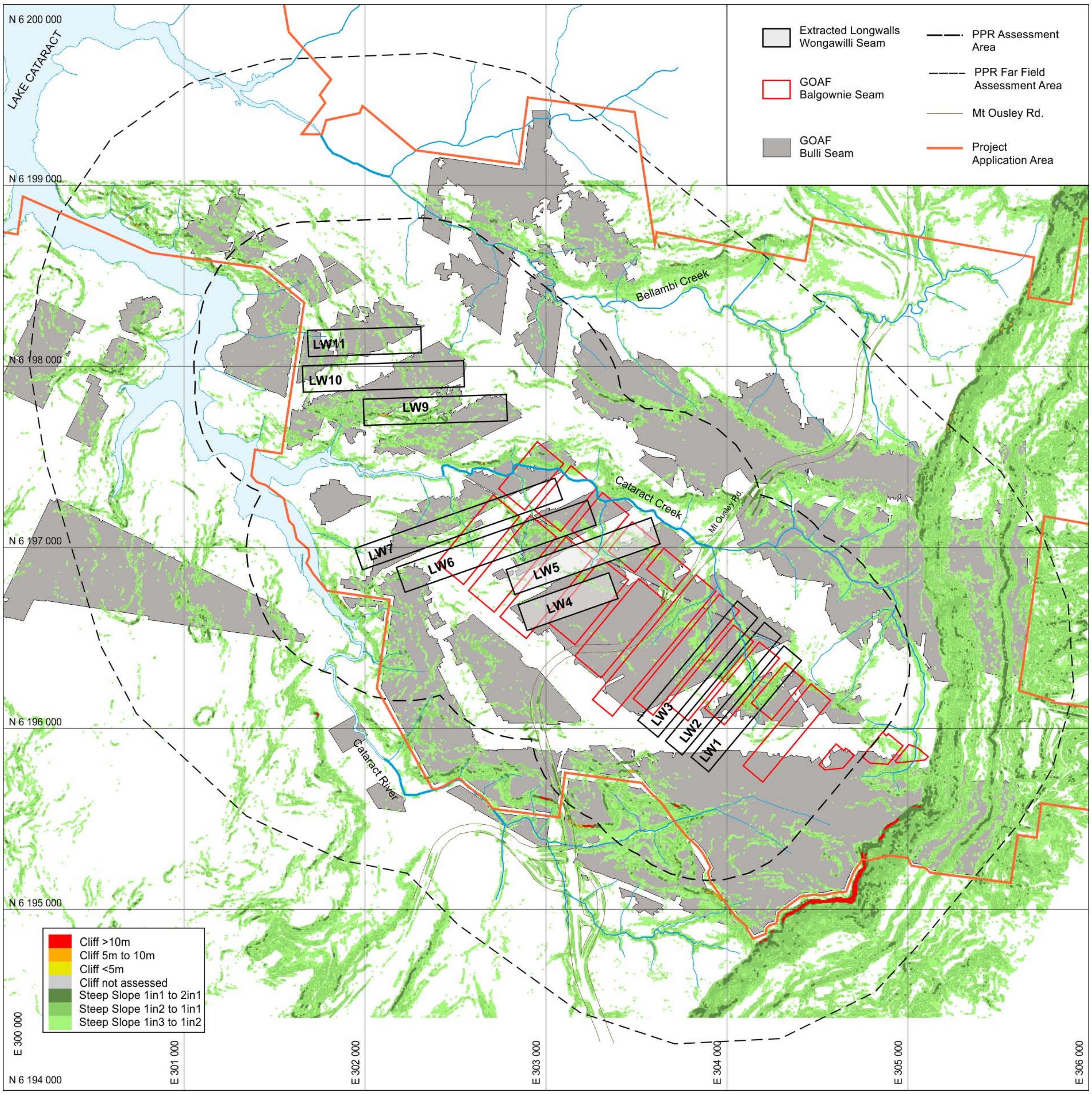


Figure 27: Location of steep slopes and cliff formations.

Cataract Creek and several short sections of cliffs typically less than 3m high but up to about 7m at drainage lines along the Hawkesbury Sandstone outcrop on the southern side of Cataract Creek. There are also some cliff formations of greater than 10m high cliff formations along the southern periphery of the PPR Assessment Area.

Most of the sandstone cliff formations are less than 3m high and occur along the edge of the Hawkesbury Sandstone outcrop as a series of typically discontinuous outcrops and detached boulders. Figure 28 shows a variety of photographs of sandstone cliff formations typical of the PPR Assessment Area. Individual sandstone rock formations are typically less than 20m in length with sections of overhang in some of the formations and numerous isolated or toppled boulders scattered on the slopes immediately below.

On the southern side of Cataract Creek there are several locations where flow down drainage lines has locally increased the height of the cliff formation.

Figure 29 shows one such cliff formation located immediately downstream of CCUS4. This site was not identified during site visits conducted prior to preparation of the initial PPR subsidence assessment. It was inspected during a site visit on 28 May 2014. The sandstone cliff formation at this site is approximately 3m high and 110m long tapering from a rocky outcrop at either end to a maximum height at the watercourse of about 7.1m.

At the location of the watercourse the 3.3m thick sandstone unit has been undercut by the erosion of a softer mudstone layer to create a 4.5m deep overhang and void that is approximately 3.8m high and 30m long. At the time of the site visit on 28 May 2014, water emanating from CCUS4 was flowing over the edge of this formation. There is evidence of impacts from previous mining in the Balgownie Seam that includes collapse of section of overhanging formation to the west that is some 20m long and some subsidence related cracking of the sandstone outcrop to the west of the watercourse.

Several similar features are located further to the east along the same outcrop at other drainage lines. These other features are either located on drainage lines that have no permanent flow or have been impacted by previous mining so that water emerges from the base of the rock formation during periods of low flow rather than flowing over it. Some impact from previous mining is apparent at each of these rock formations. Proposed mining is expected to cause further impacts including rock falls and cracking.

The cliff formations associated with Brokers Nose on the Illawarra Escarpment are remote from proposed mining and there is considered to be no potential for mining subsidence movements to impact the cliff formations along the Illawarra Escarpment.

The critical factor for the stability of sandstone cliff formations is horizontal compression along the line of the cliffs. Once this compression is greater than about 50-100mm per 20m length of cliff formation, rock falls become likely and their frequency increases as the compression increases, as the overhang increases, and as tree root invasion becomes more prevalent.




Figure 28: Sandstone cliff formations typical of the PPR Assessment Area.

Figure 29: Overhanging sandstone formation downstream of CCUS4.

There is considered to be some potential for rock falls on up to 5% of the length of cliff formations directly mined under with potential for perceptible impacts such as tension cracking on up to 30% of the length of cliff formations directly mined under and extending outside the goaf edge to a distance of 0.4 times overburden depth (typically about 140m). A minor rock fall at approximately MGA 302600E, 6197000N on Hawkesbury Sandstone outcrop is considered likely to have been associated with mining activity in the Balgownie Seam and is typical of the impacts that are expected. This rock fall was difficult to detect, and was relatively minor in the context of ongoing natural erosion at the site.

The environmental consequences of impacts on steep slopes are considered to be generally negligible although some cracks may need to be filled in where they are crossed by vehicle access tracks.

6.2 Heritage Features

Nineteen Aboriginal heritage sites have been identified within the PPR Assessment Area. These are described separately in Biosis (2013). The locations of these sites are shown in Figure 30 relative to proposed mining and summarised in Table 5.

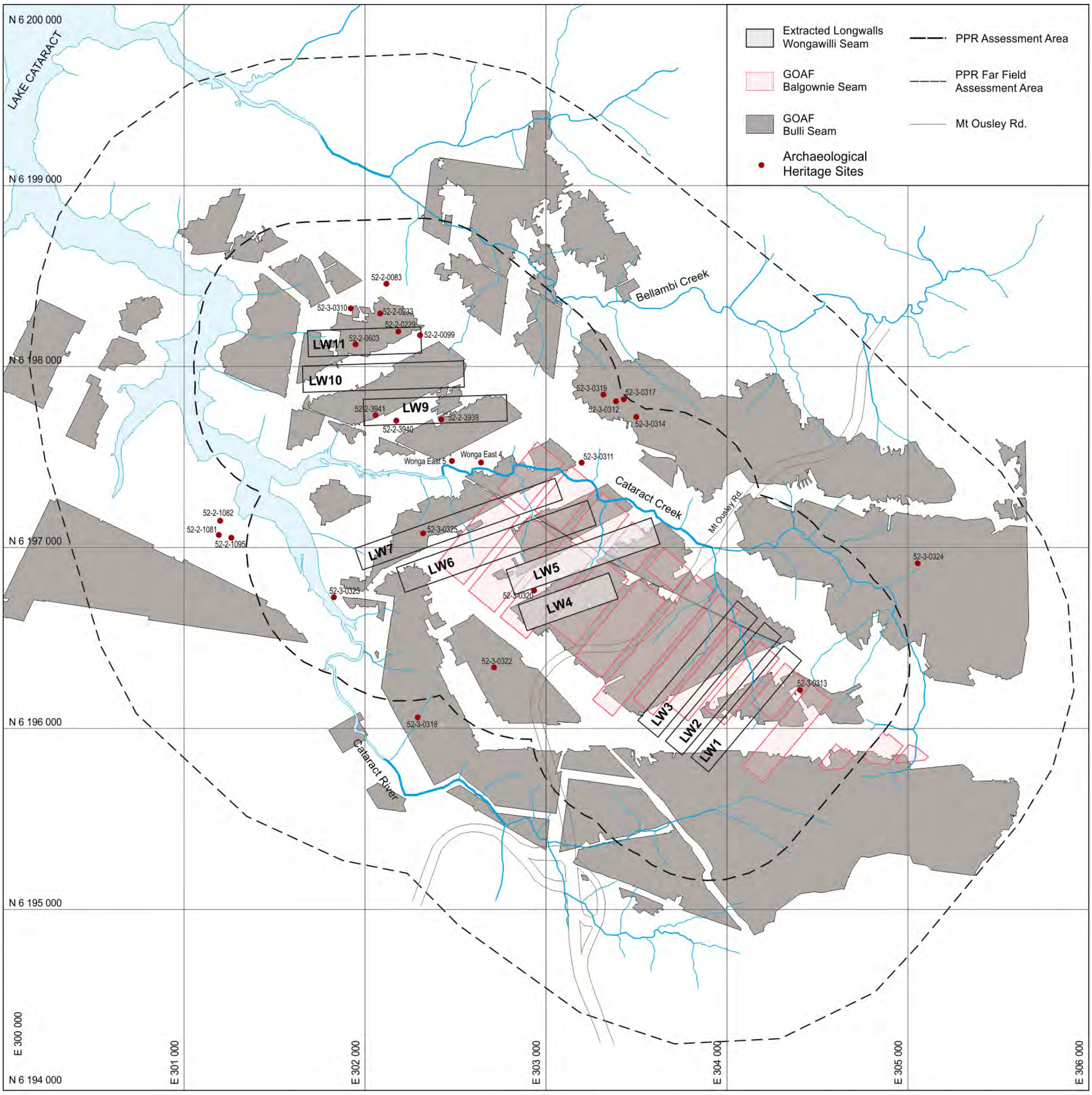


Figure 30: Location of Archaeological Heritage Sites relative to historic mining and proposed longwall panels.

Table 5: Subsidence Parameters Expected at Heritage Sites

Site ID	Subsidence at Site (m)	Adjacent Subsidence Used for Strain and Tilt Calcs (m)	Overburden Depth (m)	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)	Compressive Horizontal Movement Along 20m Section of Cliff (mm)
52-2-3939	0.8	2	340	8.8	18	29	350
52-2-3940	0.6	1.5	340	6.6	13	22	250
52-2-3941	1.2	1.5	340	6.6	13	22	250
52-2-0603	1.5	1.5	340	6.6	13	22	250
Wonga East 4	< 0.1	< 0.1	300	< 0.5	< 1	< 2	< 20
Wonga East 5	< 0.1	< 0.1	300	< 0.5	< 1	< 2	< 20
52-3-0320	0.7	2	340	8.8	18	29	350
52-3-0325	1.1	1.5	315	7.1	14	24	250
52-3-0311	< 0.1	< 0.1	285	< 0.5	< 1	< 2	< 20
52-3-0310	< 0.1	< 0.1	385	< 0.5	< 1	< 2	< 20
52-2-0099	0.4	1	355	4.2	8	14	150
52-2-0229	0.7	1	365	4.1	8	14	150

There are two sites on the southern side of Cataract Creek that are above or adjacent to proposed longwall panels. Three more sites are located over Longwall 9, another above Longwall 11, and the rest are located in areas that are unlikely to be significantly affected by mining subsidence.

Estimates and measurements of subsidence movements associated with past mining activity and predictions of subsidence movements for proposed mining activity are presented in Appendix 1. Table 5 presents a summary of the subsidence parameters expected from mining in the Wongawilli Seam.

6.2.1 Site 52-2-3939

Site 52-2-3939 site forms part of a 3-5m high sandstone cliff formation that protrudes from the general line of the cliffs with a 6m overhang as shown in Figure 31. The site is protected somewhat by being relatively short in length and protruding out from the general line of the cliffs in the area. The probability of rock falls at the site is assessed as being 2% which means that there is likely to be rock fall within the general area of the site i.e. somewhere along the 100-200m of cliff line that are located within a short distance of the site. Perceptible tensile cracking is assessed as having a 30% probability of being evident on rock surfaces in the general area including possibly through the site.

Figure 31: Photograph of Archaeological Site 52-2-3939.

6.2.2 52-2-3940

Site 52-2-3940 is part of an extended (100m long) line of 4-6m high cliff formations, some of which have already fallen either naturally or as a result of previous mining in the Bulli Seam more than 50 years ago, and has a 5m overhang as shown in Figure 32.

The site is estimated to have previously experienced approximately 0.1m of subsidence with horizontal compression of about 0.1m. Proposed mining of Longwall 9 in the Wongawilli Seam is expected to cause up to 0.6m of additional subsidence with 1.5m expected nearby, up to 250mm of additional compression at the site, and tensile strains of about 7mm/m.

The site is considered to be vulnerable to further rock falls because it is part of a long line of cliffs, some of which have already collapsed. The probability of rock falls at the site is assessed as being 5% which equates to a 5m rock fall being likely somewhere along the 100m section of cliff line adjacent to the site. Perceptible tensile cracking is assessed as having a 30% probability of being evident on rock surfaces in the general area including possibly through the site.

Figure 32: Photograph of Archaeological Site 52-2-3940.

6.2.3 52-2-3941

Site 52-2-3941 is part of a 3-4m high cliff formation that been previously involved in a rock fall. The overhang that constitutes the site is located below a detached boulder and has an overhang of approximately 4m. Figure 33 shows a photograph of the site including the fractured rock strata where the boulder has detached from the general cliff formation.

There are several characteristics of the rock fall that indicate it is likely to have been associated with mining in the Bulli Seam more than 50 years ago. The site is estimated to have previously experienced approximately 0.2m of subsidence with horizontal compression of about 0.1m. Proposed mining of Longwall 9 in the Wongawilli Seam is expected to cause up to 1.2m of additional subsidence with 1.5m expected nearby, up to 250mm of additional compression at the site, and tensile strains of about 7mm/m.

The site itself is not considered vulnerable to further rock falls because it is detached from the cliff line and is not large enough to experience significant lateral compression so the probability of a rock fall at the site is considered to be low (<1%). However, the probability of further rock falls in the general

Figure 33: Photograph of Archaeological Site 52-2-3941.

vicinity of the site along the standing cliff line is assessed as being 5%. This probability equates to a 5m length of the adjacent 100m of cliff formation likely to experience a rock fall. Perceptible tensile cracking is assessed as having a 30% probability of being evident on rock surfaces in the general area although a tension crack directly through the site is considered unlikely.

6.2.4 52-2-0603

Site 52-2-0603 is located high up on the ridge line. The cliff formation is estimated to be 50-70m long and the overhang where the rock art is located is approximately 4m deep and 3m high as shown in Figure 34. The rock in the roof of the overhang is only about 1-2m thick but relatively continuous.

The site is estimated to have experienced up to 0.3m of subsidence as a result of previous Bulli Seam mining activity with horizontal movement of about 0.1m although it is possible that the geometry of the Bulli Seam mining was sufficiently narrow in this area to prevent significant subsidence movements at the site. Proposed mining of Longwall 11 is expected to cause up to 1.5m of additional subsidence and up to 250mm of horizontal compression.

Figure 34: Photograph of Archaeological Site 52-2-0603.

The site's location near the top of the ridge is likely to have reduced some of the horizontal compression because there is currently no evidence of a rock fall within the period of previous mining. There is a rock fall evident on a nearby formation, but this fall appears to be too recent (last few years) for it to have been directly associated with previous mining subsidence.

The level of horizontal compression expected is assessed as being likely to cause perceptible cracking in the vicinity of the site with the probability of rock fall assessed as being 5-10%. The nature of the site is such that a rock fall anywhere along the 30-40m length of the overhang is likely to be considered as having impacted the site.

6.2.5 Grinding Groove Sites

There are several grinding groove sites located on bare rock areas in upland areas away from creeks. Perceptible cracking is expected in up to 30% of bare rock areas when these areas located directly above longwall panels

Outside the goaf edge, the frequency of cracking is expected to decrease in magnitude with distance from the goaf edge and become imperceptible beyond a distance of about 0.4 times the overburden depth or about 120-150m from the goaf edge.

Within any given site where cracking occurs, individual cracks may be perceptible as tension cracks that cause the rock to move apart, usually on natural joints if these exist but also through intact rock, shear cracks that cause opening and lateral displacement of the two sides, and compression cracks that result in the rock surface popping up in slabs. Shear and tension cracks tend to be more prevalent in upland areas.

The probability of one of the tension or shear cracks directly intersecting a grinding groove depends on the site characteristics, but is generally low because such cracks tend to be widely spaced (5-10m). However, the potential for a bare rock sites to be impacted generally is expected to up to about 30%.

Compression fracturing tends to be more prevalent in topographic low points and the fracturing that occurs tends to affect a larger proportion of the site.

6.2.6 Other Sites

The Wonga East 4, Wonga East 5, 52-3-0310, and 52-3-0311 sites are located beyond the footprint of the longwall panels and are not expected to be perceptibly impacted by mining subsidence because of their location.

Sites 52-2-0099, 52-2-0229, 52-3-0320 and 52-3-0325 are located within the boundaries of the longwall panels and some perceptible impacts are expected in the general area of these sites as a result. Those sites that are associated with detached boulders such as 52-3-0325 are considered unlikely to be significantly impacted.

6.3 Surface Infrastructure

Surface infrastructure located within the PPR Assessment Area includes the Mount Ousley Road, four power transmission lines that run between Mount Ousley and the Illawarra Escarpment with two of these lines having pylons directly over the Longwall 2 and the chain pillar between Longwalls 1 and 2, and the storage of Lake Cataract. Other infrastructure within the extended assessment area includes the Picton Road Interchange and communications tower infrastructure near the top of Brokers Nose.

6.3.1 Mount Ousley Road

Mount Ousley Road is protected from direct mine subsidence by a horizontal distance from the nearest goaf edge of greater than half overburden depth. Low levels of vertical subsidence of less than about 100mm in total are expected in the vicinity of Mount Ousley Road with up to approximately 40mm of this maximum having already occurred from mining Longwall 4 and 5. Longwalls 6-11 are not expected to cause additional subsidence along the road alignment. Longwalls 2 and 3 are expected to cause all additional subsidence that occurs on the road alignment. These low level vertical movements expected are expected to be imperceptible for all practical purposes.

The 2002 ACARP Method for predicting valley closure indicates horizontal movement in a downslope direction caused by mining below the slope on the southern side of Cataract Creek is likely to generate closure at the creek crossing as summarised in Table 6.

Table 6: Predicted Horizontal Closure Across Cataract Creek at Mount Ousley Road

Longwall	Maximum Incremental Closure Predicted (mm)	Maximum Cumulative Closure Predicted (mm)
4	6	6
5	11 **(10)**	17
2	1	18
3	1	19

The upper limit of 19mm of compression in the bottom of the valley estimated at the completion of all proposed mining is expected to be accompanied by a similar level of cumulative tensile cracking toward the top of the slope. Some of the tensile cracking that began during Longwall 4 appears to be continuing during mining of Longwall 5 particularly at Peg 46 on P Line. The ongoing cracking observed near Peg 46 may also include sub-base deterioration associated with repetitive vehicle loading and fines migration into the crack that that formed during Longwall 4.

The Picton Road Interchange is located on the opposite side of Cataract River and the opposite side of a tributary that joins Cataract River at the interchange. Longwalls 1-5 are located predominantly below the north facing slope that leads down to Cataract Creek. As these longwall panels start below the ridge and mine away to the north, horizontal movements in a downslope direction are considered unlikely to extend across Cataract River to interact with the Picton Road Interchange. The bridge on the Picton Road Interchange is further protected by being on the far side of the west flowing tributary to Cataract River.

On this basis, there is considered to be no potential for significant horizontal movements to impact the Picton Road Interchange. A monitoring strategy is considered appropriate to confirm that subsidence movements are of low level and of no significance for the structures around the interchange. Once this monitoring regime has established there is no significant interaction, a reduction in the frequency of monitoring is considered appropriate.

The road cutting on the northern side of Cataract Creek has been formed in Hawkesbury Sandstone strata to create embankments up to about 10m high. These embankments are located beyond 500m from the nearest longwall panel on the opposite side of Cataract Creek. There is considered to be no potential for mining induced cliff falls to occur along this section of exposed rock.

6.3.2 Power Transmission Lines

There are four power transmission lines located in two corridors between Mount Ousley Road and the Illawarra Escarpment. Figure 35 shows photographs of the four different types of support structure used on these lines. The 330kV and 132kV lines are supported on trussed steel pylons. One of the 33kV lines is supported on single pole structures and the other one is supported on double pole structures that appear to have been replaced in the last few years.

All four lines were potentially mined under by late stage pillar extraction in the main heading pillars in the Bulli Seam, although the Bulli Seam mining may have preceded construction of the lines and by Longwalls 1 and 3 in the Balgownie Seam.

The power transmission towers T56 (on the 330kV line) and E57 (on the 132kV line) are suspension towers located in an area where there was 1-1.2m of vertical subsidence measured during mining of the Longwall 3 in the Balgownie Seam. The tower locations are noted on subsidence plans as T56 and T52 so it appears likely that they were in place when Longwall 3 was mined in 1975.

In general, suspension towers are located on straight sections of line and the conductors are suspended from the tower structure on hanging insulators rather than directly to fixed insulators on the structure. However, it is noted that T56 is located at a slight change of direction in the line. The side load associated with this slight change in direction is counteracted by rotation from vertical of the suspended insulators as can be seen in Figure 35. In contrast, E57 is located on a straight section of line and the insulators hang vertically.

Figure 35: Power transmission lines above Longwalls 1 and 2.

The towers T56 and E57 are 100m and 200m respectively down slope from the area of cracking at the topographic high point near the start of proposed Wongawilli Seam Longwall 3. The tension cracking observed is consistent with expected ground movements. These towers do not appear to have been significantly impacted by previous mining possibly because they are located on Hawkesbury Sandstone and, fortuitously, the cracks have not passed between the legs of the towers.

The structural integrity of pylons is sensitive to even small levels of differential displacement between the four legs. It would appear that cracking or differential movement did not occur through the sandstone strata between the tower legs so that the tower foundations moved together as one unit allowing any subsidence and tilting of the pylons to occur without compromising the structural integrity of the towers themselves. Small tilting and horizontal movements of the towers as a whole are normally able to be accommodated by rotation of the suspended insulators that support the conductors. Realigning the insulators during subsequent maintenance allows any misalignment to be rectified.

The predicted subsidence at the tower locations are detailed in Table 7 and illustrated in Figure 36.

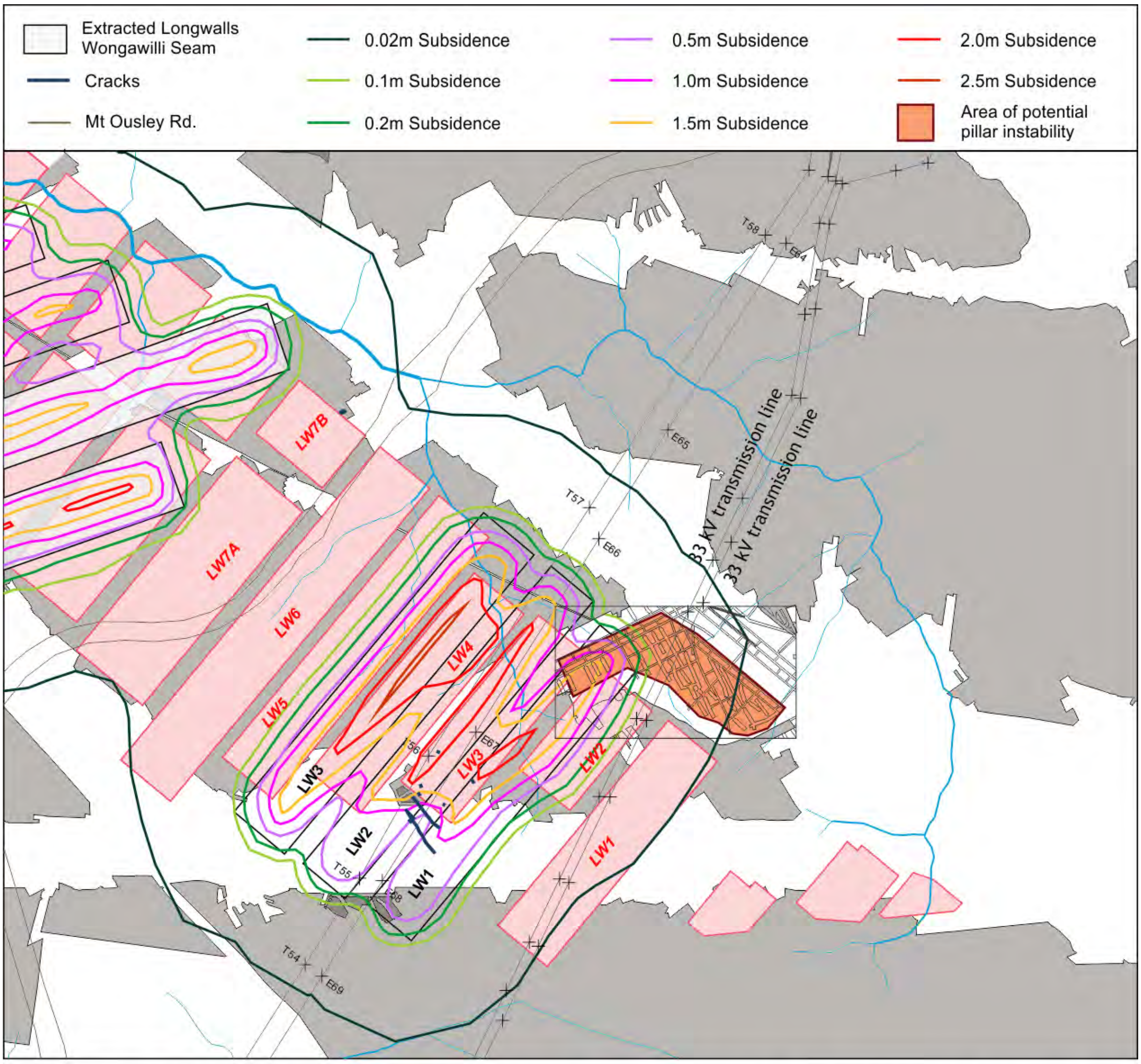


Figure 36: Location of power transmission structures relative to proposed longwalls, Balgownie Seam longwalls, and area of potential pillar instability in the Wongawilli Seam.

There is an area where there is some potential for pillar collapse in the Bulli Seam to cause additional subsidence. This area is shown in Figure 36. Fortunately, the towers and poles are located outside the area likely to be affected by any pillar instability.

Table 7: Subsidence Expected at Power Pylon Locations

Tower	Subs (m)	Maximum Tensile Strain (mm/m)	Maximum Compressive Strain (mm/m)	Maximum Tilt (mm/m)	Differential movement over 10m (mm)	Horizontal Movement (m)
330kV T54	0.03	< 0.2	0	< 0.5	< 2	< 0.1 NE
330kV T55	0.5	4.6	9	15	50	0.3 NE
330kV T56	2.2	11.2	22	37	120	0.7 NE
330kV T57	0.05	< 0.2	0.0	< 0.5	< 2	<0.1 SW
132kV E66	0.07	< 0.2	0.0	< 0.5	< 2	<0.1 SW
132kV E67	1.8	11.8	0.0	39	120	0.3 NE
132kV E68	0.3	4.8	10	16	50	0.7 NE
132kV E69	0.03	< 0.2	0	< 0.5	< 2	<0.1 NE
33kV Lines	< 0.1	< 0.2	0	< 0.5	N/A	<0.1 W

The four towers located directly over the longwall panels are expected to permanently move in the direction of mining. The horizontal movement is expected to range up to 700mm and is likely to be greatest on the two towers located directly over the goaf, T56 and E67.

The proposed mining is expected to cause ground movements that have potential to compromise the structural integrity of towers T55, T56, E67 and E68 if the movements occur differentially between the tower legs.

Although there has been previous cracking nearby and such cracking is likely to continue to localise further ground movements (i.e. movement will occur by further opening existing cracks rather than forming new cracks) the risk of new cracking causing structural damage is considered to be too high to be acceptable without some form of mitigation. It is considered likely that all four towers would require some mitigation works if the hazard of differential movements is to be eliminated during the period of mining Longwalls 1, 2 and 3.

The use of a cruciform foundation is one of several options that can be used to mitigate the potential impacts of mining. Some active realignment is likely to be required, particularly on Tower E67 where permanent tilts of up to 39mm/m are expected. Tilting of 39mm/m equates to a horizontal movement at the top of the tower of about 800mm. This movement may be able to be accommodated by rotation of the hanging insulators, but this needs to be checked in consultation with the power utility companies that own the infrastructure. It may be necessary to suspend the conductor in roller sheaves during the period of active subsidence to equalise conductor tensions.

A single point tie down may be required on the western leg of the cruciform for T56 to provide rotational stability of the structure given the lateral loads associated with the slight change in direction at this tower but the loads involved are expected to be small enough to be able to be accommodated through appropriate design.

The adjacent towers to the south T54 and E69 are considered to be sufficiently remote from mining for there to be no significant potential for ground movements. These towers are protected by an angle of draw of 30°. Both towers are located on ground that is sloping away from the direction of mining in an area where the slope is not directly mined under. Some monitoring of these towers is recommended, but there does not appear to be a compelling case to provide additional protection.

The adjacent towers to the north T57 and E66 are protected by an angle of draw of 26° and 23° respectively, and they are therefore remote enough for systematic ground movements to be low. However, both towers are located on top of a ridgeline where tension cracks tend to be concentrated. While the direction of mining toward the ridge tends to lessen the potential for cracking on the ridge line, there is nevertheless considered to be a low level hazard associated with the potential for cracking between the tower legs with potential to compromise the structural integrity of the tower. It may be possible to cut a slot or confirm that the tower will be protected by detailed consideration of the local site conditions, but a site specific risk assessment is required to develop a mitigation strategy for these towers.

There is a significant change in direction on both the 330kV and 132kV transmission lines at a point approximately 1km north of the northern ends of Longwalls 1, 2 and 3. Some additional monitoring of these structures may be appropriate to monitor and manage any changes in conductor tension that results from the subsidence movements. Far-field movements are not expected to create any significant hazard in terms of the structural integrity of these towers because of the low levels of movement and even lower levels of differential movement expected at 1km from the goaf edge.

The 33kV lines are supported on single and double pole structures. The double pole structure appears to be relatively new. These structures are tolerant to mine subsidence movements. Mining of Longwall 1 in the Balgownie Seam caused subsidence of 0.8-1.2m below four of these pole locations and 0.4-0.6m on four others. It is considered unlikely that this mining caused any significant impact to these lines although they may have needed to be straightened up at the completion of mining.

The 33kV single and double pole structures are relatively tolerant of subsidence movements and because these structures are located more than 60m outside of the footprint of the longwall panels, only low levels of subsidence and no significant impacts are expected. No protection measures are considered necessary for the 33kV single and double pole structures, although some before and after mining survey monitoring program is recommended to confirm the low levels of ground movement that are expected.

6.3.3 Cataract Water Supply Reservoir

No impacts are expected on the Cataract Reservoir from the proposed mining. The FSL including the section that extends up Cataract Creek is protected from the nearest longwall goaf by a nominal horizontal distance of greater than 203m at 290m overburden depth (equivalent to 0.7 times overburden depth or an angle of draw of 35°). Vertical subsidence at the FSL is expected to be less than about 20mm.

Geological structures within the PPR Assessment Area are relatively well defined because of the previous mining that has occurred in the overlying Bulli Seam over a large area and the overlying Balgownie Seam in a more limited area. The only geological structure that extends through to the proposed longwall panels in the PPR Assessment Area and the reservoir is Dyke D8. The horizontal distance along the dyke from the end of Longwall 10 to the FSL is approximately 560m at an overburden depth of 320m at the FSL.

The faults labelled F2 are apparent in the workings in Corrimal Colliery but become degraded in the Bulli Seam workings at South Bulli Colliery. These faults are not proposed to be directly intersected in the Wongawilli Seam but there is a flow pathway between the faults and the Wongawilli Seam mining horizon through the Bulli Seam mine workings that intersect both.

There is considered to be no potential for proposed mining to intersect the stored waters directly. There may be potential for flow along the dyke via the Bulli Seam, but experience in the Southern Coalfield indicates that dykes are very rarely hydraulically conductive except when affected by mining subsidence at shallow depth. There does not appear to have been any significant inflow associated with mining the Bulli Seam on this dyke. Mining in the Wongawilli Seam 560m away from the reservoir is not expected to have any potential to increase hydraulic conductivity between the reservoir and the mine.

There are a number of small pre-existing Bulli Seam mining areas where coal has been extracted that are located within the 0.7 times depth protection zone around the FSL. There does not appear to be any direct connection between the reservoir and the mining horizon through these mining areas. Although their presence appears to reduce the effectiveness of the 0.7 times depth barrier between the FSL and the proposed mining somewhat, particularly for mining of Longwalls 7 and 9, the pathway for seepage from the reservoir to the mine is likely to be predominantly along horizontal shear planes at or just below the level of the valley. The calculated height of depressurisation using the method forwarded by Tammetta (2012) for a Bulli Seam pillar extraction panel is well below the level of any horizontal shear planes capable of interacting with the reservoir.

As a result, there is not considered to be any potential for these existing Bulli Seam mining areas to significantly reduce the effectiveness of the 0.7 time depth barrier.

6.3.4 Telecommunications Infrastructure

There is a telecommunications tower located on Brokers Nose on the Illawarra Escarpment. This telecommunications infrastructure and the cliff formations at Brokers Nose are protected by a horizontal distance of approximately 1km from the nearest point on Longwall 1. No ground movements are expected at this distance from the proposed mining because there is no potential for significant horizontal stress concentration along the escarpment and no potential for change in any of the other stress components.

7. Management Strategies

The subsidence management strategies have been discussed in the previous section, but are consolidated in this section.

7.1 Survey Monitoring

Survey monitoring is expected to provide the primary basis for informing the processes used to manage subsidence impacts. This monitoring is discussed first because it underpins all the other management processes.

Conventional subsidence monitoring using repeat surveys in three dimensions with far-field GPS control is considered to provide the industry best practice subsidence monitoring technique in steep terrain. This type of three dimensional surveying captures the full three dimensional ground movements independent of location to an accuracy that is suitable to characterise the nature of the ground movements. Strains and tilts are not necessarily captured to the same level of accuracy as is possible with levelling and peg to peg chaining but the reduced accuracy is offset by capturing all components of movement rather than just the components in the direction of the subsidence line. It is recommended that the existing survey lines are monitored in three dimensions using this approach.

Two cross lines across each panel and a centreline subsidence line are considered appropriate to monitor subsidence movements in the relatively complex subsidence environment above Longwalls 1-11. The three dimensional movements on the active sections of these lines should be monitored regularly, particularly at the commencement of each longwall panel and during mining below or near significant infrastructure. The broader network should be resurveyed at the midpoint and end of each longwall panel or about every 2-3 months whichever occurs first.

It is recommended that a survey monitoring base line is extended to include three dimensional far field GPS control for a distributed array of monitoring points that are located at easily accessible locations across the mining area as well as around the periphery of the mining area out to about 3km. This monitoring network can then be checked at any time and used to confirm the levels of movement that have occurred on all the monitoring lines and infrastructure in the area. This distributed array is intended to provide an overview of any movements that are occurring. The array can also be used to provide confirmation of the accuracy of the survey control grid.

High resolution point to point measurement of valley closure across Cataract Creek is recommended at as many crossing points as can practically be established from an environmental perspective. The four that are currently located across Cataract Creek are considered suitable locations and the establishment of a similar measurement point at Mount Ousley Road would add another. The establishment of further closure points would be recommended across the southern branch of Cataract Creek prior to mining Longwalls 1-3. It would be useful to extend these somewhat to increase the horizontal coverage so as not to miss any closure movements that occur beyond the ends of the convergence line, although the practical difficulties of surveying in a rainforest environment are recognised.

7.2 Infrastructure Management

The mining impacts on infrastructure that need to be managed include the Mount Ousley Road, the power transmission lines, the Cataract Water Supply Storage, and the telecommunications facility at Brokers Nose.

7.2.1 Mount Ousley Road

Management of the Mount Ousley Road and any subsidence impacts using a technical committee such as was used for Longwalls 4 and 5 is considered appropriate for the ongoing management of subsidence impacts to the road.

The half depth stand-off of mining from Mount Ousley Road is considered to significantly reduce the potential for impacts on the highway and this potential will reduce further as active mining moves away from the road.

Some low level ground movements have been observed and surface cracking has also been observed on the road surface particularly around the crest of the ridge between Cataract Creek and Cataract River where stretching movements are expected. It is recommended that the observed surface cracks are filled from time to time to reduce potential for ingress of surface water into the formation because unlike conventional road cracks that are likely to occur mainly in the surface layers, these subsidence cracks are likely to extend through the full section including into the foundation rock. It is possible that water ingress into the road formation through cracks may cause loss of fines from the sub-base with increased potential for pavement cracking, surface deterioration, deterioration in ride quality generally, and ultimately public safety.

Continued visual monitoring of the Mount Ousley Road, perhaps at reduced frequency is recommended, as well as survey monitoring at the end of each panel as the basis to confirm the actual subsidence movements are consistent with those predicted.

A high level of monitoring of the Mount Ousley Road and Picton Road Interchange have been appropriate during mining of Longwalls 4 and 5 in close proximity to the highway. However, some reduction in the frequency of the survey monitoring is now considered appropriate given the low level and zero change respectively that have so far been observed. A management strategy based on regular visual inspections and end of panel surveying unless otherwise triggered would appear to be sufficient to manage the levels of impacts expected once Longwalls 4 and 5 have been completed.

The frequency of monitoring, particularly of the Mount Ousley Road may need to increase again during mining of Longwalls 2 and 3.

Some refinement to the surveying technique is recommended to better measure opening movements at the top of the ridge and closure across Cataract Creek. Point to point surveying between fixed prisms, a general upgrade to three dimensional surveying, and replication of P Line survey marks to the edge of the southbound lanes is recommended.

7.2.2 Power Transmission Towers

A technical committee comprising representatives from the colliery, the power utility companies, the Mine Subsidence Board, and government regulators is recommended to manage potential impacts on the power transmission towers. This forum provides all interested parties with understanding and control of the management processes.

Several of the power transmission towers are likely to require the construction of cruciform bases to allow the hazard associated with differential subsidence to be eliminated. It is noted that there is usually a significant lead time involved in getting cruciforms approved, financed, designed, and constructed.

Monitoring on the power transmission poles and towers needs to be designed in consultation with the power utility companies. It is envisaged that automatic monitoring systems capable of transmitting data back to a website portal would be a practical solution for capturing tilt and differential movements between individual legs.

Prior to the approach of Longwall 1, a number of short survey lines should be located in the vicinity of the panel of small pillars at the northern end of the panel to confirm the nature and extent of subsidence that may occur as a result of any pillar destabilisation in this area.

All the survey monitoring points for the power transmission towers and the telecommunications infrastructure on Brokers Nose should be linked back into the distributed array of monitoring points and the control already established for Mount Ousley Road.

7.2.3 Cataract Reservoir

The Dams Safety Committee (DSC) is a statutory body with legal powers to manage mining to protect the stored waters in Cataract Reservoir. As is appropriate, the DSC takes a conservative view of the potential threats of mining to the stored waters because of the challenges of effectively remediating any leakage of water from the reservoir to the mine. The DSC also recognises that some minor loss is inevitable and is tolerable. The colliery has been working with the DSC for many years and it is considered that the management process that has been adopted in the past continues to be appropriate.

The management of potential impacts revolves around providing a sufficient standoff from the FSL, confirming that there are no geological structures with potential to provide elevated hydraulic conductivity between the reservoir and the mining horizon and that any such structures will not be adversely affected by mining, and monitoring the mine water balance to confirm the magnitude of any flows that occur.

The 0.7 times depth (nominally 203m) stand-off from the FSL is considered to be the primary control for protecting the stored waters of Cataract Reservoir and this barrier is expected to provide a high level of protection to these stored water. The presence of existing pillar extraction areas within the barrier reduces the protection afforded by the barrier to 80m from the FSL in some areas.

Geological structure in the area is well defined by the presence of previous mining. The D8 dyke is considered to be the only geological structure with potential for increased hydraulic conductivity but there is a separation between the reservoir and the mine along the dyke of approximately 500m horizontally and 360m vertically and exposures underground do not indicate a history of increased inflow despite previous mining adjacent to the dyke directly under Cataract Creek.

A review of the integrity of the mine water balance is recommended to confirm that all sources of water are accounted for on a regular and ongoing basis with suitably calibrated monitoring equipment.

The piezometer monitoring network currently in place provides an indication of the changes in groundwater characteristics around the site. Further monitoring in areas where there are multiple levels of mining stacked above each other and in the area between the reservoir and the mine would increase confidence in and understanding of the impacts of mining on the groundwater system. The design of this monitoring would need to be done in consultation with the DSC.

It is noted that there are limited options to control any significant inflow from the reservoir through sealing up the longwall panels or the mine portals because the Wongawilli Seam, the Balgownie Seam, and the Bulli Seam are all hydraulically connected in this area through the interconnected goafs. The 0.7 times depth offset between the longwall panels and the FSL has been designed as the primary control and is expected to be effective to control an potential for inflow from Cataract Reservoir into the mine.

7.2.4 Telecommunications Infrastructure

No mining subsidence movements are expected at the site of the telecommunications infrastructure located on Brokers Nose. Nevertheless engagement with the owners of the infrastructure and regular monitoring to confirm that there have been no changes is recommended.

7.3 Natural Features

The detail of monitoring of swamps, heritage sites, and creek biota is beyond the scope of this report and has been addressed in other specialist reports.

However, it is recommended that one or more technical committees are formed to design monitoring programs that not only review the changes that may be associated with proposed mining but also take the opportunity to review the longer term impacts from previous mining in the same area. These technical committees should include external expertise from the community where appropriate so that monitoring programs are targeted, appropriate, can be ongoing, and are transparent to all stakeholders.

8. RESPONSE TO SUBMISSIONS

A range of submissions were received in response to the Underground Expansion Project Pt3A. These submissions were received prior to the PPR amendments. The PPR amendments have already addressed many of the issues raised. In this section, a number of these issues are discussed in the context of the PPR design and how they have driven the changes that have been made to the layout.

A second set of submissions were prepared in response to the PPR. The response to this second set of submissions is included in Appendix 1 of this report. Many of the issues addressed in this second set of submissions have been addressed in this update of the PPR subsidence assessment.

8.1 Accuracy of Prediction

The reduced level of accuracy of the prediction methodology in multi-seam environments was raised in a number of submissions.

While this concern is valid, the recent subsidence monitoring above Longwalls 4 and 5 and a review of previous subsidence monitoring above the Balgownie Seam longwall panels and a review of local Bulli Seam subsidence profiles provides a strong basis of local site based experience to allow more accurate predictions to be made.

The subsidence prediction technique used has been updated to reflect the available data. The revised approach is based on using the available data to provide insight in the subsidence mechanics and continuing to develop this understanding recognising the various subsidence processes involved.

The results of this previous monitoring indicate that, although the magnitude of subsidence is greater in a multi-seam environment where there has been previous subsidence of the overburden strata because of the lower shear stiffness of previously disturbed strata, the subsidence behaviour in a multi-seam environment is similar to single seam subsidence in its general characteristics. There are some differences but these are generally subtle, second order effects and do not change the general characteristics of subsidence behaviour. A difference that does need to be recognised is the potential for pillar instability in areas of standing pillars in overlying seams.

The subsidence monitoring above Longwalls 4 and 5 indicates that subsidence occurs primarily over the panel being mined with only low levels of ground movement outside. Vertical subsidence occur as low level movements at the goaf edge and become less than 20mm at about 0.7 times depth from the goaf edge. There are more gradual profiles evident over previously mined goaf compared to over solid, but the differences are relatively small and tend to soften the ground movements at the goaf edge. Sag subsidence can be controlled by limiting the width of the panel but the panel widths required to keep subsidence to any given level are much less than in a single seam mining environment because of the reduced bridging capacity of previously disturbed overburden strata.

The issue of pillar instability and recovery of latent subsidence associated with bridging strata at the goaf edge is recognised as having potential to cause additional subsidence. This potential needs to be considered on a site by site basis, but experience of mining the Balgownie Seam longwalls and Longwalls 4 and 5 in the Wongawilli Seam suggest that the potential is less than was initially envisaged and the impacts are of a relatively low level. Nevertheless, an area of standing pillars near the finish of Longwall 1 is recognised as having potential to become destabilised with potential for additional subsidence. Additional monitoring is recommended in this area, but it is noted that any additional subsidence associated with pillar instability is not expected to have a significant impact on any infrastructure or significant natural features in the area near the finish of Longwall 1.

Although there is somewhat greater uncertainty for subsidence predictions in a multi-seam environment, the available data and further monitoring data is expected to continue to provide a strong base for further understanding. The behaviour observed is repeatable and consistent with the mechanics of the processes involved.

8.2 Geological Structures

There are a number of geological structures located in the general area of the proposed mining, but only one is considered to be significant in the context of the proposed mining. The others are located away from the areas of mining and are not considered to have any significant potential to be affected by mining.

A significant benefit of the previous mining activity is that the dykes and faults through the area are very well defined by previous mining activity. It is not credible that there could be other major structures in the proposed longwall area because any such geological structures would be evident in the overlying seams. This certainty of location of geological features gives this site a significant advantage in terms of potential geological issues.

A dyke referred to as D8 crosses several of the longwall panels and passes close to several others. The dyke is continuous through to the surface and vertical. There is no experience of it being hydraulically conductive or in any way affecting the subsidence behaviour except in so far as the dyke has modified the mine layout which has itself altered the surface subsidence.

The Corrimal Fault is located to the south and east of the proposed longwall area and dips to the north. This structure tapers to the west and is not evident in the mine workings in the Bulli Seam above Longwall 6 proposed to be mined in the Wongawilli Seam. This type of tapering behaviour is typical of geological faults in the Southern Coalfield. The Corrimal Fault dips to the north. The fault is remote from Longwalls 4 and 5 and has tapered to less than 1m throw by the gateroads of the proposed Longwall 6. The Corrimal Fault is therefore not expected to have any significant influence on either height of fracturing, subsidence behaviour, or the hydraulic conductivity of the overburden strata.

Other faults such as the Rixons Pass Fault and Woonona Fault are remote from the area of mining and are not expected to be affected by mining.

8.3 Pillar Instability in the Bulli Seam

The potential for pillar instability in the Bulli Seam has been discussed above. There is certainly some potential in the vicinity of Longwall 1 and the particular area where this potential exists has been identified as needing special consideration. Other areas where there may be a similar potential are more difficult to identify because the mine records for the period of mining may be incomplete or inaccurate.

A large part of the Bulli Seam mine workings have been mined under by the Balgownie Seam longwall panels (1970-1982) and more recently by the Wongawilli Seam longwalls (2012-2013). The subsidence monitoring from both periods of mining indicate that there has been no evidence of any significant subsidence event associated with pillar instability although there are several areas where a low level of additional subsidence has been observed and this is additional subsidence is attributed to recovery of latent subsidence from earlier mining activity.

Even if such instability were to occur, the irregular nature of the panels that have been developed and their limited width mean that the surface subsidence that results is likely to be less than a few hundred millimetres and limited in size to within the area of the panel affected. Such a low level of additional subsidence is within the tolerance of the subsidence predictions that have been made and the impacts associated with any such subsidence would be within the range of predicted impacts.

The Mount Ousley Road is protected by a barrier of approximately 170m and the area adjacent to the Mount Ousley Road has already been mined under by the Balgownie Seam longwall panels so it is not credible that there could be marginally stable pillars in the Bulli Seam still standing in this area.

Some of the towers on the power transmission lines are planned to be subsided up to several metres and the additional subsidence that may result from pillar instability in the Bulli Seam is not considered to have potential to cause any significant additional impacts compared to those that are already planned for.

Although the potential for pillar instability in the Bulli Seam is possible, the significance of any surface subsidence that may result is considered to be low, especially in terms of impacts to major surface infrastructure. Major infrastructure will need to be protected from expected subsidence. The increment of additional subsidence due to pillar stability is not expected to have any significant incremental impact on this infrastructure.

8.4 Valley Closure, Upsidence and Far-Field Movements

The prediction of valley closure, upsidence, and far-field movements is recognised as not being an exact science even for single seam mining. Nevertheless some characteristics are recognised. The influence of horizontal stresses as a source of energy to displace rock strata is dependent on their magnitude. Near to the Illawarra Escarpment and adjacent to previous mining activity as this site is, the in situ horizontal stresses are likely to be significantly diminished both as a result of the free surface of the escarpment and as a result of previous mining activity.

Nevertheless, SCT understands that a far-field subsidence monitoring survey network has been installed and is planned to be further upgraded to allow measurement of any such movements. These movements are unlikely to be significant in the context of any of the infrastructure located in the vicinity of the proposed mining area.

The predictions of valley closure and upsidence are recognised as being upper bound predictions because they are based on experience in deep gorges where the in situ stresses are much higher than they are at this site. A program of predicting, monitoring and response (limiting the length of longwall panels) is considered to be an effective method of managing this uncertainty. The monitoring available from the Balgownie Seam longwall panels and from Longwall 5 indicates that this method is likely to be effective in terms of managing impact on Cataract Creek.

The offsets that have been designed into the revised mine layout and the avoidance of mining directly under the main channel of Cataract Creek provide a buffer against closure related impacts. The commitment by WC to stop the longwalls short if closure movements become excessive provides an additional level of management control.

8.5 Illawarra Escarpment

There is considered to be no potential for the proposed mining to impact on the Illawarra Escarpment and in particular the section of Hawkesbury Sandstone outcrop at Brokers Nose. It should be recognised that there is always potential for cliff falls to occur naturally as part of the natural erosion processes of cliffs. Two such natural events have occurred in the last six years, one on Mount Keira in 2007 and a second at Clifton in 2013.

The only recognised mechanism for the cliff formations on the Illawarra Escarpment at Brokers Nose to be impacted by mining would be for horizontal stress concentrations to occur along the line of the escarpment. However, the cliffs associated with Brokers Nose are 900-1000m from Longwall 1 and are therefore too far away from the proposed longwall panels for there to be any potential for significant horizontal stress concentrations between the longwall panels and the escarpment.

8.6 Subsidence Management Methods

In the submissions there has been some discussion over the accuracy of the surveying and the adaptive management approach proposed by WC.

The subsidence monitoring systems being used at Russell Vale Colliery are undergoing continued upgrading from two dimensional surveying techniques used during the initial stages of mining Longwall 4 through to full three dimensional subsidence monitoring with a far-field GPS survey control network. The monitoring network used for Longwall 5 is considered to be an intermediate step. Additional monitoring and further upgrading of the monitoring is proposed in this report.

Adaptive management strategies are being practiced by WC including the significant revision to the mine layout represented by the PPR. Closure monitoring across Cataract Creek is planned to be used for Longwalls 6 and 7.

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APPENDIX 1 - SUBSIDENCE MOVEMENTS PREDICTED FOR SWAMPS AND ARCHAEOLOGICAL SITES

Seam Depths

Swamp	RL of Bulli Seam Floor (mAHD)	Surface RL (m AHD)	Overburden Depth to Bulli Seam (m)	Overburden Depth to Balgownie Seam (m)	Overburden Depth to Wongawilli Seam (m)
CCUS1	75	360	285	295	320
CCUS2	85	370	285	295	320
CCUS3	55	355	300	310	335
CCUS4	50	340	290	300	325
CCUS5	38	310	272	282	307
CCUS6	65	350	285	295	320
CCUS7	85	355	270	280	305
CCUS8	75	345	270	280	305
CCUS9	52	345	293	303	328
CCUS10	50	330	280	290	315
CCUS11	5	345	310	320	340
CCUS12	15	370	355	365	390
CCUS13	5	340	335	345	370
CCUS14	115	390	275	285	310
CCUS15	60	385	325	335	360
CCUS16	0	300	300	310	335
CCUS17	60	385	325	335	360
CCUS18	60	385	325	335	360
CCUS19	60	385	325	335	360
CCUS20	70	360	290	300	325
CCUS21	70	350	280	290	315
CCUS22	-2	315	317	327	352
CCUS23	55	365	310	320	345
CRUS1	50	350	300	310	335
CRUS2	65	275	210	220	245
CRUS3	80	375	295	305	330
BCUS1	90	360	270	280	305
BCUS2	50	335	285	295	320
BCUS3	50	315	265	275	300
BCUS4	35	330	295	305	330
BCUS5	37	310	273	283	308
BCUS6	17	325	308	318	343
BCUS11	25	360	335	345	370
52-2-3939					340
52-2-3940					340
52-2-3941					355
52-2-0603					380
Wonga East 4					300
Wonga East 5					300
52-3-0320					340
52-3-0325					315
52-3-0311					285
52-3-0310					385
52-2-0099					355
52-2-0229					365

Subsidence Movements after Bulli Seam was Mined

Swamp	Subsidence Used (m)	Overburden Depth (m)	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)
CCUS1	0.7	285	3.7	7.4	12
CCUS2	0.1	285	0.5	1.1	2
CCUS3	1	300	5.0	10.0	17
CCUS4	0.1	290	0.5	1.0	2
CCUS5	0.5	272	2.8	5.5	9
CCUS6	1	285	5.3	10.5	18
CCUS7	1	270	5.6	11.1	19
CCUS8	0.1	270	0.6	1.1	2
CCUS9	0.1	293	0.5	1.0	2
CCUS10	0.5	280	2.7	5.4	9
CCUS11	1	340	4.4	8.8	15
CCUS12	0.5	355	2.1	4.2	7
CCUS13	0.1	335	0.4	0.9	1
CCUS14	1	275	5.5	10.9	18
CCUS15	0.1	325	0.5	0.9	2
CCUS16	0.5	300	2.5	5.0	8
CCUS17	0.1	325	0.5	0.9	2
CCUS18	0.1	325	0.5	0.9	2
CCUS19	0.1	325	0.5	0.9	2
CCUS20	1	290	5.2	10.3	17
CCUS21	1	280	5.4	10.7	18
CCUS22	0.5	317	2.4	4.7	8
CCUS23	0.1	310	0.5	1.0	2
CRUS1	0.5	300	2.5	5.0	8
CRUS2	0.5	210	3.6	7.1	12
CRUS3	0.4	295	2.0	4.1	7
BCUS1	1	270	5.6	11.1	19
BCUS2	0.5	285	2.6	5.3	9
BCUS3	0.5	265	2.8	5.7	9
BCUS4	0.5	295	2.5	5.1	8
BCUS5	0.5	273	2.7	5.5	9
BCUS6	0.1	308	0.5	1.0	2
BCUS11	0.5	335	2.2	4.5	7

Site ID	Subs at Site (m)	Adjacent Subsidence Used for Strain and Tilt Calcs (m)	Overburden Depth (m)	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)	Compressive Horizontal Movement Along 20m Section of Cliff (mm)
52-2-3939	0.2	0.2	340	0.9	1.8	3	40
52-2-3940	0.1	0.1	340	0.4	0.9	1	20
52-2-3941	0.2	0.2	355	0.8	1.7	3	40
52-2-0603	0.3	0.3	380	1.2	2.4	3.9	50
Wonga East 4	< 0.1	< 0.1	300	< 0.5	< 1	< 2	< 20
Wonga East 5	< 0.1	< 0.1	300	< 0.5	< 1	< 2	< 20
52-3-0320	0.1	0.1	310	0.5	1	2	20
52-3-0325	0.3	0.3	285	1.6	3	5	60
52-3-0311	< 0.1	< 0.1	255	< 0.5	< 1	< 2	< 20
52-3-0310	0.1	0.1	355	0.4	1	1	20
52-2-0099	0.1	0.1	325	0.5	1	2	20
52-2-0229	0.2	0.2	335	0.9	2	3	40

Incremental Subsidence Measured During Balgownie Seam Mining

Swamp	Subsidence Used (m)	Overburden Depth (m)	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)
CCUS1	0.8	295	4.1	8.1	14
CCUS2	1	295	5.1	10.2	17
CCUS3	1	310	4.8	9.7	16
CCUS4	0.8	300	4.0	8.0	13
CCUS5	0.1	282	0.5	1.1	2
CCUS6	1	295	5.1	10.2	17
CCUS7	0.1	280	0.5	1.1	2
CCUS8	0.1	280	0.5	1.1	2
CCUS9	0.1	303	0.5	1.0	2
CCUS10	0.1	290	0.5	1.0	2
CCUS11	0.1	340	0.4	0.9	1
CCUS12	0.1	365	0.4	0.8	1
CCUS13	0.1	345	0.4	0.9	1
CCUS14	0.1	285	0.5	1.1	2
CCUS15	0.5	335	2.2	4.5	7
CCUS16	0.1	310	0.5	1.0	2
CCUS17	0.3	335	1.3	2.7	4
CCUS18	0.1	335	0.4	0.9	1
CCUS19	0.1	335	0.4	0.9	1
CCUS20	1	300	5.0	10.0	17
CCUS21	1	290	5.2	10.3	17
CCUS22	0.1	327	0.5	0.9	2
CCUS23	1	320	4.7	9.4	16
CRUS1	0.1	310	0.5	1.0	2
CRUS2	0.1	220	0.7	1.4	2
CRUS3	0.1	305	0.5	1.0	2
BCUS1	0.1	280	0.5	1.1	2
BCUS2	0.1	295	0.5	1.0	2
BCUS3	0.1	275	0.5	1.1	2
BCUS4	0.1	305	0.5	1.0	2
BCUS5	0.1	283	0.5	1.1	2
BCUS6	0.1	318	0.5	0.9	2
BCUS11	0.1	345	0.4	0.9	1

Site ID	Subsidence at Site (m)	Adjacent Subsidence Used for Strain and Tilt Calcs (m)	Overburden Depth (m)	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)	Compressive Horizontal Movement Along 20m Section of Cliff (m)
52-2-3939	< 0.1	< 0.1	340	< 0.5	< 1	< 2	< 20
52-2-3940	< 0.1	< 0.1	340	< 0.5	< 1	< 2	< 20
52-2-3941	< 0.1	< 0.1	355	< 0.5	< 1	< 2	< 20
52-2-0603	< 0.1	< 0.1	380	< 0.5	< 1	< 2	< 20
Wonga East 4	< 0.1	< 0.1	300	< 0.5	< 1	< 2	< 20
Wonga East 5	< 0.1	< 0.1	300	< 0.5	< 1	< 2	< 20
52-3-0320	1.1	1.2	320	5.6	11	19	200
52-3-0325	N/A	N/A	295	N/A	N/A	N/A	N/A
52-3-0311	< 0.1	< 0.1	265	< 0.5	< 1	< 2	< 20
52-3-0310	N/A	0.1	365	N/A	N/A	N/A	N/A
52-2-0099	N/A	0.1	335	N/A	N/A	N/A	N/A
52-2-0229	N/A	0.2	345	N/A	N/A	N/A	N/A

Incremental Subsidence for Proposed Mining of Wongawilli Seam

Swamp	Subsidence Used (m)	Overburden Depth (m)	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)
CCUS1	1.5	320	7.0	14.1	23
CCUS2	2	320	9.4	18.8	31
CCUS3	1.5	335	6.7	13.4	22
CCUS4	2	325	9.2	18.5	31
CCUS5	1.5	307	7.3	14.7	24
CCUS6	2	320	9.4	18.8	31
CCUS7	0.1	305	0.5	1.0	2
CCUS8	0.1	305	0.5	1.0	2
CCUS9	0.1	328	0.5	0.9	2
CCUS10	0.8	315	3.8	7.6	13
CCUS11	2	340	8.8	17.6	29
CCUS12	1.5	390	5.8	11.5	19
CCUS13	0.1	370	0.4	0.8	1
CCUS14	0.1	310	0.5	1.0	2
CCUS15	0.1	360	0.4	0.8	1
CCUS16	0.1	335	0.4	0.9	1
CCUS17	0.1	360	0.4	0.8	1
CCUS18	0.1	360	0.4	0.8	1
CCUS19	0.1	360	0.4	0.8	1
CCUS20	0.1	325	0.5	0.9	2
CCUS21	2	315	9.5	19.0	32
CCUS22	0.1	352	0.4	0.9	1
CCUS23	1.5	345	6.5	13.0	22
CRUS1	1.5	335	6.7	13.4	22
CRUS2	0.1	245	0.6	1.2	2
CRUS3	0.1	330	0.5	0.9	2
BCUS1	0.1	305	0.5	1.0	2
BCUS2	0.1	320	0.5	0.9	2
BCUS3	0.1	300	0.5	1.0	2
BCUS4	1.5	330	6.8	13.6	23
BCUS5	0.1	308	0.5	1.0	2
BCUS6	0.1	343	0.4	0.9	1
BCUS11	1.5	370	6.1	12.2	20

Site ID	Subsidence at Site (m)	Adjacent Subsidence Used for Strain and Tilt Calcs (m)	Overburden Depth (m)	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)	Compressive Horizontal Movement Along 20m Section of Cliff (m)
52-2-3939	0.8	2	340	8.8	18	29	350
52-2-3940	0.6	1.5	340	6.6	13	22	250
52-2-3941	1.2	1.5	340	6.6	13	22	250
52-2-0603	1.5	1.5	340	6.6	13	22	250
Wonga East 4	< 0.1	< 0.1	300	< 0.5	< 1	< 2	< 20
Wonga East 5	< 0.1	< 0.1	300	< 0.5	< 1	< 2	< 20
52-3-0320	0.7	2	340	8.8	18	29	350
52-3-0325	1.1	1.5	315	7.1	14	24	250
52-3-0311	< 0.1	< 0.1	285	< 0.5	< 1	< 2	< 20
52-3-0310	< 0.1	< 0.1	385	< 0.5	< 1	< 2	< 20
52-2-0099	0.4	1	355	4.2	8	14	150
52-2-0229	0.7	1	365	4.1	8	14	150

Cumulative Subsidence at the Completion of Bulli and Balgownie Seam Mining

Swamp	Subsidence Used (m)	Overburden Depth (m)	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)
CCUS1	2	285	10.5	21.1	35
CCUS2	1.1	285	5.8	11.6	19
CCUS3	1.1	300	5.5	11.0	18
CCUS4	0.9	290	4.7	9.3	16
CCUS5	0.6	272	3.3	6.6	11
CCUS6	2	285	10.5	21.1	35
CCUS7	1	270	5.6	11.1	19
CCUS8	0.1	270	0.6	1.1	2
CCUS9	0.1	293	0.5	1.0	2
CCUS10	0.6	280	3.2	6.4	11
CCUS11	1	340	4.4	8.8	15
CCUS12	0.5	355	2.1	4.2	7
CCUS13	0.1	335	0.4	0.9	1
CCUS14	1.2	275	6.5	13.1	22
CCUS15	0.2	325	0.9	1.8	3
CCUS16	0.5	300	2.5	5.0	8
CCUS17	0.1	325	0.5	0.9	2
CCUS18	0.1	325	0.5	0.9	2
CCUS19	0.1	325	0.5	0.9	2
CCUS20	2	290	10.3	20.7	34
CCUS21	2	280	10.7	21.4	36
CCUS22	0.5	317	2.4	4.7	8
CCUS23	0.9	310	4.4	8.7	15
CRUS1	0.5	300	2.5	5.0	8
CRUS2	0.6	210	4.3	8.6	14
CRUS3	0.6	295	3.1	6.1	10
BCUS1	1	270	5.6	11.1	19
BCUS2	0.5	285	2.6	5.3	9
BCUS3	0.5	265	2.8	5.7	9
BCUS4	0.6	295	3.1	6.1	10
BCUS5	0.5	273	2.7	5.5	9
BCUS6	0.1	308	0.5	1.0	2
BCUS11	0.5	335	2.2	4.5	7

Site ID	Subsidence at Site (m)	Adjacent Subsidence Used for Strain and Tilt Calcs (m)	Overburden Depth (m)	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)	Compressive Horizontal Movement Along 20m Cliff (m)
52-2-3939	0.2	0.7	340	3.1	6.2	10	120
52-2-3940	0.1	0.7	340	3.1	6.2	10	120
52-2-3941	0.2	0.7	355	3.0	5.9	10	120
52-2-0603	0.3	0.6	380	2.4	4.7	7.9	120
Wonga East 4	< 0.1	< 0.1	300	< 0.5	< 1	< 2	< 20
Wonga East 5	< 0.1	< 0.1	300	< 0.5	< 1	< 2	< 20
52-3-0320	1.1	1.2	320	5.6	11	19	200
52-3-0325	0.3	0.3	315	1.4	3	5	60
52-3-0311	< 0.1	< 0.1	285	< 0.5	< 1	< 2	< 20
52-3-0310	0.1	0.1	385	0.4	1	1	20
52-2-0099	0.1	0.1	355	0.4	1	1	20
52-2-0229	0.2	0.2	365	0.8	2	3	40

Total Cumulative Subsidence at Completion of Bulli, Balgownie and Wongawilli Seam Mining

Swamp	Subsidence Used (m)	Overburden Depth (m)	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)
CCUS1	2	285	10.5	21.1	35
CCUS2	3	285	15.8	31.6	53
CCUS3	2.5	300	12.5	25.0	42
CCUS4	2.4	290	12.4	24.8	41
CCUS5	1.8	272	9.9	19.9	33
CCUS6	3.8	285	20.0	40.0	67
CCUS7	1	270	5.6	11.1	19
CCUS8	0.1	270	0.6	1.1	2
CCUS9	0.1	293	0.5	1.0	2
CCUS10	1.5	280	8.0	16.1	27
CCUS11	3	340	13.2	26.5	44
CCUS12	1.5	355	6.3	12.7	21
CCUS13	0.1	335	0.4	0.9	1
CCUS14	1.3	275	7.1	14.2	24
CCUS15	0.2	325	0.9	1.8	3
CCUS16	0.5	300	2.5	5.0	8
CCUS17	0.1	325	0.5	0.9	2
CCUS18	0.1	325	0.5	0.9	2
CCUS19	0.1	325	0.5	0.9	2
CCUS20	2	290	10.3	20.7	34
CCUS21	3.8	280	20.4	40.7	68
CCUS22	0.5	317	2.4	4.7	8
CCUS23	2.1	310	10.2	20.3	34
CRUS1	0.8	300	4.0	8.0	13
CRUS2	0.6	210	4.3	8.6	14
CRUS3	0.6	295	3.1	6.1	10
BCUS1	1	270	5.6	11.1	19
BCUS2	0.5	285	2.6	5.3	9
BCUS3	0.5	265	2.8	5.7	9
BCUS4	2	295	10.2	20.3	34
BCUS5	0.5	273	2.7	5.5	9
BCUS6	0.1	308	0.5	1.0	2
BCUS11	2	335	9.0	17.9	30

SiteID	Subs at Site (m)	Adjacent Subsidence Used for Strain and Tilt Calcs (m)	Overburden Depth (m)	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)	Compressive Horizontal Movement Along 20m Section of Cliff (m)
52-2-3939	1	2.4	340	10.6	21.2	35	450
52-2-3940	0.7	1.6	340	7.1	14.1	24	300
52-2-3941	1.4	1.6	355	6.8	13.5	23	250
52-2-0603	1.8	1.8	380	7.1	14.2	23.7	300
Wonga East 4	< 0.1	< 0.1	300	< 0.5	< 1	< 2	< 20
Wonga East 5	< 0.1	< 0.1	300	< 0.5	< 1	< 2	< 20
52-3-0320	1.8	3.2	340	14.1	28	47	450
52-3-0325	1.4	1.8	315	8.6	17	29	250
52-3-0311	< 0.1	< 0.1	285	< 0.5	< 1	< 2	< 20
52-3-0310	< 0.1	< 0.1	385	< 0.5	< 1	< 2	< 20
52-2-0099	0.5	1	355	4.2	8	14	150
52-2-0229	0.9	1	365	4.1	8	14	150

APPENDIX 2 – RESPONSE TO SUBMISSIONS TO PPR

RESPONSE TO SUBMISSIONS TO PREFERRED PROJECT REPORT

The response to submissions to the PPR report presented in this section is a slight revision of SCT Letter Report NRE14123A dated 23 December 2013. Many of the issues raised in this initial response have been included in this updated version of the PPR Subsidence Assessment.

The submissions considered in this response are those from:

1. Independent Review of Subsidence Impact Assessment by Professor B. Hebblewhite.
2. NSW Government Department of Resources and Energy (DRE).
3. Sydney Catchment Authority (SCA).
4. NSW Government Office of Environment and Heritage (OEH).
5. Wollongong City Council (WCC).
6. NSW Department of Primary Industries (DPI).
7. Dams Safety Committee (DSC).
8. NSW Government Transport Roads and Maritime Services (RMS).
9. NSW Government Heritage Council (Heritage).
10. Environmental Protection Authority (EPA).

As there are several issues raised in multiple submissions, the response to an issue is presented in most detail the first time it is raised in the order of the list above. Where it is raised in subsequent submissions, reference is made to the earlier response for brevity and expanded as necessary, but reading the document in its entirety is recommended. We note that there are several submissions – specifically those from the DSC, RMS, Heritage, and EPA – where the PPR has addressed or substantially addressed subsidence related issues raised in earlier submissions to the NRE1 No 1 Colliery – Underground Expansion Project (MP09-0013) and these submissions are not considered further in this report.

Where the issue discussed has been directly addressed in the updated report, the update is noted.

A2-1 INDEPENDENT REVIEW BY PROFESSOR B.K. HEBBLEWHITE

Professor Hebblewhite's comments are all considered to be valid points that are well made. The response in this section is mainly in relation to clarification of some of the terms used and further explanation of the reasoning behind some of the issues that may not have come through clearly in the PPR Subsidence Assessment presented in SCT (2013).

A2-1.1 Point A3 – "Essentially Predictable" Behaviour

In response to this point, the term "essentially" has been removed in the updated copy of the PPR.

The use of the term "essentially predictable" in the original PPR was intended to convey the concept that the multi-seam subsidence behaviour observed above Longwalls 4 and 5 has characteristics that are very similar to the subsidence behaviour observed above longwall panels where only one seam has been mined. These characteristics are also evident from other sites that have yet to become available in the public domain given the relatively recent development of multi-seam longwall mining in NSW. Although the effects of multi-seam subsidence are yet to be fully characterised, the monitoring experience available confirms that the behaviour is consistent with single seam subsidence but with some differences associated with the disturbance caused by previous mining.

Even for single seam mining, regarding subsidence behaviour as being "entirely predictable" may be somewhat optimistic. However, an approach based on understanding the mechanics of the various processes involved – specifically sag subsidence over individual longwall panels and elastic strata compression above and below the chain pillars but also various forms of non-conventional subsidence behaviour – provides a basis to predict subsidence behaviour with a degree of certainty that is usually sufficient to allow appropriate management of potential impacts.

In a multi-seam subsidence environment where extracted coal seams are relatively close together such as in the PPR project area, there appears to be three main characteristics that are slightly different to single seam subsidence behaviour and they all relate to the fact that initially intact overburden strata is softened somewhat above each extracted panel to a height approximately equal to the panel width. As a result:

1. Overburden strata softened by previous mining has reduced shear stiffness (i.e. is softer in "bending") compared to undisturbed strata so the strata is less effective at bridging across the void created by mining a new panel. The subsidence engineering concepts of sub-critical and super-critical subsidence behaviour still apply, but the width at which full subsidence develops (supercritical width) is much less in a multi-seam environment.

2. The "reworking" of already subsided overburden strata causes an increase of maximum subsidence in supercritical width panels (very wide relative to depth) from 50-65% of seam thickness typical of single seam operations to 60-80% of combined seam thickness. In the PPR, the panels are still subcritical in width and so maximum subsidence is limited by panel width.

3. Goaf edge subsidence is somewhat greater at 200-300mm where there has been previous mining in the overlying seams compared to 100-200mm typical of undisturbed strata. The goaf edge subsidence profile is also somewhat more gradual.

Pillar instability may also cause additional subsidence where previously stable standing pillars in the overlying coal seams are destabilised. This effect is considered separately in Section A2-1.6.

A2-1.2 Points A6 and A7 - Adaptive Management

The concept of adaptive management was forwarded in the PPR as a method of managing closure across Cataract Creek and at a strategic level (rather than on an individual swamp basis) for managing impacts on swamps. In this section, the application of this approach is discussed further.

A2-1.2.1 Point A6 - Cataract Creek

The experience of monitoring closure across Cataract Creek during mining of Longwall 5 indicates characteristics that make an adaptive management approach likely to be suitable to manage the magnitude of closure across Cataract Creek. This monitoring indicates that the closure commenced when Longwall 5 was about 400m from Cataract Creek and has continued at a steady rate of about 12mm/100m of longwall retreat since then. A six week period of longwall stoppage when Longwall 5 was approximately 130m away from finishing showed low level additional closure of less than 5mm. This steady, predictable response allows planning for a pre-determined level of closure across Cataract Creek well in advance of reaching any given set target.

The challenge with an adaptive management approach for Cataract Creek is determining the level of closure when impacts are considered to be significant. A target of 200mm has been adopted based on experience of mining near creeks and rivers in Hawkesbury Sandstone strata. Recognising that the base of Cataract Creek is located within the outcrop of the Bald Hill Claystone, it is possible that closure may be occurring on the Hawkesbury / Bald Hill Claystone contact without causing any perceptible impact to the creek bed.

Available evidence including the absence of any significant fracturing or other impacts in the creek bed from previous mining including Longwalls 4 and 5 indicates that closure movements may be occurring above the level of the creek bed so that the types of impacts observed in Hawkesbury Sandstone where horizontal shear and resulting closure typically occurs below the level of the creek bed may not be occurring in Cataract Creek. However, further surveying scheduled for the end of Longwall 5 and analysis of this monitoring data is required to confirm this hypothesis. In the meantime, visual inspections continue to form a critical part of the adaptive management strategy for Cataract Creek and so far there has been no perceptible impact.

A2-1.2.2 Point A7 - Adaptive Management of Swamps

The concept of adaptive management for swamps is not considered valid on the scale of individual swamps because the changes are unlikely to occur in a timeframe that is appropriate to managing longwall retreat. However, the approach is considered to be a valid method of managing mining impacts on swamps more generally at a strategic level given that the data available from previous longwall mining in the Balgownie Seam does not indicate high levels of subsidence related impact to any of the swamps in the area (Biosis 2013).

While it is accepted that there is no baseline data available from this earlier mining, the fact remains that CCUS4 was subsided by up to 0.9m and appears to have continued to thrive. Other swamps in the general area have also been similarly subsided and also appear to continue to thrive. Thus there is opportunity to study the impacts of previous mining on swamps over the longer terms of 30 years for the Balgownie Seam longwalls and 60-80 years for Bulli Seam monitoring at least on a comparative scale with similar swamps where coal has been extracted.

The proposal to mine Longwall 6 below CCUS4 provides the opportunity to get some baseline data and then monitor the changes that occur over the longer term. It is accepted that there may be some changes, but the magnitude of the changes are not thought likely to be significant based on the experience of previous mining below the site. By carefully measuring any physical changes including rainfall, subsidence movements, vegetation, groundwater pressures, and surface flows it should be possible to determine over the medium to long term how significant any impacts may be. This experience will then be available to inform future assessments of similar swamp types.

A2-1.3 Point A9 – Explanation of Bulli Seam Goaf on 0.7 Times Depth Protection Barrier

This point has been clarified in the updated PPR subsidence assessment but is discussed in more detail below.

A 0.7 times depth protection barrier to the full supply level (FSL) of Cataract Reservoir has been used as the basis to design the layout of longwall panels in the Wonga East mining area. The presence of a Bulli Seam goaf in areas between the ends of the proposed longwall panels and the Cataract Reservoir reduces the effectiveness of the 0.7 times depth barrier but it does not mean that the barrier is ineffective. In this section, an explanation of the nature of the barrier and its effectiveness is provided. This explanation drifts into a discussion on groundwater issues which is starting to get outside the domain of a subsidence assessment and therefore wasn't discussed in detail in the subsidence assessment report (SCT 2013). However, given the significance of the issue raised by Professor Hebblewhite, a more detailed explanation is provided here to clarify the point that was being made.

The key issue for controlling the effectiveness of a barrier is maintaining the integrity of the pathway for flow from the reservoir to the mine workings. The FSL is at RL289.9m while in the area beyond the end of Longwall 7, the Bulli Seam mining horizon is approximately RL35m and the Wongawilli Seam horizon is approximately RL0m.

The only credible pathways for leakage from the reservoir to the mine are either horizontally from the reservoir to the subsided strata above the longwall goaf and then downward through this strata into the mine or via geological structures. The potential for through going geological structures is discussed separately below. Any vertical pathway to the mine roadways directly below the reservoir is clearly not of high enough hydraulic conductivity to be an issue given that these roadways already exist and there is no evidence of any inflow.

The 200m horizontal barrier (equivalent to 0.7 times 290m) provides a significant barrier to horizontal flow given the hydraulic conductivities of rock strata and, supported by the fact that there is no experience of leakage from reservoirs or water bodies for barriers of this size, appears more than adequate. However, the presence of an existing goaf in the Bulli Seam within this barrier may reduce the effectiveness of this barrier against possible leakage into the mine as noted in SCT (2013). Some very good work presented by Tammetta (2012) allows this potential to be investigated.

Tammetta (2012) presents an empirical relationship that is based on published experience from all around the world of longwall mining interactions with groundwater. The relationship allows the height of depressurisation above the mining height to be calculated as a linear function of panel width multiplied by seam thickness mined raised to the power of 1.4 and overburden depth raised to the power of 0.2.

The height of depressurisation is significant because it defines the point above the mining horizon at which the vertical hydraulic conductivity of the overburden strata reduces sufficiently to support a hydrostatic water pressure profile in the overburden strata. Looking at it the other way around, the height of depressurisation is the height below which vertical leakage through the subsided overburden strata starts to become significant as a pathway for inflow. A source of surface recharge is still required for inflow to occur, but the pathway exists at overburden depths less than the height of depressurisation.

Monitoring at Russell Vale Colliery and at other sites confirms the Tammetta relationship. The widest of the Bulli Seam goaf areas within the barrier to the reservoir is approximately 180m. For a 2.4m high mining height (assuming complete extraction and a conservative seam height) at 280m deep, the height of depressurisation is approximately 160m, so there is still 120m of strata with sufficiently low hydraulic conductivity to maintain a hydrostatic groundwater profile above the top of any of the Bulli Seam goafs in the barrier. The presence of this 120m of strata means there is still no significant vertical pathway to the mine despite the presence of the extracted panels in the Bulli Seam.

The observation that mining in the Wongawilli Seam causes vertical ground movements that are substantially within the footprint of the panel means that ground movements and overburden disturbance are substantially limited to within the panel footprint.

The height of depressurisation can be conservatively estimated as the combined thickness of mining in all seams at the depth of the lowest seam and a panel width of the panel being mined. Monitoring experience at GW-01, a groundwater pressure monitoring borehole near where Mount Ousley Road crosses Cataract Creek, confirms the Tammetta relationship still applies in an area where both the Balgownie and Bulli Seams have been mined.

Longwall 7 is 125m wide at a depth of approximately 290m. Apart from one small area where there is a narrow overlap, there is nowhere that all three seams are fully extracted together and certainly nowhere within the 0.7 depth barrier.

For the proposed 125m wide Longwall 7 mined below the Bulli Seam (there is no mining in the Balgownie Seam at the south western end of Longwall 7), the height of depressurisation is calculated using the Tammetta relationship to be 260m (for a combined mining height in the two seams of 5.0-5.4m). This means that the height of depressurisation may be approaching the surface and although there may still be some barrier to vertical flow near the surface, the main protection against inflow from the reservoir is the horizontal barrier of 200m. This barrier is maintained all around Longwall 7 and so there is considered to be no potential for significantly increased inflow from the reservoir to the mine as a result of mining Longwall 7.

Even if there were to be some further instability in the Bulli Seam goafs within the barrier as a result of mining Longwall 7, which is considered most unlikely, the height of depressurisation considered above is for the worst case of full extraction or complete destabilisation of all pillars and the height of depressurisation is therefore not expected to be greater than 260m.

Notwithstanding the discussion presented above that indicates there is no potential for Longwall 7 to significantly increase inflow from the reservoir to the mine, there is still a need to continue to confirm the heights of depressurisation above multiple goafs and to confirm that any depressurisation over Longwall 7 is not causing a change in the groundwater regime between the reservoir and the mine.

Further groundwater pressure monitoring boreholes are planned to be drilled including one at a site above Longwall 4 where all three seams have been mined, several others between the end of Longwall 7 and the reservoir, and another near Cataract Creek to monitor depressurisation as Longwall 7 approaches. The first borehole is aimed to confirm the height of depressurisation above three mined seams before Longwall 7 starts. The several boreholes between the reservoir and the start of Longwall 7 are aimed to confirm the direction of groundwater flow continues to be toward the reservoir above the 200m barrier.

A2-1.4 Point A10 – Body of Evidence to Support Predictions of Multi-Seam Subsidence

The subsidence monitoring data available from Russell Vale Colliery is valuable data but there are other sites where high quality multi-seam data is emerging. Unfortunately, it is early days and data from these sites has yet to make its way into the public domain so it can be referenced in a subsidence assessment report of this type. The results are nevertheless convincing and surprisingly consistent. It is anticipated that the experience from additional sites should be available in the public domain by mid-2014.

A2-1.5 Point C1 – Swamp Constraints

The point is made that the constraint in relation to upland swamps lacks quantitative or measurable definition of how the impacts of mining are translated into a design constraint. This point is accepted. The challenge is that there does not seem to be a large body of evidence available to confirm whether upland swamps that depend for their water primarily on rainfall recharge are significantly impacted by mining subsidence. The issue of impacts of mining on upland swamps is an area that requires further work at a strategic level to confirm that there are indeed long term impacts and the nature of these impacts.

Previous mining in the Bulli Seam and the Balgownie Seam at Russell Vale Colliery and in the Bulli Seam all along the Illawarra Escarpment provide a long history of the effects of mining subsidence on these types of swamps. While there is limited baseline data currently available, it seems that the swamps above Wonga East provide an opportunity to get not only baseline data but also data on the scale of any impacts. A comparative study is therefore planned to monitor swamps where there will be no further mining to swamps that will be mined under.

CCUS4 is a swamp that was mined under and subsided about 0.9m in the early 1980's. CCUS4 appears to still be in good health (Biosis 2013). To step Longwall 6 around CCUS4 would significantly reduce the coal resource able to be recovered from Longwall 6. By accepting that there may be some impacts to this swamp but also that these impacts may not significantly affect the health of the swamp (as per previous mining), the opportunity exists to monitor the ground movements, groundwater impacts, and any ecological changes to provide evidence to guide future strategic planning of longwalls in close proximity to these types of upland swamps.

Mining is proposed under the fringes of CCUS5 which has been partly mined under previously in the Bulli Seam and CRUS1 which has been significantly mined under previously in the Bulli Seam. The opportunity exists to monitor any ecological changes as a function of distance from Longwall 7 as a guide to offset distances that may be required in the future.

The need for more of this type of monitoring is reiterated elsewhere by Professor Hebblewhite's comments and emphasised in Point G1. The need for more monitoring is recognised and accepted.

A2-1.6 Point C6 – Pillar Run

This point has been clarified in the updated PPR subsidence assessment.

The point made in respect of not including elastic compression subsidence in the same discussion as "pillar run" is accepted and the two mechanisms are recognised to be unrelated. The linking of these two completely separate processes was in response to concerns raised by DRE in earlier submissions to the NRE1 No 1 Colliery – Underground Expansion Project (MP09-0013) and again in their response to the PPR discussed further in Section A2-2.

The DRE concern under the heading "pillar run" was not just, or even primarily, about conventional pillar run caused by pillar instability, although this is clearly an issue in some localised areas. Their concern appears to be more directed toward possible low level goaf remobilisation from both horizontal stress relief and additional elastic pillar compression of barriers that they were concerned may affect infrastructure such as Mount Ousley Road, Picton Road Interchange, and the high voltage power lines located between Mount Ousley Road and the Illawarra Escarpment. There is not a universal term for these types of movements, but the term "pillar run" is accepted as perhaps not best suited to describe them.

A2-1.7 Point C9 – Balgownie Seam Subsidence Monitoring and Swamp Impacts

SCT is not aware of any ecological monitoring in relation to swamps from the period of mining longwall panels in the Balgownie Seam from 1970 to 1982. This information would be most useful as baseline monitoring if it is available.

Unfortunately, most of the Balgownie Seam subsidence monitoring (all except Longwall 11) comprises only vertical subsidence. The period when the Balgownie Seam was mined was very early in the development of subsidence monitoring in NSW and survey instruments suitable for routine monitoring of subsidence in three dimensions were not yet widely available or affordable. Although the monitoring is considered to be of a high standard for the time, the monitoring detail is relatively limited by contemporary standards.

A2-2 DRE Submission

The DRE submission dated 26 November 2013 presents feedback to the PPR on several areas of DRE responsibility. The response presented in this section relates only to subsidence issues raised in the submission.

The potential for some remobilisation of the overlying Bulli Seam pillars is accepted and the differences of definition between a "pillar run" associated with underground safety and the use of the term to describe irregular or additional subsidence possibly beyond the boundaries of proposed mining are recognised.

Experience to date of monitoring subsidence from Longwalls 4 and 5 does not show any evidence of significant irregular or additional subsidence beyond that which would be expected in a multi-seam environment where both main heading pillars and pillar extraction areas are present. There is some evidence of small movements of less than a few centimetres on Mount Ousley Road that can properly be attributed to normal subsidence beyond the goaf edge, to the far-field redistribution of horizontal stresses, and to downslope movement but these are of low level and these have occurred incrementally rather than suddenly. There is evidence that these low level movements are localised at pre-existing goaf edges consistent with remobilisation of existing fractures within the overburden strata as would be expected.

There is also some evidence from subsidence monitoring undertaken during longwall mining in the Balgownie Seam of additional subsidence of up to about 0.7m directly over longwall panels that again can be properly attributed to remobilisation of Bulli Seam workings and destabilisation of pillars within the Bulli Seam. These areas have all been associated with areas where additional subsidence would be expected because of the irregular extraction geometry in the Bulli Seam. There is some softening of the goaf edge apparent, but the surface subsidence does not appear to have been unduly irregular as a result of the overlying Bulli Seam pillars.

Further geotechnical investigations are planned and further consultation with DRE on these concerns is recommended.

A2-3 SYDNEY CATCHMENT AUTHORITY (SCA)

The SCA submission discusses a range of issues. Only those that relate to subsidence, geological structure, and groundwater interactions are discussed in this section. The SCA expresses major concerns about:

- Lack of geological investigations.
- Induced leakage from Cataract Reservoir.
- Longwall mining within the Dams Safety Notification Area.
- Impacts on swamps such as CCUS4.

A2-3.1 Point 4 – Review of Geological Structures

Previous mining in the Bulli Seam and Balgownie Seams are considered to provide a very strong basis for defining geological structures in the area the proposed mining. The Bulli Seam records are considered poor to reasonable due to the drafting standards of the time but nevertheless show the location of major structure. The Balgownie Seam records are considered to be to a high standard. The degree of confidence in the location of geological structures is much greater than would normally be possible at a green fields site based on drilling and seismic investigations because it has been possible to accurately locate all faults and dykes underground, determine their throw, and directly inspect some of them. This circumstance is fortunate given the very real issues of surface access limitations in the SCA administered Special Area.

There still seems to be some confusion about the naming and extent of geological fault structures and the ability of drilling to delineate fault structures. Further discussion with the site geologist is recommended to clarify the confusion that appears to still exist. Some of this confusion may be a result of naming conventions, particularly in relation to the Rixons Pass Fault which is located to the north of the PPR mining area and well outside of any area likely to be affected by mining subsidence. Previous reporting by others indicated that Dyke D8 may have been an extension of Rixons Rass Fault but this interpretation has been revised on the basis of more detailed information (Clark 2013).

There is also seems to be an underlying concern that the presence of geological faults has potential to significantly modify the response of the 300m of overburden strata to subsidence movements. In the author's experience, the concept of geological fault structures significantly changing the response of the overburden strata is not supported by experience. Near surface thrust faults have occasionally been apparent in subsidence profiles and a closely spaced pair of dykes is known to have once locally modified a subsidence profile, but these are very unusual.

The concept of geological structures interacting with overlying pillars causing them to become unstable is not considered a significant issue in the context of the proposed mining. The creation of a longwall goaf directly below remnant pillars in the Balgownie and Bulli Seams is expected to destabilise small pillars as discussed in the body of this report. The presence or otherwise of geological fault structures does not significantly change this process and the additional subsidence that results from any instability has already been factored into the subsidence estimates.

Again it is reiterated, the level of geological detail available at this site from being able to mine up to and through all the geological structures in the area is far in excess of the detail that is usually available. This detail is more than adequate to confirm that there is no potential for geological fault structures to significantly affect the height of depressurisation, the magnitude of subsidence, or the connectivity between the reservoir and the mine at the mining depths in this area.

A2-3.2 Point 4.1 – Subsidence Predictions

In the section of the SCA submission titled "Subsidence Predictions" the method of subsidence prediction and the recommendations from SCT (2013) are restated but with some slight changes compared to what was intended. In this section the methods used to predict subsidence and the recommendations are clarified.

The subsidence prediction method is based primarily on empirical observations made during mining of Longwalls 4 and 5 recognising that previous mining in the overlying seams has modified the shear stiffness of the overburden strata.

Previous subsidence data from longwall mining in the Balgownie Seam, and from mining in the Bulli Seam further to the west are also presented to show that there has previously been significant subsidence below Cataract Creek and most of the swamps within the PPR mining area. Bulli Seam subsidence data from further west was used because no subsidence data is available for the mining in the Bulli Seam within the PPR area due to the age of the workings.

Maximum tilts and strains are estimated using empirical data presented by Holla and Barclay (2000) for the increment of subsidence associated with mining the Wongawilli Seam. Holla and Barclay (2000) did not present an incremental subsidence approach. The approach used should not to be confused with the incremental profile method routinely used by Mine Subsidence Engineering Consultants Pty Ltd (MSEC) and which has not been used here.

SCT did not recommend confirmation that there are no geological structures with potential to provide elevated hydraulic conductivity between the reservoir and the mining horizon. SCT already considers that there is sufficient confirmation that there are no such structures based on the high level of geological information available and considers that there is no potential for these structures to be significantly impacted by mining subsidence. However, it was noted that the protection strategy relies on having this information.

SCT is not aware of any recommendation for a program of work to test the hydraulic conductivity of the dyke. The experience of mining through dykes in the Southern Coalfield is that they do not provide a pathway for inflow for the mining depths at this site.

The increase in subsidence over Longwall 4 due to mining Longwall 5 is consistent with compression of the chain pillar and surrounding strata as expected. As the pillar and strata above and below the chain pillar compress at the edge of panel, so the subsidence in the adjacent previously mined panel increases by about half the compression on the edge of the panel. Further subsidence over previous panels is routinely measured and the increased subsidence observed over Longwall 4 is entirely consistent with expectation.

The statement is made that "*SCA considers it highly likely that the actual vertical subsidence of Longwall 5 will surpass the revised predicted values if Longwall 6 and others are mined*". The predictions have been made based on a conservative interpretation of the available information, but SCT would be pleased to learn of and discuss in more detail the approach that SCA has used to support this statement.

The comment that the "*reliability of subsidence predictions are critical for the assessment of other impacts and environmental consequences*" is considered to be something of an overstatement. Certainly the subsidence predictions need to be soundly based, but it should be recognised that any small differences between predicted and actual subsidence do not usually change the way that surface impacts are managed. The greater challenge is determining the relationship between any given level of subsidence and the environmental consequences so that impacts can be more appropriately assessed.

It is unclear what the call for comprehensive assessment of the behaviour of all faults and dykes in the proposed mining area is aiming to achieve particularly given the high level of detail currently available. The Corrimal Fault tapers out in the vicinity of proposed Longwalls 6 and 7 in the Wongawilli Seam. The ground movements associated with subsidence from mining in the Bulli Seam do not appear to have had any adverse impact on the surface or on hydraulic connectivity with the reservoir. The D8 dyke has been thoroughly tested by mining in the Balgownie and Bulli Seams, again without becoming apparent on the surface in the subsidence profiles or otherwise increasing the hydraulic conductivity of the overburden strata. Some further discussion to better understand the requirements is recommended.

A2-3.3 Point 4.1 – Impacts on Cataract Reservoir

The 200m wide barrier to Cataract Reservoir is considered to provide a high level of protection to the stored waters of Cataract Reservoir. The explanation relating to concerns about the Bulli Seam goafs are discussed above in Section A2-1.3.

The concept of restricting mining within the DSC Notification Area does not appear to be based on experience of impacts or the understanding outlined in the Reynolds Inquiry and subsequently administered by the DSC. The experience base and the restrictions to mining are based on depth to mining and include significant factors of safety. It is entirely appropriate that there be a DSC Notification Area to provide a mechanism to provide timely engagement of mining companies with the DSC so that suitable protection measures can be developed. However, this requirement for timely engagement has no relation to the physical protection barrier required to protect the stored waters.

The recommendation to use exploration drilling to confirm the extent of the Corrimal Fault is not considered practical, likely to be effective, or necessary. Development roadways will prove the existence, location, and displacement of this structure prior to any longwall mining. Further discussion is recommended to better understand the concerns that are being raised.

A2-3.4 Point 4.1 – Impacts on Cataract Creek

On the basis that the definition of “presumptive” as stated in the Chambers Twentieth Century Dictionary is “grounded on probable evidence” and “an assumption made failing proof to the contrary” the statement that SCA considers it presumptive of SCT to suggest that there has not been any impact on the creek is accepted. The original comment in SCT (2013) was intended to convey the point that despite 1.4m of subsidence and a probable closure of several hundred millimetres associated with this subsidence, there is no apparent evidence to suggest that Cataract Creek is losing significant flow into the mine or there is significant flow diversion into and along the stream bed.

The issues relating to adaptive management of closures on Cataract Creek are discussed in Section A2-1.2.1. The experience to date indicates that closure can be managed through adaptive management practices. The main challenge relates to determining how much closure is tolerable.

A2-3.5 Point 4.1 – Impacts on Swamps

The issues relating to adaptive management of swamps are discussed in Section A2-1.2.2.

Proposed longwall mining below CCUS4 is expected to cause some physical changes to the swamp and the first order stream that flows from it. However, the swamp has previously been subsided by up to 0.9m and SCT understands that there are not known to have been any significant adverse consequences over the long term (30 years since that subsidence occurred). There is therefore some basis to consider that further subsidence will not cause impacts that are significant enough to be an issue for the long term health of the swamp.

The context of the suggestion to monitor CCUS4 closely during mining of Longwall 6 is to provide high quality information that can be used to make informed strategic judgements for other swamps in the area.

A2-4. OFFICE OF ENVIRONMENT AND HERITAGE (OEH)

OEH raises concerns in relation to:

- Impacts on coastal upland swamps EEC.
- Potential loss of water to deep storage.
- Impacts on threatened species.

These are not subsidence related issues, but some of the issues raised by OEH relate to subsidence estimates. The following section focuses on clarifying the subsidence related aspects.

A2-4.1 Attachment A - Upland Swamps

The concept of valley closure is raised in respect to upland swamps. Some clarification of this concept may assist the discussion. Valley closure occurs primarily as a result of dilation of the subsiding overburden strata below topographic high ground. Dilation is a natural characteristic or rock and rock like materials when subject to disturbance and occurs in all directions.

When sloping terrain is subsided, strata dilation forces are unopposed on the downslope side and following principles of conservation of energy (i.e. following the path of least resistance) horizontal movements occur in the direction of least resistance which is directly downslope. This direction gives rise to the term "horizontal movements in a downslope direction" or "downslope horizontal movements".

Downslope movements give rise to valley closure in topographic low points and stretching at topographic high points. Below the level of valley floor, the potential for downslope movement is curtailed by the buttressing effect of strata below the opposite bank and movement toward the valley of strata below the base of the valley is effectively prevented. The difference in movement is accommodated as horizontal shear movements on horizontal bedding planes at a level close to the base of the valley.

In Hawkesbury Sandstone strata, the bedding planes that are activated by horizontal movements in a downslope direction are typically at a level 3-6m below the base of the river channel because these bedding planes appear to be active as part of the natural valley forming processes that occur over geological time. In some circumstances, it is possible for lower strength shear horizons to be preferentially activated above the base of the creek so that the bedrock in the creek bed is not overloaded in compression and fractured.

These processes are occurring on a scale of whole valleys. For instance closure movements measured during mining of Longwall 5 show that closure of up to 50mm has occurred along a 1km section of Cataract Creek. On the scale of individual upland swamps of the size present in PPR mining area, there is typically not enough energy available within the subsiding rock strata either side of the shallow valleys where the swamps are located for valley closure to be significant enough to fracture rock. In effect, the entire swamp moves down the slope toward the main valley of Cataract Creek rather than the sides of the shallow valley moving laterally across the slope toward the swamp.

The main subsidence processes that are likely to cause cracking of the bedrock below the swamps in the PPR are associated with systematic horizontal movements and associated conventional strains. The estimates of maximum strain and tilt provided in Appendix 1 are based on maximum credible values in the general vicinity of the swamp for the level of subsidence anticipated. However, these predictions are not expected to occur at all locations within any given swamp and may not occur within a given swamp at all.

A2-4.2 Attachment A – Surface Water

OEH describes a range of studies that help to quantify the effect of mining on potential inflows from the surface. It is noted that the findings of these studies remain consistent with studies conducted in the 1970's as part of the Reynolds Inquiry and which have been used to regulate mining adjacent to stored waters since that time. The height of depressurisation above individual longwall panels has recently been shown by Tammetta (2012) to be predictable with a high degree of confidence confirming that the Reynolds Guidelines are very conservative (as they should be).

The changes in panel widths and chain pillar widths referred to by OEH have been designed to both control surface inflows and inflows from the reservoir and the third and fourth order sections of Cataract Creek. The first and second order sections of Cataract Creek have not been specifically protected but are generally also protected.

In the original NRE1 No 1 Colliery – Underground Expansion Project (MP09-0013), large chain pillars were required to maintain low levels of surface subsidence in the expectation that the overburden strata would bridge across each individual panel. Subsidence monitoring from Longwalls 4 and 5 have shown that previous mining has compromised the bridging capacity of the overburden strata and, consistent with the adaptive management strategy being used at this site, the mine layout has been redesigned in the PPR so that there is no mining directly below the third and fourth order sections of Cataract Creek. The lack of overburden bridging and the mine layout redesign make the need for overly large chain pillars to reduce subsidence redundant. The chain pillars have consequently been resized to sizes that are appropriate to maintain stable working conditions underground and move Longwall 7 outside the 0.7 depth barrier to Cataract Reservoir.

It is recognised that OEH and other agencies have not had the benefit of being able to examine the groundwater studies.

A2-5 Wollongong City Council (WCC)

WCC has expressed a number of concerns. The concerns that relate to subsidence that have not been addressed by the PPR are mainly in relation to proposed mining under swamps CCUS4, CCSU5, and CRUS1. These issues are discussed in previous sections of this report, specifically Sections A2-1.2.2, A2-1.7, A2-3.4, and A2-4.1 of this Appendix.

A2-6 NSW Department of Primary Industries (DPI)

DPI has raised a number of concerns. The concerns that relate to subsidence mainly relate to changes in panel dimension. Other concerns relate to groundwater and these are not specifically addressed in this report although some of the discussion around height of depressurisation is relevant. It is recognised that DPI and other agencies have not had the benefit of being able to examine the groundwater studies.

The changes in panel width are discussed in Section A2-4.2, but are discussed further here for clarification. The width of the longwall panels is maintained at a maximum of 150m across most of the PPR with reduced width in Longwalls 1, 2, and 7 to fit within various constraints and provide protection to surface features and the existing main heading developments underground.

The subsidence predictions that have been made are based on the results of monitoring above Longwalls 4 and 5 and these results provide a strong basis for predicting the magnitude of subsidence that can be expected above the remaining panels in the PPR with sufficient accuracy to enable management strategies to be developed

Appendix C

RUSSELL VALE COLLIERY – UNDERGROUND EXPANSION PROJECT, PREFERRED PROJECT REPORT, WONGA EAST GROUNDWATER ASSESSMENT

GeoTerra

Groundwater
Exploration Services

WOLLONGONG COAL LTD

RUSSELL VALE COLLIERY
UNDERGROUND EXPANSION PROJECT
PREFERRED PROJECT REPORT
WONGA EAST
GROUNDWATER ASSESSMENT

Bellambi, NSW

NRE1 – R1C GW

19 JUNE, 2014

NRE8 R1C GW (19 June 2014)

Wollongong Coal Ltd
PO Box 281
Fairy Meadow NSW 2519

Attention: Dave Clarkson

Dave,

RE: Russell Vale Colliery – Underground Expansion Project, Preferred Project Report, Wonga East Groundwater Assessment

Please find enclosed a copy of the above mentioned report.

Yours Faithfully

GeoTerra Pty Ltd	**GES Pty Ltd**
Andrew Dawkins	**Andy Fulton**
Principal Hydrogeologist (MAusIMM CP-Env)	Principal Hydrogeologist

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Date	Rev	Comments
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02/06/2014	A	Incorporate review comments
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1. INTRODUCTION

As part of the proposed Underground Expansion Project (UEP), Wollongong Coal Ltd (Wollongong Coal) proposes to extract coal from the Wongawilli Seam by longwall extraction from Longwalls 1 to 3 and Longwalls 6 to 11 in the Wonga East mining domain.

Longwalls 4 and 5 in the Wongawilli Seam at Wonga East were recently mined between April 2012 and January 2014.

The proposed workings are contained within Consolidated Coal Lease 745 (CCL745) and Mining Lease 1575 (ML1575), both of which are held by Wollongong Coal.

The proposed and historic workings are predominantly located within the Metropolitan Special Area as shown in **Figure 1**. The Metropolitan Special Area is a restricted area managed by the Sydney Catchment Authority.

The Study Area is located approximately 13km northwest of Wollongong and is defined as the area within the 20mm predicted subsidence zone (SCT Operations 2014) above the proposed Wongawilli Seam workings.

Potential Significant Feature Zones have been defined as 600m wide zones that extend from the edge of the secondary extraction footprint for the assessment of any potentially significant natural features (NSW Planning Assessment Commission, 2009).

In addition, Risk Management Zones have been defined with 400m wide (or 40^o angle of draw from the edge of the proposed underground workings) corridors that extend centrally from the creek centre line for the Cataract River, Cataract Creek and Bellambi Creeks.

Where either of these two zones extend outside the footprint of the 20mm subsidence zone, they have been incorporated in the Study Area for this assessment.

Within Wonga East, 1^{st} and 2^{nd} order tributary creeks drain into the 3^{rd}, and subsequently 4^{th} order catchment of Cataract Creek, downstream of the freeway, and the 3^{rd} order catchments of Cataract River.

The Wonga East catchments drain directly into Cataract reservoir and subsequently, to Broughtons Pass weir. Cataract River subsequently drains downstream to the off-take to the Macarthur Water Treatment plant at Broughtons Pass Weir.

Cataract River is regulated by Cataract Dam, upstream of the Lizard Creek / Wallandoola Creek confluence, as well as by Broughton's Pass Weir, downstream of their confluences with Cataract River.

The Study Area is focussed on the main channel of Cataract Creek, with Bellambi Creek on the northern periphery and Cataract River in the western region.

None of the main creek channels will be undermined by the proposed workings.

The Study Area contains steep gradient valleys that drain off the western slopes of the Illawarra escarpment to Cataract reservoir in the west.

The proposed Wonga East workings predominantly underlie the Cataract Creek catchment, and to a lesser degree, the Cataract River and Bellambi Creek catchments.

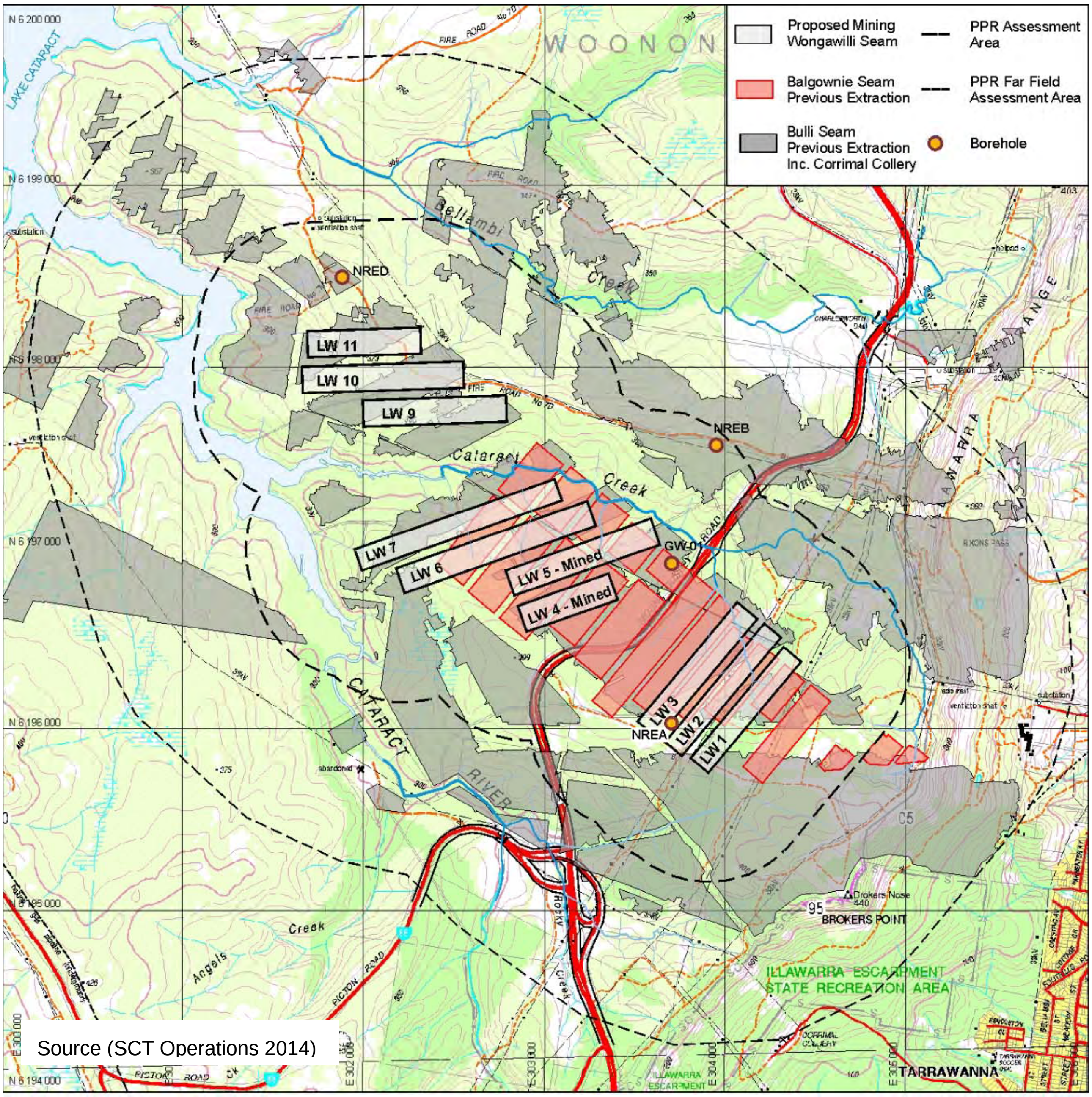


Figure 1 Wonga East Historic and Proposed Mining

Thirty nine upland headwater swamps that meet the definition of being a Coastal Upland Swamp Endangered Environmental Community are present in the Wonga East Study Area within the Cataract Creek, Cataract River and Bellambi Creek catchments (Biosis, 2014).

Land use within the Study Area generally consists of undeveloped bushland, including some limited fire access and power transmission access trails.

This study provides a baseline assessment of the current status of potentially affected groundwater systems within the proposed mining area in accordance with the Director-Generals Requirements (DGR's) for the project as well as subsequent Preferred Project

Report review correspondence by the relevant regulatory departments.

Office assessments, field monitoring, laboratory analysis and computer modelling studies have been used to prepare a baseline assessment of the shallow and deep groundwater systems, as well as perched upland swamp water levels, water quality and aquifer hydraulic parameters within the Study Area.

The study assesses the potential mining impact on the groundwater systems, as well as providing a potential indicative management and monitoring strategy that will be suitable to manage any potential adverse effects that may be caused by subsidence.

Related groundwater features within the Study Area include:

- a regional water table which has been intersected between 17m to 48m below surface within the Hawkesbury Sandstone. Where paired measurements are available, the regional aquifer has been shown to be hydraulically separated from the upland swamps by up to 15m of dry to unsaturated, weathered Hawkesbury Sandstone;
- shallow, perched, ephemeral aquifers within the upper (<20m deep) Hawkesbury Sandstone;
- headwater swamps within Cataract Creek, Bellambi Creek and Cataract River catchments;
- shallow (<1.9m deep) perched, ephemeral highly variable water level aquifers within the swamps, and;
- "Losing" streams, which predominate in the upper catchments, where stream water permeates into the regional Hawkesbury Sandstone aquifer, and "gaining" streams in incised sections, where groundwater seeps under gravity into the main creek channels.

Previous underground mining in and adjacent to the Study Area has been conducted through longwall mining of the Bulli Seam in Wollongong Coal's lease area to the west, east and beneath Cataract reservoir, as well as in BHP Billiton's (BHPB) Cordeaux and Corrimal lease areas to the south and the BHP Old Bulli workings to the north.

Multi seam mining has been conducted at Wonga East through:

- bord and pillar, as well as pillar extraction of the Bulli Seam at Wonga East, along with predominantly bord and pillar mining, and to a lesser degree, longwall extraction in the old Australian Iron and Steel (AIS) (subsequently BHPB) Bulli Colliery workings to the north and Corrimal colliery to the south of Wonga East.
- longwall extraction of the Balgownie Seam at Wonga East, and;
- extraction of Longwalls 4 and 5 in the Wongawilli Seam at Wonga East.

The proposed mine plan has been specifically designed to not directly undermine the main channels of Cataract and Bellambi Creeks, Cataract River or Cataract reservoir.

The proponent has committed to developing a closure based trigger system for managing impacts on the creek with the exact values to be determined based on the best available predictive models and assessment of existing closure data from LW 4 & 5. This will be undertaken in liaison with regulators as part of the development of management plans for Cataract Creek.

The stream assessment for the Study Area is discussed seperately in WRM Water and Environment (2014), whilst the swamp assessment is detailed in Biosis (2014).

1.1 Scope of Work

In accordance with the Director General's Requirements for Project Application 09_0013, (20/3/2009), the requirements for the groundwater component of the assessment are:

- *a description of the existing environment, using sufficient baseline data;*
- *an assessment of the potential impacts of all stages of the project, including any cumulative impacts, taking into consideration any relevant guidelines, policies, plans and statutory provisions and the findings and recommendations of the recent Southern Coalfield inquiry;*
- *a description of the measures that would be implemented to avoid, minimise, mitigate, rehabilitate/remediate, monitor and/or offset the potential impacts of the project, including detailed contingency plans for managing any potentially significant risks to the environment, and;*
- *a detailed assessment of the potential impacts of the project on the quantity, quality and long-term integrity of the groundwater resources in the project area, paying particular attention to the Upper Nepean River sub-catchment (Metropolitan Special Area)*;

This document also addresses submissions from the relevant regulators in response to the Underground Expansion Project Preferred Project Report provided by Gujarat NRE Coking Coal Ltd (now Wollongong Coal Ltd) to the Department of Planning and Infrastructure (DoPI), on 28 August 2013, as well as subsequent correspondence between Wollongong Coal, DoPI and its authorised representatives.

Geoterra Pty Ltd (Geoterra) and Groundwater Exploration Services Pty Ltd (GES) were commissioned by Wollongong Coal Ltd to address any potential groundwater impacts relating to the proposed extraction and associated subsidence of the Wongawilli Seam in the Wonga East mining area, as proposed for the UEP.

The groundwater investigation was conducted to assess the current and historic:

- standing water levels and / or hydrostatic pressures within formations overlying the existing and proposed workings;
- groundwater quality of the upland swamps, shallow and deeper Hawkesbury Sandstone units;
- hydraulic parameters of the upland swamps, Hawkesbury Sandstone and other formations overlying the proposed workings, and;
- any observed or inferred groundwater discharge zones into local streams.

In addition, the study aims to:

- identify potential groundwater dependent ecosystems;
- collate and review mine water management data;
- collate and review additional data from adjacent mines and government agencies;
- develop a conceptual groundwater model and represent the Study Area with a numerical MODFLOW SURFACT groundwater model to assess potential underground mining impacts on the local and regional groundwater system;

- provide a qualitative and quantitative assessment of cumulative impacts from adjacent existing and approved mines;
- assess post mining groundwater impacts in regard to groundwater level recovery;
- develop measures to avoid, mitigate and/or remediate potential impacts on groundwater resources, and;
- indicate groundwater monitoring measures that will measure any impacts on the local and regional groundwater system.

The study provides a baseline, pre-mining assessment of the potentially affected groundwater systems within the proposed mining area and has been conducted to satisfy the requirements for an Environmental Assessment

2. RELEVANT LEGISLATION AND GUIDELINES

The report has been prepared with reference to the following documents;

- Barnett et al, 2012, Australian Groundwater Modelling Guidelines, Water lines Report, National Water Commission, Canberra
- National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC);
- NSW State Groundwater Policy Framework Document (NSW Department of Land and Water Conservation [DLWC]);
- NSW State Groundwater Quality Protection Policy (DLWC);
- NSW Draft State Groundwater Quantity Management Policy (DLWC);
- NSW Groundwater Dependent Ecosystem Policy (DLWC);
- Murray-Darling Basin Commission Groundwater Quality Sampling Guidelines Technical Report No 3 (MDBC);
- Murray-Darling Basin Commission. Groundwater Flow Modelling Guideline (MDBC);
- Water Management Act 2000;
- Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 (NSW Office of Water – NOW); and
- NSW Aquifer Interference Policy (NOW).

2.1 State Groundwater Policies and Management Plans

The aquifers are covered, as appropriate, by the generic State Groundwater Policy (DLWC, 1997), Groundwater Quality Protection Policy (DLWC, 1998).

The Study Area lies within Groundwater Flow System 5 (GFS5) Hawkesbury Sandstone - South-East (Grey and Ross, 2003) which includes the catchment of Cataract Dam. As the area is within the Sydney Catchment Authority controlled Metropolitan Special Area, no groundwater supply work development is permitted as it is a protected area. As such, there are no private bores. GFS5 has a sustainable yield estimate of 58,000 ML/year (Grey and Ross, 2003).

The *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011* encompasses the Study Area. The Study Area is within the Sydney Basin Nepean Groundwater Source Area.

The water sharing plan annual rainfall recharge in the Sydney Basin Nepean Groundwater Source Area is assessed at 224,483ML/year. This volume is subdivided into consumptive pool water and environmental water, with 124,915ML/year of the long term annual average recharge being reserved as environmental water. The remaining volume is classified as a sustainable yield or long term average extraction limit of 99,568ML/year.

The current extraction limits and groundwater entitlement volumes do not include all water taken through aquifer interference activities such as mine voids (remnant or otherwise).

Reservation of environmental water aims to support the long term viability of the aquifers and their dependent ecosystems.

While it does not extend into the Study Area, there is currently an embargo on further applications for sub-surface water licences in the Southern Coalfield (ordered under section 113A of the Water Act, 1912), for areas covering the:

- Nepean Sandstone Water Shortage Zone GWMA 607 (gazetted 8 June 2007); and
- NSW Southern Highlands (gazetted 21 May 2004 and 16 December 2005).

2.2 Water Management Act 2000

The *Water Management Act 2000* allows for the development fo water sharing plans (WSPs). The rules of WSPs determine how water is to be allocated between water users and the environment. WSPs include extraction limits to ensure that there is sufficient water in the water source to maintain environmental health.

In regard to swamps, the Water Management Act provides for protection of groundwater dependent ecosystems (GDEs) in Sections 3, 5 and 9. GDEs are also protected through clauses 8(1) and 9 as well as Schedule 4 of the WSP.

Upland Swamps within the Study Area are not representative of the Temperate Highland Peat Swamps on Sandstone (THPSS) EEC listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The listing advice for the THPSS EEC (TSSC 2005) contains a number of criteria not met by the upland swamps within the Study Area.

It is understood that the Department of Environment (DoE) are currently reviewing the listing of upland swamps, and that the new listing advice is likely to cover swamps on the Woronora plateau, as outlined in Biosis (2012).

Notwithstanding, the upland swamps within the Woronara Plateau were considered to be significant by the Office of Environment and Heritage (OEH)in the Bulli PAC report.

2.3 Water Sharing Plan for the Greater Metropolitan Region Groundwater Water Sources 2011

The water sharing plan also includes rules aimed at protecting Groundwater Dependent Ecosystems consistent with the Groundwater Dependent Ecosystem Policy (DLWC, 2002). The policy includes wetlands, terrestrial vegetation and caves or karst systems. In the proposed plan, terrestrial ecosystems are protected by a 200m stand off for new bores from any sandstone escarpment where hanging swamps or base flow to rivers is supported by groundwater. It should be noted, however, that no extraction bores are proposed and there are no “hanging” swamps, as opposed to “Upland” swamps in the Study Area

The Project is located within the Sydney Basin Nepean Groundwater Source (Management Zone 2) under the WSP. The rules of the WSP that may be relevant to the proposed mining include:

- A commercial access licence under a controlled allocation order may be made in relation to any unassigned water in this water source

To minimise interference between neighbouring works

Clause 39 of the WSP states that no water supply works (bores) to be granted or amended within the following distances of existing bores:

- 400m from an aquifer access licence bore on another landholding, or
- 100m from a basic landholder rights bore on another landholding, or
- 50m from a property boundary (unless written consent from neighbour), or
- 1,000m from a local or major water utility bore, or
- 200m from a NSW Office of Water monitoring bore (unless written consent from NSW Office of Water).

To protect bores located near contamination

Clause 40 of the WSP states that no water supply works (bores) are to be granted or amended within:

- 250m of contamination as identified in the WSP, or
- 250m to 500m of contamination as identified within the plan unless no drawdown of water will occur within 250m of the contamination source,
- a distance greater than 500m of contamination as identified within the plan if necessary to protect the water source, the environment or public health and safety.

To protect water quality

Pursuant to clause 40 of the WSP, to minimise the impact on water quality from saline interception in the shale aquifers overlying Sydney basin sandstone, the bore being used to take groundwater must be constructed with pressure cement to seal off the shale aquifer as specified by the Minister.

To protect bores located near sensitive environmental areas

Clause 41 of the WSP provides that no water supply works (bores) to be granted or amended within the following distances of high priority Groundwater Dependent Ecosystems (GDEs) (non Karst) as identified within the plan:

- 100m for bores used solely for extracting water under basic landholder rights, or
- 200m for bores used for all other access licences.

The above distance restrictions for the location of works from high priority GDEs do not apply where the GDE is a high priority endangered ecological vegetation community and the work is constructed and maintained using an impermeable pressure cement plug from the surface of the land to a minimum depth of 30m.

The Project is not located near any high priority GDEs listed under the WSP.

No water supply works (bores) to be granted or amended within the following distances from these identified features:

- 500m of high priority karst environment GDEs, or
- a distance greater than 500m of a high priority karst environment GDE if the Minister is satisfied that the work is likely to cause drawdown at the perimeter of the high priority karst GDE, or
- 40m of a river or stream or lagoon (3rd order or above),
- 40m of a 1st or 2nd order stream, unless drilled into underlying parent material and slotted intervals commence deeper than 30m. (30m may be amended if demonstrate minimal impact on base flows in the stream.), or
- 100m from the top of an escarpment.

To protect groundwater dependent culturally significant sites

Clause 42 of the WSP states that no water supply works (bores) to be granted or amended within the following distances of groundwater dependent culturally significant sites as identified within the plan: ,

- 100m for bores used for extracting for Basic Landholder Rights, or
- 200m for bores used for all other aquifer access licences.

The Project is not located near any groundwater dependent culturally significant sites under the WSP.

Rules for replacement groundwater works

Clause 38 of the WSP states that a replacement groundwater work must be constructed to take water from the same water source as the existing bore and to a depth specified by the Minister.

A replacement work must be located within:

- 20 metres of the existing bore; or
- If the existing bore is located within 40 metres of the high bank of a river the replacement bore must be located within 20 metres of the existing bore but no closer to the high bank of the river or a distance greater if the Minister is satisfied that it will result in no greater impact

Replacement works may be at a greater distance than 20 metres if the Minister is satisfied that doing so will result in no greater impact on the groundwater source and its dependent ecosystem.

The replacement work must not have a greater internal diameter or excavation footprint than the existing work unless it is no longer manufactured. If no longer manufactured the internal diameter of the replacement work must be no greater than 110% of the existing work.

To manage bores located near contaminated sites

Under clause 44 of the WSP, the maximum amount of water that can be taken in any one year from an existing work within 500 metres of a contamination source is equal to the sum of the share components of the access licences nominating that work at commencement of the plan.

To manage the use of bores within restricted distances

Under clause 44 of the WSP, the maximum amount of water that can be taken in any one year from an existing work within the restricted distances to minimise interference between works, protect sensitive environmental areas and groundwater dependant culturally significant sites is equal to the sum of the share component of the access licence nominating that work at commencement of the plan.

To manage the impacts of extraction

The Minister may impose restrictions on the rate and timing of extraction of water from a water supply work to mitigate the impacts of extraction.

Available Water Determinations

The Available Water Determination (AWD) represents the volume of water that can be taken per unit share. The maximum allowable AWD is 1 ML per share. The AWD for aquifer access licences in the Sydney Basin Nepean Groundwater Source is currently 1 ML per share.

AWDs are prescribed by NOW and may change in response to climatic conditions or growth in use.

Trading Rules

Section 71Q of the WM Act allows the Minister to alter the assignment of shares between multiple water access licences. That is, part of the share component from one licence can be assigned to the other licence. Share components can only be re-assigned between water access licences in the same water source.

Clause 47 of the WSP states that assignment of shares between licences is prohibited under certain circumstances. Relevantly, within the Sydney Basin Nepean Groundwater Source, an assignment of share from Management Zone 2 to Management Zone 1 is prohibited if the trade will cause the total share component for Management Zone 1 to exceed the total share component at the commencement of the plan. Trading within management zones permitted subject to local impact assessment.

Conversion to another category of access licence

Clause 46 of the WSP prohibits the conversion of water access licences from one category to another within the water sources that are subject to the WSP.

2.4 NSW Aquifer Interference Policy

The NSW Aquifer Interference Policy was released in September 2012.

Under the policy, and the associated WM Act, an aquifer is a geological structure or formation that is permeated with water or is capable of being permeated with water. Groundwater is defined as all water that occurs beneath the ground surface in the saturated zone. For the purpose of the policy, the term “aquifer” has the same meaning as groundwater system.

The *Water Management Act 2000* defines an aquifer interference activity as the:

- penetration of an aquifer,
- interference with water in an aquifer,
- obstruction of the flow of water in an aquifer,
- taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations, and the;
- disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

A water licence is required under the *Water Management Act 2000,* unless an exemption applies or water is being taken under a basic landholder right, where any act by a person carrying out an aquifer interference activity causes the:

- removal of water from a water source;
- movement of water from one part of an aquifer to another part of an aquifer;
- movement of water from one water source to another water source, such as from an aquifer to an adjacent aquifer, an aquifer to a river/lake, or from a river/lake to an aquifer.

The AIP lists a number of activities that are deemed to be minimal impact aquifer interference activities. In terms of mining, activities considered as having a minimal impact include:

- sampling and coring using hand held equipment;
- trenching and costeaning;
- access tracks;
- leachate ponds and sumps if constructed, operated and abandoned in accordance with appropriate standards and guidelines as determined by the Minister;
- construction and ongoing use of tailings and ash dams if lined with an impervious layer providing these are carried out in accordance with their planning and other approvals;
- caverns, tunnels, cuttings, trenches and pipelines (intersecting the water table) if a water access license is not required;

The Aquifer Interference Policy also states that monitoring bores are deemed to be minimal impact activities if the bores are:

- required by a development consent under Part 4 or an approval under Part 5.1, of the Environmental Planning and Assessment Act 1979,
- required or undertaken as a result of an environmental assessment under Part 5 of that Act,
- required by a condition of an environment protection license under the Protection of the Environment Operations Act 1997, or where;
- core holes, stratigraphic (chip) holes, geo-environmental and geotechnical bores, works or activities intersecting the water table if they are decommissioned in such a way as to restore aquifer isolation to that which existed prior to the construction of the bore, work or activity and that the decommissioning is conducted within a period of 28 days following completion of the bore, work or activity;

The *Water Management Act 2000* includes the concept of ensuring "no more than minimal harm" for both the granting of water access licenses and the granting of approvals. Water access licenses are not to be granted unless the Minister is satisfied that adequate arrangements are in force to ensure that no more than minimal harm will be done to any water source as a consequence of water being taken under the license.

Where a water access licence has been applied for by a method consistent with a controlled allocation process then adequate arrangements are in force to ensure that no more than minimal harm will occur. This is because the controlled allocation process allows for the allocation of a proportion of the unassigned water within the relevant water source using a conservative approach. Furthermore, unassigned water can only occur where total water requirements within a water source are less than the long-term average annual extraction limit specified in the relevant water sharing plan.

Where water is to be taken from a water source that has no unassigned water or insufficient unassigned water to account for any inflows to the activity, either surface or groundwater, then water entitlements will need to be purchased from an existing licensed user.

Any access licence dealing requiring the Minister's consent will need to consider the requirements of section 71Y of the *Water Management Act 2000,* including the water management principles that require water sources to be protected and social and economic benefits to be maximised.

Aquifer interference activities may induce flow from adjacent groundwater sources or flow from connected surface water sources to compensate for the water taken from the aquifer in which the activity is occurring or to fill the void created in the aquifer.

Where an aquifer interference activity is taking water from a groundwater source, and this causes movement from an adjacent, overlying or underlying groundwater source, separate aquifer access licenses are required for the groundwater source and for any adjacent, overlying or underlying groundwater sources.

Where an aquifer interference activity causes movement of water from a connected regulated or unregulated river water source into the groundwater source, then an access license in the regulated or unregulated river water source is required to account for the take of water from that water source and another access license in the groundwater source is required for the remainder of the take.

Where an aquifer interference activity is incidentally taking water from a river it must be returned to that river when river flows are at levels below which water users are not permitted to pump.

It is the proponent's responsibility to ensure that the necessary licenses are held with sufficient share component and water allocation to account for all water take, both for the life of the activity and after the activity has ceased.

In determining what licenses are required and which water source(s) the activity will take water from, the following need to be considered;

- prediction of the total amount of water that will be taken from each connected groundwater or surface water source on an annual basis as a result of the activity and after closure of the activity. Where required, predictions should be based on modeling conducted in accordance with the Australian Groundwater Modeling Guidelines;
- how and in what proportions this take will be assigned to the affected aquifers and connected surface water sources;
- how any relevant license exemptions might relate to the water to be taken by the

activity;
- whether the water is taken at a fixed or varying rate;
- whether sufficient entitlements and allocations are able to be obtained;
- consideration of water sharing plan rules;
- by what mechanism and license category the water will be obtained, consistent with any trading rules specified in either the Minister's access license dealing principles and/or relevant water sharing plans;
- the effect that activation of existing entitlement may have on future available water determinations for the proposed license category and entitlement volume;
- actions required both during operation and post-closure to minimise the risk of inflows to a mine void as a result of flooding. Set-back distances from rivers should be no less than that required to ensure structural integrity of the river bank during flooding events. Levee banks or landforms should also be constructed at the appropriate time to prevent at least a 1 in 100 year flood from entering the site either during or after operation, and;
- a strategy for accounting for any water taken beyond the life of the operation of the project, such as holding the appropriate entitlement or surrendering a component of the entitlement at the end of the project. Where a license or part of a license has been surrendered to the Minister, a security deposit or condition of consent under the EP&A Act may account for or require the upfront payment of fees and subsequently the license may be retained for the period of ongoing take of water or cancelled.

Where uncertainty in the predicted inflows may have a significant impact on the environment or other authorised water users, the applicant will need to report on:

- potential for causing or enhancing hydraulic connection between aquifers or between groundwater and surface water sources, and quantification of this risk;
- quantification of any other uncertainties in the groundwater or surface water impact modeling conducted for the activity; and
- strategies for monitoring actual and reassessing any predicted take and how changes will be accounted for, including analysis of water market depth and/or in situ mitigation and remediation options

Where there is ongoing take of water, the holder must retain a license until the system returns to equilibrium or surrender it to the Minister. Surrendering entitlements that adequately cover any likely future low available water determination periods is preferable.

The NSW Office of Water will assess the potential impacts of the aquifer interference activity against the minimal impact considerations, as well as any specific rules in a relevant water sharing plan

There are two levels of minimal impact considerations specified in **Table 1**.

Groundwater sources have been divided into "highly productive" and "less productive". Highly productive groundwater is defined as a source that is declared in the Regulations and:

- has total dissolved solids less than 1,500 mg/L, and
- contains water supply works that can yield water at a rate greater than 5 L/sec.

Highly productive groundwater sources are grouped into:

- Alluvial;
- Coastal sands;
- Porous rock;
    - o Great Artesian Basin - Eastern Recharge and Southern Recharge;
    - o Great Artesian Basin - Surat, Warrego and Central;
- other porous rock, and
- fractured rock

Less productive groundwater sources are grouped as:

- Alluvial;
- Porous rock, and;
- Fractured rock.

Table 1 Minimal Impact Considerations for Aquifer Interference Activities – Less Productive Porous Rock Groundwater Sources

Water Table	Water Pressure	Water Quality
LEVEL 1		
Less than or equal to 10% cumulative variation in the water table, allowing for typical post water sharing plan (WSP) variations, 40m from any: High priority groundwater dependent ecosystems, or High priority culturally significant site; listed in the schedule of the relevant WSP. A maximum of 2m decline cumulatively at any water supply work.	A cumulative pressure head decline of not more than 2m decline at any water supply work.	Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.
LEVEL 2		
If there is more than 10% cumulative variation in the water table, then appropriate studies will need demonstrate to the ministers satisfaction that the variation will not prevent the long term viability of the dependent ecosystem or significant site If more than 2m decline cumulatively at any water supply work then make good provisions should apply.	If there is more than a 2m pressure head decline, then appropriate studies will need to demonstrate to the ministers satisfaction that the decline will not prevent the long term viability of the water supply works unless make good provisions apply	If the above condition is not met, then appropriate studies will need to demonstrate to the minister's satisfaction that the change in groundwater quality will not prevent the long term viability of the dependent ecosystem, significant site or affected water supply works.

If the predicted impacts are less than the Level 1 minimal impact considerations, then these impacts will be considered as acceptable.

Where an activity's predicted impacts are greater than Level 1, but they exceed it by no more than the accuracy of a robust model, then the project will be considered as having acceptable impacts, with monitoring, as well as potential mitigation or remediation required during operation.

If the predicted impacts exceed Level 1 by more than the accuracy of a robust model, then the assessment will need to involve additional studies, and if the impacts will not prevent the long-term viability of the water dependent asset, then the impacts will be considered acceptable.

A risk management approach to assessing the potential impacts of aquifer interference activities will be adopted, where the level of detail required is proportional to the likelihood of impacts occurring on water sources, users and dependent ecosystems and the potential consequences.

In addition to the volumetric water licensing considerations, a proponent will need to provide;

- baseline groundwater depth, quality and flow;
- a strategy for complying with any water access rules;
- potential water level, quality or pressure impacts on nearby water users, connected ground / surface water sources and groundwater dependent ecosystems;
- the potential for increased saline or contaminated water inflows to aquifers and highly connected river systems;
- the potential to cause or enhance hydraulic connection between aquifers;
- the potential for river bank instability, or high wall instability or failure to occur;
- the method for disposing of extracted water;
- contingency plans or remedial measures if impacts are outside of the licensing and approval requirements.

If a development consent under Part 4, Division 4.1 or Part 5.1 of the EP&A Act has been granted or for any approved mining or CSG production activity that was not subject to the Gateway process, the maximum predicted annual water quantities are to be licensed from the commencement of the activity.

Aquifer Interference Approval

Under the WM Act, an aquifer interference activity requires:

- The necessary volumetric WALs
- A separate aquifer interference approval.

An aquifer interference approval confers a right on its holder to carry out specified aquifer interference activities at a specified location or area.

Under section 91F of the WM Act, it is an offence to carry out an aquifer interference activity without an aquifer interference approval. An aquifer interference activity includes the penetration, interference or obstruction of flows within an aquifer or to take or dispose of waters from an aquifer.

However, section 91F of the WM Act does not currently apply. Section 88A provides that Part 3 of Chapter 3 (including section 91F) applies to each part of the State or each water source and each type or kind of approval that relates to that part of the State or that water source that is declared by proclamation. In essence, the AIP applies, however the approvals framework has not been finalised.

A framework for the implementation of the AIP was produced by NoW (October 2013) and this report addresses the key issues in this document.

Licences for Impacts on Stream Baseflow

Any reduction in baseflow as a result of depressurisation will also require a water access licence under the WSP for the unregulated rivers. The Project is located within the Upper Nepean and Upstream Warragamba water source under the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011*.

Any take of surface water / baseflow as a result of depressurisation of deeper aquifers will require a water access licence within this water source.

2.5 Environment Protection and Biodiversity Conservation Act 1999

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) is the main Commonwealth environmental legislation that provides legal framework to protect and manage matters of environmental significance including nationally and internationally important flora, fauna, ecological communities and heritage.

The EPBC Act was amended to introduce a new matter of national environmental significance named the *"Protection of Water Resources from Coal Seam Gas Development and Large Scale Coal Mining Development".*

Pursuant to the EPBC Act, an action that has, will have, or is likely to have a significant impact upon Matters of National Environmental Significance (MNES) is declared a "controlled action" and requires the approval of the Commonwealth Minister for Environment.

Approval under the Commonwealth EPBC Act is in addition to requirements under NSW State legislation.

The EPBC Act lists Matters of National Environmental Significance (MNES) that must be addressed when assessing the impacts of a proposal.

Water resources are also an MNES and the potential impact of the Project must be assessed in accordance with the Independent Expert Scientific Committee's Information Guidelines for *Proposals Relating to the Development of Coal Seam Gas and Large Coal Mines where there is a Significant Impact on Water Resources* (IESC, February 2013) and the *Significant Impact Guidelines 1.3: Coal Seam Gas and Large Coal Mining Developments – Impacts on Water Resources* (Department of Environment, December 2013). The criteria are presented below for;

Hydrological Characteristics, covering changes in the:

- water quantity, including the timing of variations in water quantity;
- integrity of hydrological or hydrogeological connections, including substantial structural damage (e.g. large scale subsidence), and;
- area or extent of a water resource.

Water Quality, in regard to, if;

- there is a risk that the ability to achieve relevant local or regional water quality objectives would be materially compromised;
- a project creates risks to human or animal health or to the condition of the natural environment as a result of the change in water quality;
- a project substantially reduces the amount of water available for human consumptive uses or for other uses, including environmental uses, which are dependent on water of the appropriate quality;
- a project could cause persistent organic chemicals, heavy metals, salt or other potentially harmful substances to accumulate in the environment;
- a project could seriously affect the habitat or lifecycle of a native species dependent on a water resource;
- there is a significant worsening of local water quality (where current local water quality is superior to local or regional water quality objectives), and if:
- high quality water is released into an ecosystem which is adapted to a lower quality of water

2.6 Southern Coalfields Inquiry, Metropolitan and Bulli Seam Operations Planning Assessment Commission

In addition to the policies and guidelines outlined in Section 2.0, the three following reports have also guided the current assessment:

- NSW Dept of Planning, 2008 Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield – Strategic Review;
- NSW Planning Assessment Commission, 2009 The Metropolitan Coal Project Review Report, and;
- NSW Planning Assessment Commission, 2010 Bulli Seam Operations PAC Report

The combined groundwater related issues highlighted in the above Planning Assessment Commission (PAC) reports that are addressed in this study are:

- the use of 3D groundwater numerical modelling that can adequately address high contrasts in hydraulic properties and steep hydraulic gradients in non-steady state flow domains
- aquifer numerical modelling used as a management tool for the ongoing prediction of impacts attributed to longwall extraction
- adequate density and duration of observations with respect to redirected surface flows and regional strata depressurisation, ideally with a minimum two years of baseline environmental data collected at appropriate frequency and scale
- the possibility of a fault or dyke, or other linear features providing a potential leakage conduit from surface to below the Bald Hill Claystone and development of a strategy to characterise the structure and determine the magnitude and extent of the leakage.

The reports indicate that groundwater monitoring regimes and impact assessments should be based on:

- shallow piezometers monitoring groundwater levels within significant upland swamps, drainages or connected alluvium with sufficient distribution to characterise the swamp with a high level of confidence in potentially affected areas. Water level measurements should be automated with daily or more frequent recording;
- sufficient piezometers in swamps and associated regional groundwater systems to verify perching and to monitor the underlying hardrock water table
- groundwater quality classification through regular sampling and analyses that can discriminate mining related impacts and ionic species attributable to new water/rock interactions;
- deep piezometer installations to monitor pore pressures in the natural rock strata with sufficient distribution to describe the distribution of deep aquifer pressures with a high level of confidence using automated daily or more frequent recording;
- strata porosity and permeability measurements used to calculate subsurface flows and presentation of a database to facilitate impact assessment using packer testing, variable head testing, test pumping, core analyses (matrix properties and defects inspections) and geophysical logging where appropriate; and
- a mine water balance (Beca, 2010) to confirm groundwater transmission characteristics of the coal seam, overburden and drainage characteristics of goaves and the overlying failure regimes. Use of a mine water balance can also indicate potentially anomalous mine water seepages that may be initiated by increased connectivity to surface drainage systems or in association with igneous intrusions. The water balance should account for water pumped into and out of the mine, coal moisture, ventilation moisture and any other exports. The capacity of the mine water management system to manage increased contributions from underground operations should also be addressed.
- use of airborne laser survey for detailed topographic mapping, GIS of groundwater systems assessment and management and consideration of data generated by other mine sites
- wireline geophysical logging (natural gamma; density (neutron), resistivity, sonic, acoustic scanner) to improve interpolation of measured permeability and porosity.

3. PREVIOUS GROUNDWATER RELATED STUDIES

Within the Wollongong Coal lease area, groundwater level and / or hydrostatic water pressure monitoring has been conducted for the Hawkesbury Sandstone and underlying lithologies over the 500 series Longwalls adjacent to the western side of Cataract reservoir (Singh, R.N. Jakeman, M. 2001).

Vibrating wire piezometers in open standpipe bores P501 and P502 were used to monitor groundwater levels since December 1992 and August 1993 over Longwalls 501 and 502 respectively and since November 1998 in an open standpipe piezometer P514 over Longwall 514.

Geoterra (2012) conducted a detailed groundwater model and impact assessment for both the Wonga East and Wonga West proposed mining domains as part of the original Underground Expansion Project Part 3A (Pt3A) application.

The extent of historic fracturing and depressurisation due to subsidence over previous Wollongong Coal workings was assessed in SCT Operations (2014) and the findings are discussed in subsequent sections of this report.

In addition, stream water quality, groundwater seepage and stream flow studies have been conducted since 2001, as outlined in Geoterra (2014A).

4. PREVIOUS AND PROPOSED MINING

4.1 Previous Mining

Three coal seams have been mined at Russell Vale Colliery.

The uppermost is the 2 - 2.5m thick Bulli Seam where most of the previous mining activity has occurred. The 1.3m thick Balgownie Seam is located 5 - 10m below the Bulli Seam, whilst the 7 - 9m thick Wongawilli Seam is located 18 - 26m below the Balgownie Seam. However, only the bottom 3 - 3.5m of the Wongawilli Seam has been mined.

4.1.1 Bulli Seam

The Bulli Seam was mined between the late 19th Century and about 1950, initially as a hand worked bord and pillar operation and then with some mechanized pillar extraction. Bulli Seam mining continued under and to the west of Cataract reservoir, initially as a continuation of Continuous Miner pillar extraction operations and then as a longwall mining operation until 2002.

4.1.2 Balgownie Seam

The Balgownie Seam was started in the late 19th Century in the Wonga East area using hand worked methods for a brief period. Mining restarted in the late 1960’s with continuous miners, then from 1970 to 1982 as one of the first longwall operations in Australia. To the north, some additional mining in the Balgownie Seam included a first workings continuous miner bord and pillar thin seam mining operation between 2001 and 2003 in Gibson's Colliery (S Wilson, pers comm.).

4.1.3 Wongawilli Seam

Mining of the Wongawilli Seam mining access started in 2008 at Wonga East. This seam has been mined by Longwall 4 from 22/4/2012 to 23/09/2012 and by Longwall 5 between 15/01/2013 and 12/01/2014.

4.2 Proposed Mining

Wollongong Coal is proposing to mine additional longwall panels in an area referred to as the Wonga East mining area at Russell Vale Colliery.

After consideration of submissions from the community and government agencies to its earlier Underground Expansion Project Part 3A (Pt3A) application, Wollongong Coal (then Gujarat NRE Coking Coal) significantly modified the application through a Preferred Project Report (PPR). The Preferred Project does not include any mining in the Wonga West area.

The current proposal includes the extraction of Longwalls 6 and 7 in the Wongawilli Seam to the south of Cataract Creek, as well as Longwalls 9 to 11 to the north of Cataract Creek, between Mt Ousley Road and Cataract Reservoir, within the SCA managed land. Longwall 8 has been excluded from the Underground Expansion Project by the PPR.

To the east of Mt Ousley Road, on private land, Wollongong Coal proposes to extract Longwalls 1 to 3 in the Wongawilli Seam as shown in **Figure 1**.

4.3 Observed and Predicted Subsidence

The following section is a compilation of relevant findings from SCT Operations (2013) and SCT Operations (2014).

Previous mining in the Bulli and Balgownie Seams is estimated to have caused up to 1.9m of subsidence.

Maximum subsidence due to mining in the Wongawilli Seam is predicted to range from 1.5m over the slightly narrower LW7 to 2.6m over LW3 where the overburden depth is shallowest with overlying goaf in both seams.

Maximum tilts are anticipated to range from 24mm/m over LW10 through to 51 mm/m above LW3. The peak values are anticipated to occur at the goaf edges and with areas of higher change in topographic gradient. Across a panel, systematic tilts are likely to range from 50 - 90% of peak values.

Maximum strains are anticipated to range from peaks of 14mm/m over LW10 to 31mm/m over LW3. Tensile peaks are most likely to occur at topographic high points and compression peaks are most likely at topographic lows. More generally across the panel, systematic strains are likely to be 20 - 30% of the peak values.

The predicted closure across Cataract Creek ranges from 10 – 50mm adjacent to Longwalls 9 to 11, 400mm adjacent to Longwalls 6 and 7, with up to 650mm adjacent to Longwalls 6 and 7.

These estimates are provided as upper limit values as they are based on experience in deep gorges at high stress levels.

Monitoring to date has recorded closures that are much less than predicted maxima consistent with the local site conditions.

Table 2 summarises subsidence that has occurred in the area of extraction during mining in the Bulli Seam (estimated) and the Balgownie Seam (measured) as well as observed and predicted subsidence due to the proposed mining in the Wongawilli Seam.

Movements outside the goaf edge are expected to be essentially similar to the movements observed during mining of Longwalls 4 and 5. Vertical movements (of greater than 20mm) are expected to be substantially limited to within a distance of 0.7 times the overburden depth from the nearest goaf edge (equivalent to an angle of draw of 35°).

In areas where there has been previous mining in both the overlying seams, vertical subsidence at the goaf edge is expected to be up to 300 - 500mm and the goaf edge subsidence profile over the panel is expected to be generally steeper than in areas where the overburden strata has not been disturbed by previous mining. In areas where there is either solid coal or substantial coal pillars directly above the goaf edge, goaf edge subsidence is expected to be of the order of 100 - 200mm.

Potential pillar instability in the Bulli Seam may cause additional surface subsidence when the proposed longwall panels are mined in the Wongawilli Seam, but the area likely to be affected at the northern end of LW1 is likely to require special consideration.

Table 2 Historic and Predicted Subsidence

	Previous Bulli and Balgownie Seam Subsidence (m)	Predicted and Measured Subsidence (m)	Predicted and Measured Tilt (mm/m)	Predicted and Measured Tensile Strain (mm/m)	Predicted and Measured Compressive Strain (mm/m)	Maximum Cataract Creek Closure (mm)
LW1	1.3	2.1	40	12	24	650
LW2	1.1	2.1	40	12	24	610
LW3	1.3	2.6	51	15	31	350
LW4	1.9	2.1 **(1.6)**	35 **(30)**	10.5 **(7.5)**	21 **(14)**	N/A
LW5	0.9	1.9 **(1.8)**	36 **(30)**	10.8 **(6)**	22 **(12)**	**(49)** at closure site CC4
LW6	1.5	2.1	38	11	23	400
LW7	1.2	1.5	28	8	17	400
LW9	0.5	2.1	32	10	19	50
LW10	0.6	1.6	24	7	14	30
LW11	0.6	2.1	30	9	18	10

NOTE: There is NO proposed Longwall 8 **(measured parameters are in brackets)**
Valley closure survey site CC4 in not the same as stream flow / pool / geochem site CC4

For further details and a location plan of the closure monitoring lines CC1 to CC4, refer to (SCT Operations, 2013).

5. STUDY AREA DESCRIPTION

5.1 Wonga East Catchments and Topography

Stream water level monitoring in pools and at selected flow constriction sites in Cataract Creek and Cataract River have been conducted since November 2010, with volumetric stream flow assessment conducted as outlined in WRM Water and Environment (2014).

The following sections describe the individual catchments in the Wonga East study area.

5.1.1 Cataract Creek

Cataract Creek is a 4th order stream for most of its length and is approximately 5.5km long from its headwaters to the upstream reaches of the Lake Cataract storage.

Channel invert elevations fall from approximately 340m AHD to 285m AHD, with the channel being relatively gently sloping at a gradient of 0.9% for most of its length, except for a 0.5km reach in its headwaters, which slope at 2.5%.

Approximately 2.5km of the stream reach is located upstream, 2km within and 0.9km downstream of the predicted 20mm subsidence zone.

5.1.2 Cataract River

Cataract River is a 3rd order stream upstream of the Link Road crossing, and 4th order from the confluence near the crossing to the Lake Cataract backwater. It is approximately 6.7km long from its headwaters to the upstream reaches of the Lake Cataract storage.

Channel invert elevations fall from approximately 430m AHD to 285m AHD and the channel is relatively gently sloping at a gradient of 0.5%, for much of its length, except for a steep upstream 0.5km reach, which slopes at around 17%.

The proposed Wonga East workings do not underlie the Cataract River.

5.1.3 Bellambi Creek

Bellambi Creek is a 3rd order stream upstream for the first 5.5 km, then 4th order to the Lake Cataract backwater. It is approximately 6.4km long from its headwaters to the upstream reaches of the Lake Cataract storage.

Channel invert elevations fall from approximately 453m AHD to 286m AHD, with the channel being relatively gently sloping at a gradient of 0.6%, except for the first 1km upstream reach, which slopes at around 2.8%.

5.2 Climate

5.2.1 Rainfall

Daily rainfall has been recorded by the Bureau of Meteorology (BOM) and the SCA and its predecessors, and the nearest stations with the longest records are located at Cataract and Cataract Dam, with good quality records extending from 1883 to 1966 and 1904 to 2014 respectively.

The BOM's SILO data service has prepared Patched Point Datasets (PPDs) from the Cataract and Cataract Dam records. Gaps in the records are infilled with data interpolated from other nearby stations to provide continuous records between 1889 and the present day (WRM Water and Environment, 2014).

Annual rainfall at Cataract Dam between 1889 and 2013 varied from 480mm in 1944 to 2,293 mm in 1950, with a mean annual rainfall of 1,085 mm/a.

Cataract Dam rainfall is highest between January and June and lowest between July and December as shown in **Figure 2**.

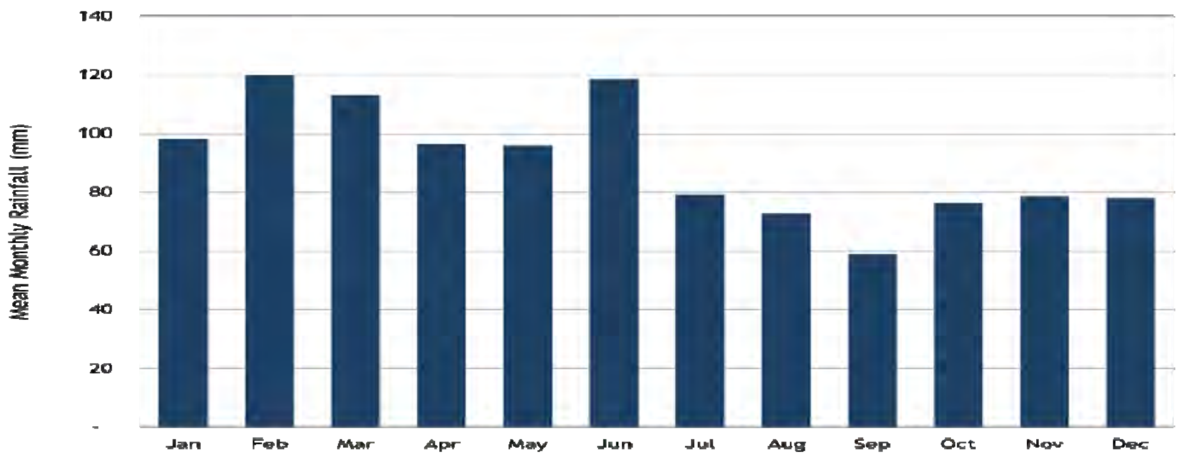


Figure 2 Variation in Mean Monthly Rainfall at Cataract Dam

Figure 3 shows a plot of cumulative rainfall residual at Cataract Dam for the period 1889 to 2013 that was prepared using the PPD. The raw data for the station is overlaid for comparison.

The cumulative rainfall residual shows departures from the long-term average (i.e. it has not been seasonally adjusted). Upward sloping lines indicate relatively wet periods, and downward sloping lines indicate relatively dry periods.

The figure shows that the period between 1905 and 1942, and the period since 1992 were relatively dry. The period from 1890 to 1900 and between 1950 and 1992 was generally relatively wet, with the exception of the late 1960s and the early 1980s. A plot of the SOI residual has been overlaid on the rainfall residual for comparison.

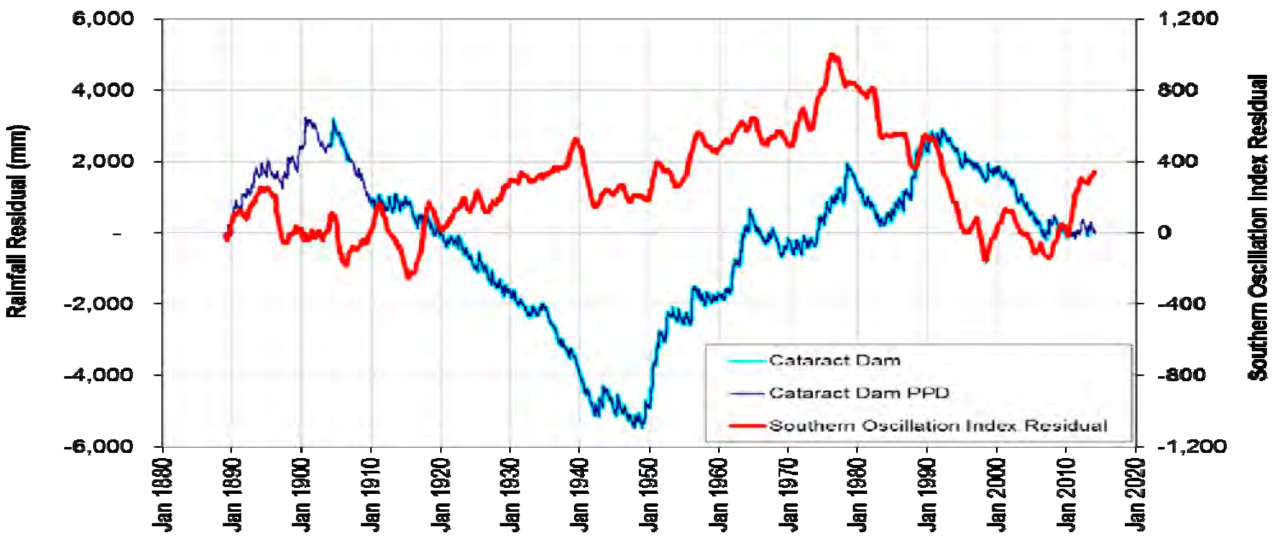


Figure 3 Rainfall Residual at Cataract Dam (1889 – 2013)

5.2.2 Evaporation

The mean annual pan evaporation at Cataract Dam is approximately 1420 mm/a as shown in **Figure 4**, and is highest in the summer months.

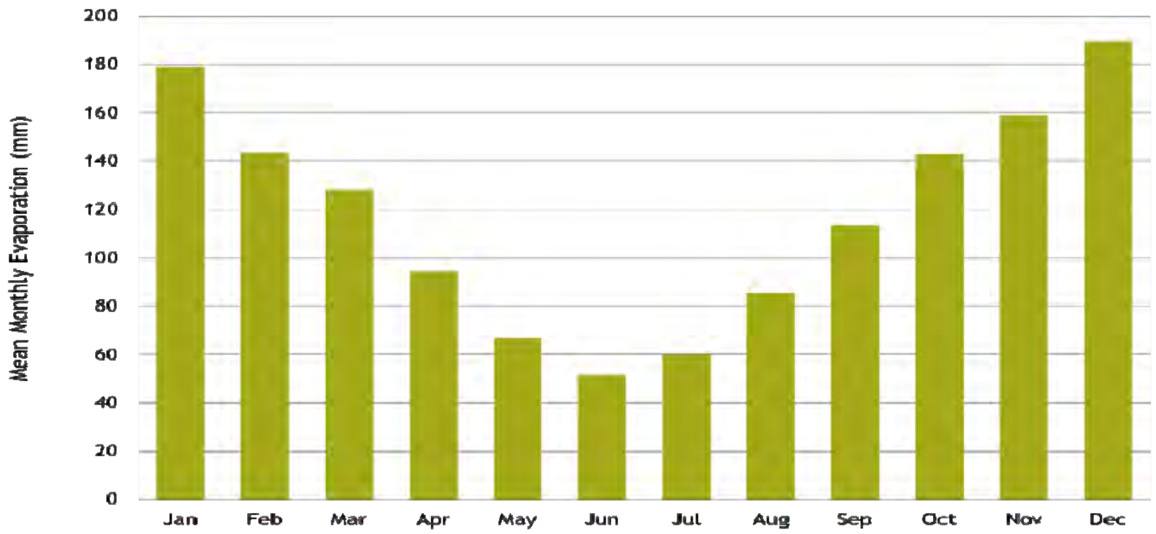


Figure 4 Monthly Pan Evaporation at Cataract Dam (PPD)

5.3 Geology

Russell Vale Colliery is situated at the southern end of the Permo-Triassic (225-270 million years) Sydney Basin within the Illawarra Coal Measures, which contains the Bulli, Balgownie and the Wongawilli seams.

The Study Area is predominantly covered by shallow hillslope-based colluvium, with very thin to no alluvial sedimentary deposits in the valley floors as shown in **Figure 5**.

Outside of the upland swamps, there are no alluvial deposits of any significance within the Wollongong Coal lease except for possibly within, or under, Cataract Reservoir.

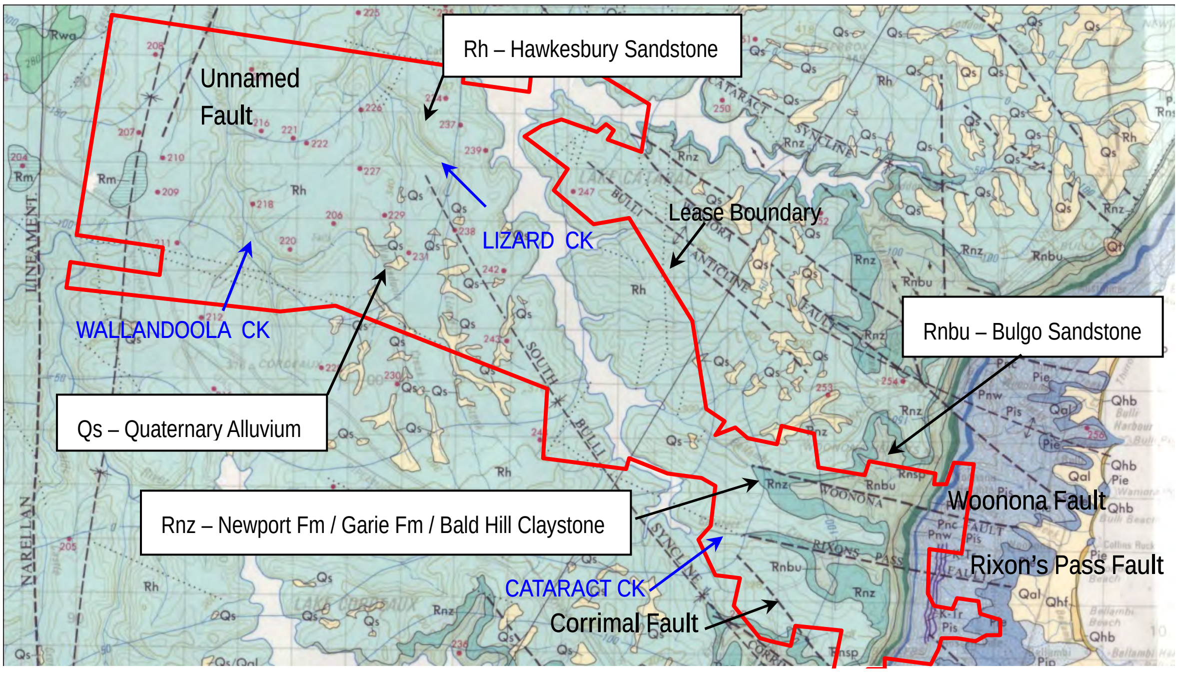


Figure 5 Published Regional Surface Geology

Quaternary unconsolidated alluvial and colluvial sediments are also present within both valley fill and headwater upland swamps, and are generally less than 2m thick, comprising humic sands and clayey sands overlying weathered Hawkesbury Sandstone.

The Quaternary sediments in the Wonga East area are, in turn, sequentially underlain by the:

Wianamatta Group (this formation is absent at Wonga East)

Hawkesbury Sandstone (absent to 181m thick) – the bedded to massive quartzose sandstone with grey shale lenses up to several metres thick is uppermost in the stratigraphic sequence in the majority of the Study Area except where it has been eroded in the headwater valleys of Cataract and Bellambi Creeks in the Wonga East area. Exposed Hawkesbury Sandstone is prevalent across the central and western areas of the lease. The Hawkesbury Sandstone also outcrops in the catchment headwaters of Wonga East, with the underlying Newport and Garie Formations, Bald Hill Claystone and Bulgo Sandstone being exposed in reaches of Cataract Creek.

It can contain up to 4% manganiferous siderite and up to 0.5% of iron sulfide (principally marcasite) with minor solid solution incorporation of nickel, zinc and manganese sulfides.

Narrabeen Group – the Narrabeen Group consists of the following units as described below.

- **Newport and Garie Formations** (4.6 - 36m thick) – The Newport Formation has interbedded grey shales and sandstones which has a variable thickness across the Study Area. The Garie Formation is generally around 3m thick and contains cream to brown, massive, characteristically oolitic claystone with a relatively constant thickness across the Study Area.

- **Bald Hill Claystone** (17 - 42m thick) – The unit is typically a chocolate brown to red brown kaolinitic marker bed claystone with silty and sandy grey and mottled grey - brown zones with a relatively constant thickness over the study Area. It predominantly consists of 50 - 75% kaolinite with hematite and siderite as accessories, which give it its distinctive colour.
- **Bulgo Sandstone** (113 - 154m thick) - thickly bedded, medium to coarse - grained lithic sandstone with occasional conglomerate and shale.
- **Stanwell Park Claystone** (15 - 26m thick) - greenish-grey mudstone and sandstone, with a general thickening of the claystone to the north west.
- **Scarborough Sandstone** (16 - 31m thick) - thickly bedded sandstone with shale and sandy shale lenses up to several metres thick.
- **Wombarra Claystone** (35 - 61m thick) – has a similar lithology to the Stanwell Park Claystone and generally thickens to the south east.
- **Coal Cliff Sandstone** (8 - 13m thick) - shales and mudstones contiguous with the underlying Bulli seam and varies from a quartzose sandstone in the east to a more shale/mudstone dominated unit in the west.

Illawarra Coal Measures – The Illawarra Coal Measures consist of interbedded shales, mudstones, lithic sandstones and coal seams, including the Bulli Seam, Loddon Sandstone, Balgownie Seam, Lawrence Sandstone, Eckersley Formation, Wongawilli Seam and Kembla Sandstone. The major coal seams in sequentially lower order are described below.

- **Bulli Seam** (2.0 - 4.7m thick) – Coal from the Bulli Seam has been worked extensively by both longwall as well as bord and pillar methods within and surrounding the Wollongong Coal lease area. The depth of cover to the Bulli Seam varies from 205 - 290m at Wonga East, with a seam dip to the north-west of approximately 1 in 30 with modification in the vicinity of the north west / south east trending South Bulli Syncline to the west of Cataract Reservoir, and a north south trending unnamed syncline to the west of Wallandoola Creek. A small scale north south trending syncline is present in the Bulli Seam workings. The Bulli Seam overlies the Balgownie Seam by 5.5 - 13.6m with a median 9.9m separation in the lease area.
- **Loddon Sandstone** (5 - 8m thick) – shale, mudstone, siltstone, sandstone with a sharp conglomeratic base
- **Balgownie Seam** (0.8 - 1.5m thick) – The Balgownie Seam has not been worked extensively in the southern coalfield, although limited longwall extraction has been conducted in the Wonga east area. The Balgownie Seam overlies the Wongawilli Seam by 10.6 - 24.7m with a median 18.7m in the lease area.
- **Lawrence Sandstone** (16 - 17m thick) – mudstone, siltstone to sandstone at the base
- **Cape Horn Seam** (0.1 - 0.4m thick) - a thin seam that is not mined commercially

- **Eckersley Formation and Hargraves Coal Member** (6 - 8m thick) – mudstone, claystone, siltstone and shales with the intercalated very thin (0.1 - 0.3m), uncommercial Hargraves Coal Seam
- **Wongawilli Seam** (6.2 - 10.5m thick) – comprised of up to 11 sub seams. It has predominantly been mined in the southern area of the Southern Coalfields, although has also been mined by Longwalls 4 and 5 in the Wollongong Coal lease. The depth of cover for Wongawilli Seam varies from 237 - 321m at Wonga East. In the lease area the Wongawilli Seam underlies the Bulli Seam by 24.1 - 36.4m with a median of 30.4m.

Lithologies underlying the Wongawilli Seam – the following units underlie the Wongawilli Seam:

- **Kembla Sandstone** (5 - 9m thick) – shale, siltstone and finer to coarse grained sandstone
- **American Creek Coal Member** (0.3 - 3.5m thick) – this seam has not been mined in the Southern Coalfields
- **Allens Creek Formation** (14 - 15m thick) – shale, siltstone and finer to coarse grained sandstone
- **Darkes Forest Sandstone** (5 - 9m thick) – fine to medium grained sandstone
- **Bargo Claystone** (10 - 12m thick) – mudstone, siltstone, shale
- **Tongarra Seam** (1.5 - 2.0m thick) – this seam was mined to a limited extent in the southern part of the Southern Coalfields
- **Wilton Formation** (minimum 4m thick) – claystone, siltstone and shale

5.4 Wonga East Geological Mapping

5.4.1 Outcrop Mapping

Outcrop mapping of the surface geology, faults and dykes in the Wonga East area was completed by Wollongong Coal geologists in 2013 (Gujarat NRE Coking Coal, 2014) as shown in **Figure 6**.

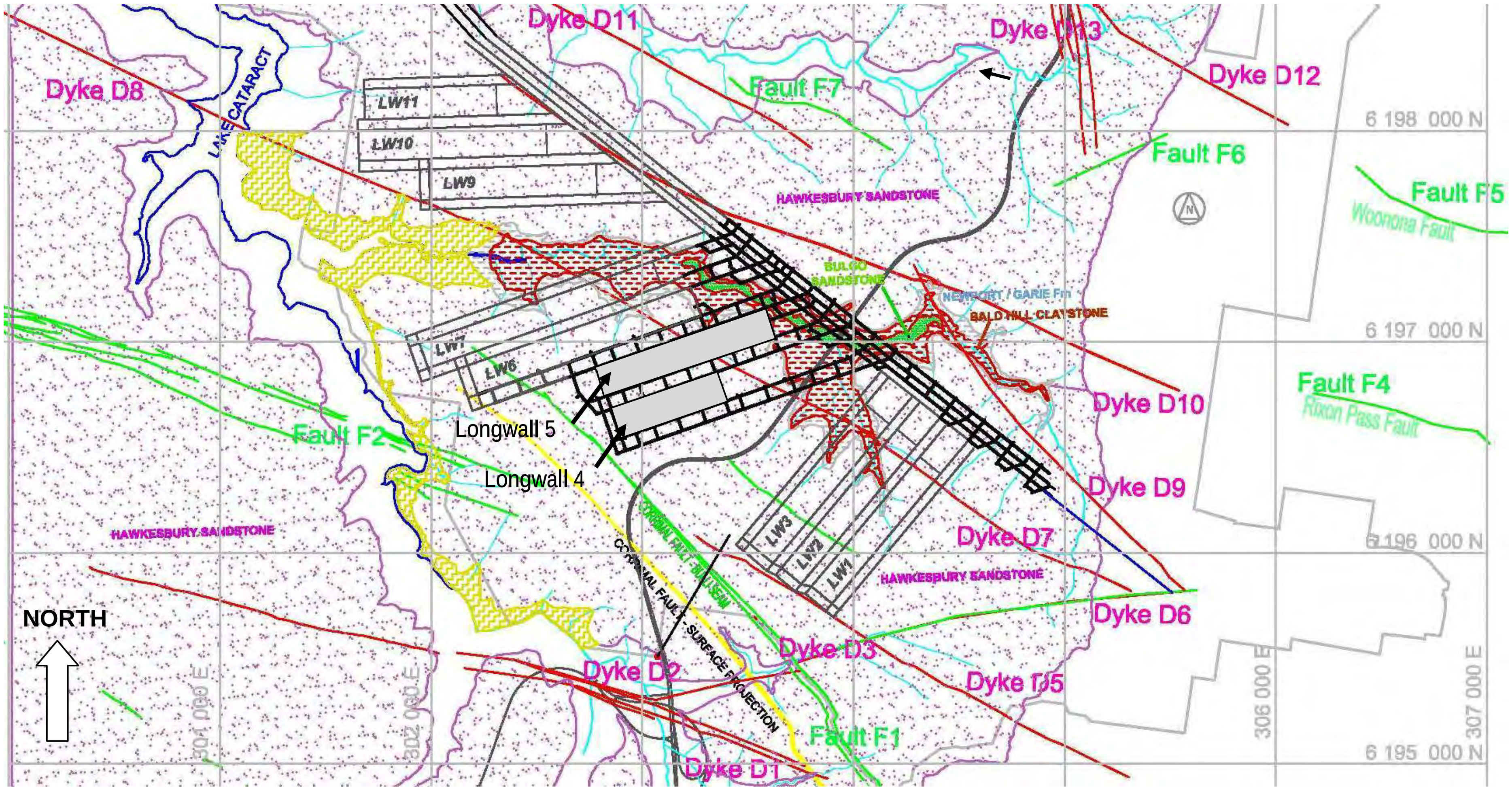


Figure 6 Wonga East Outcrop Geology and Structures

For a detailed discussion of the Wonga East outcrop geology, refer to Gujarat NRE Coking Coal (2013).

5.4.2 Underground Mapped Faults

There are no known major faults in the overburden above the proposed Wonga East workings, apart from the Corrimal Fault which has only been mapped in the Bulli workings in the western periphery of Wonga East as shown in **Figure 7**.

No known or observed groundwater inflows have been associated with any faults intersected by the workings at Wonga East in the Bulli, Balgownie or Wongawilli Seams.

At the Bulli Seam level, the Corrimal Fault has a 1.3 – 3.0m displacement in the vicinity of the proposed workings. The Corrimal Fault trends in a SE / NW direction, and is located to the west of Longwalls 1 to 3, as well as Longwalls 4 and 5. It then passes into the western ends of Longwalls 6 and 7, and phases out mid-way inside Longwall 7.

The maximum displacement of the Corrimal Fault within a 20m wide faulted zone is 28.7m, which reduces toward zero in the vicinity of the proposed LW7. It has not been mapped or interpreted to extend to the north of LW7, and is not interpreted to be present between LW7 and Cataract Reservoir.

A NW / SE trending splay off the Corrimal Fault (associated with Dyke D5) and a SW / NE fault (associated with Dyke D6) are located to the south of Longwalls 1 to 3, with the D6 fault crossing under Cataract River, to the west of the proposed Longwalls 1 to 3, outside of the 20mm subsidence zone.

The north-west south-east trending Rixon's Pass Fault is shown at surface on the 1:100,000 geological map to be sub-parallel to Cataract Creek, however, no trace of it has been identified in the Bulli or Balgownie workings.

Outside of the historic mine workings, the exact location, throw and inclination of the faulted zones are not known, and their potential position is extrapolated from drilling data and in-seam mapping.

5.4.3 Underground Mapped Intrusives

The proposed Wongawilli Seam workings are bound by:

- SE / NW trending dyke D5 (south of Longwalls 1 to 3)
- SE / NW trending dyke D9 (north of Longwalls 1 to 3)
- SE / NW trending dyke D10 (east of Longwalls 1 to 3, 5 to 7 and 9 to 11), and the
- E W trending dyke D6 (south of Longwalls 1 to 3)

The SE / NW trending Dyke D7 cuts through Longwalls 1 to 3, then phases into Dyke D8, which cuts through the eastern end of Longwall 5 and within Longwalls 6 and 7, before passing to the west of Longwalls 9 to 11. Limited in-seam silling has been mapped within the eastern end of Longwall 5, which significantly affected the extraction rate of LW5.

Dyke D8 underlies Cataract Creek between Longwall 7 and Longwall 9, but does not intersect Cataract reservoir until it is approximately 550m west of Longwall 10.

Dyke D8 has been mapped at surface as a highly weathered to illite / montmorillonite clay, or totally eroded feature of up to 0.5m wide and with up to 0.8m of displacement. It is associated with smaller first order SE / NW trending gullies over the Longwalls 1 to 3 as well as 4 to 7.

No diatremes have been identified within the proposed subsidence area, however a large sill is located to the east and north of Wonga East.

No groundwater inflows were observed when Dyke D8 (and its associated sill) was mined through by Longwall 5.

For further discussion of the Wonga East underground structures and intrusives, the reader is referred to Gujarat NRE Coking Coal (2014).

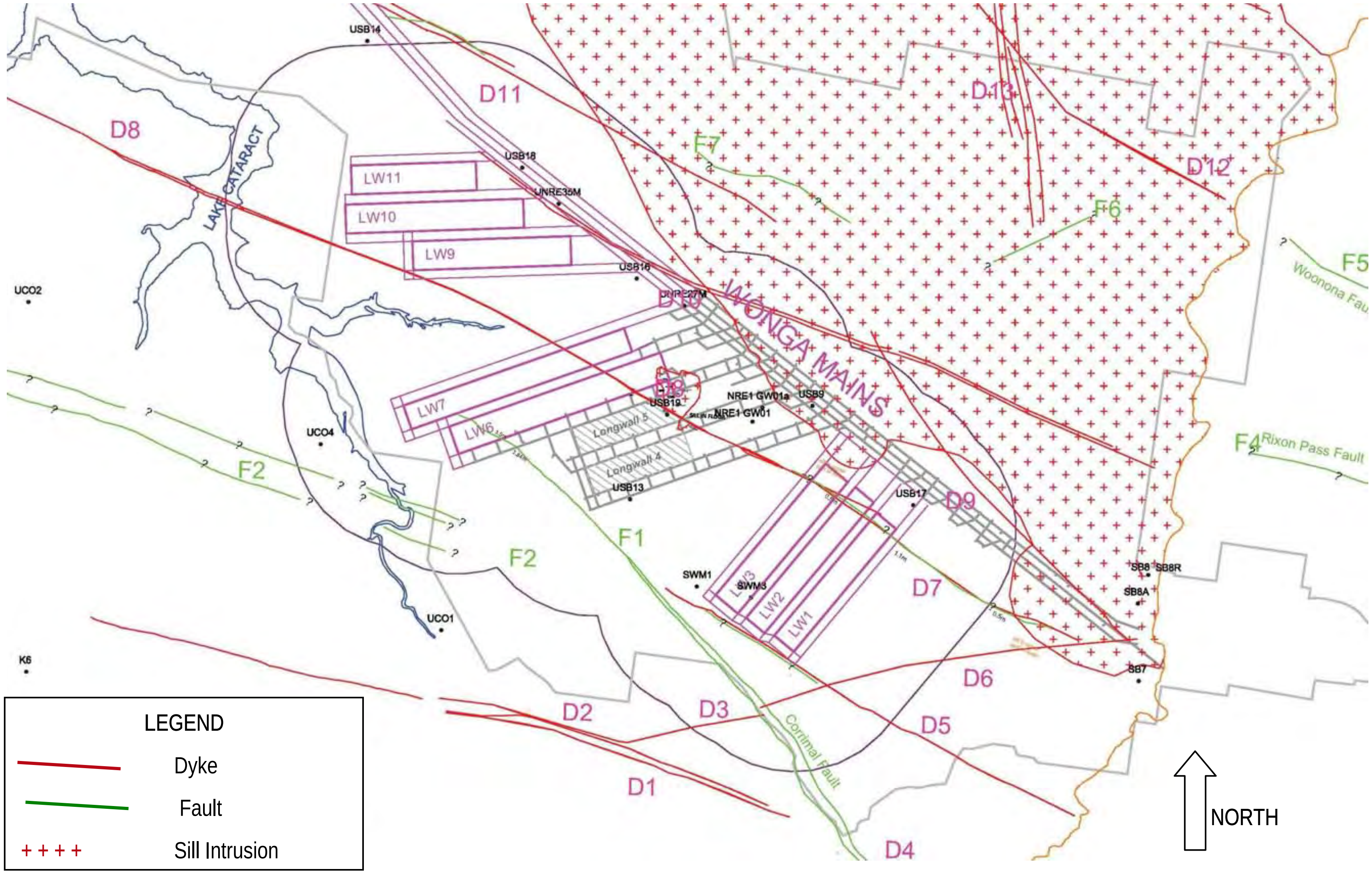


Figure 7 Wonga East (Wongawilli Seam) Structures and Intrusives

5.5 Basement Hydrogeology

Six general hydrogeological domains are present in the study area, including the:

- hydraulically disconnected (perched) upland swamps;
- hydraulically disconnected (perched), ephemeral weathered Hawkesbury Sandstone;
- deeper Hawkesbury Sandstone, which is hydraulically separated from the underlying Bulgo Sandstone and deeper lithologies by the Bald Hill Claystone, except where the claystone is fractured by subsidence or eroded away in the channel of Cataract Creek;
- Narrabeen Group sedimentary lithologies, the lower portions of which have already been locally fractured and depressurised above the existing workings and are interpreted to be fractured and/or depressurised over areas of triple seam mining, secondary extraction areas (including Longwalls 4 and 5 in the Wongawilli Seam) up to the shallow surficial strata, whilst areas only mined in the overlapping Bulli and Balgownie secondary extraction areas are interpreted to extend to the upper Bulgo Sandstone;
- Illawarra Coal Measures, which contains the Bulli, Balgownie and Wongawilli Seam aquifers that have also been fractured and depressurised to varying degrees by the existing workings and will be locally fractured and depressurised by the proposed workings, and the;
- sedimentary sequence underneath the Wongawilli Seam.

Due to the steep topography and limited alluvium within the Cataract Reservoir storage, there is no notable groundwater bearing stream based alluvium in the Study Area.

5.5.1 Hawkesbury Sandstone

Apart from aquifers in the coal seams, the main aquifer in the Study Area is the dual porosity (i.e interstitial pore space along with fractures and joint porosity) Hawkesbury Sandstone which, although having generally low permeability, can provide relatively higher groundwater yields compared to other lithologies in the area.

The Hawkesbury Sandstone outcrops over the majority of the lease area although it has been partially eroded in the central valley of Cataract Creek where the upper Bulgo Sandstone is exposed.

Regional water levels within the sandstone result from interaction between rainfall infiltration (recharge) through the shallow weathered zone into the underlying clastic rocks and with topography over geologic time. Rainfall infiltration elevates the water table whilst drainage channels incised through to the water table can provide seepage pathways that constrain groundwater levels to the elevation of stream beds through seepage into "gaining" streams.

Evapo-transpiration losses from deep and shallow rooted vegetation would also reduce the phreatic surface of the water table to varying degrees.

The low groundwater flow rates within the Hawkesbury Sandstone are primarily horizontal with minor vertical leakage due to the dominant horizontal bedding planes and bedding discontinuities interspersed with generally poorly connected vertical joints.

Ephemeral perched water tables within the upper 20m of the Hawkesbury Sandstone that are hydraulically disconnected from the underlying regional aquifer, can occur following extended rainfall recharge periods.

In rainfall recharge periods, water levels in shallow aquifers respond by rising, whilst in dry periods, levels are lowered through seepage to the local watercourses. During dry periods the salinity in surface drainages normally rises as the basement baseflow seepage proportionally increases.

Measured standing water levels in the Hawkesbury Sandstone range from to 12m to 39m below surface.

High yields of up to 30L/s have been identified outside of the local area by Sydney Catchment Authority in the Kangaloon and Leonay-Wallacia areas where the sandstone is distinctly affected by deep regional scale fracturing associated with igneous intrusions or a major regional lineament along the base of the Blue Mountains associated with the Lapstone Monocline (SCA, 2006).

These high yielding sandstones are not located in or near the Study Area.

Water quality in the Hawkesbury Sandstone generally has low salinity (81 - 420µS/cm) with relatively acidic pH (3.22-5.45) and can contain high iron levels up to 12.0mg/L in the Study Area.

5.5.2 Narrabeen Group

The Narrabeen Group lithologies have significantly lower yielding aquifers compared to the Hawkesbury Sandstone, with very minor productive supplies obtained in the Southern Coalfields due to its generally deeper elevation below surface and its very low permeability. The Bulgo Sandstone can contain salinities of up to 2300µS/cm (KBR, 2008) whilst the Scarborough Sandstone (Short et al. 2007) can average around 850µS/cm.

The Narrabeen Group is generally low yielding (<1.0L/sec), with its highest yields obtained from the coarser grained or fractured units.

The Narrabeen Group has generally low permeabilities, where the sandstones can provide porous storage with limited fracture flow and with low transmissivity, whilst mudstones, siltstones and shales effectively impede vertical flow. In some localities, groundwater flow may be enhanced by localised, secondary fracturing where faulting and/or jointing associated with bedding flexure or igneous intrusions can increase the hydraulic conductivity.

Hydraulic connection between the lithologies occurs through fractures and joints. Where vertical connectivity is present more laterally uniform pressure distributions are exhibited. Some local scale faults and dykes are present in the Study Area as shown in **Figure 7** although they are not anticipated to be large enough to enable loss of stream flow into the workings if dislocated by subsidence.

The Newport and Garie Formations, along with the underlying Bald Hill Claystone and the upper Bulgo Sandstone outcrop within the base of the headwater valleys within the Wonga East area would be directly recharged by stream flow leakage from Cataract Creek and Bellambi Creek.

The base of the Narrabeen Group is marked by the Wombarra Claystone which has very low permeability in its unsubsided state.

5.5.3 Illawarra Coal Measures

Water quality varies regionally both within and between coal seams and interburden in the Illawarra Coal Measures due to the complexity of groundwater flow, with the water being mostly brackish to saline.

The Balgownie, Bulli or Wongawilli Seams do not outcrop within the Study Area, although they outcrop along the lower section to the base of the Illawarra Escarpment. They would be recharged by vertical infiltration from overlying lithologies, and there is no direct connection between the seams and the surface creeks.

5.6 Registered Bores and Piezometers

There are no private bores or wells within the Study Area. The nearest private registered bore on the Woronora Plateau is a test bore at Appin Colliery, which is located approximately 4.9km to the north of the proposed workings.

At present, one monitoring piezometer P514 (GW102223) is recorded in the NSW Natural Resource Atlas database in the vicinity of the proposed workings.

No local data within the proposed extraction area is available on bore yields, as there are no production bores present there.

5.7 Geomorphology

The Study Area contains the regulated catchment of Cataract Creek, as well as portions of Cataract River and Bellambi Creek, upstream of Cataract Reservoir at Wonga East, which drain into Cataract Reservoir.

The catchments are described in detail in an associated report (WRM Water and Environment, 2014) to which the reader is referred for further discussion.

5.8 Stream Flow, Stream Water Quality, Rainfall and Land Use

The Study Area stream flow, stream water quality, rainfall and land use is described in detail in WRM Water and Environment (2014) and Geoterra (2014A) to which the reader is referred to for further discussion.

Based on drilling information and site observations, streams are interpreted to be "losing" in the Wonga East catchment headwaters and "gaining" near Cataract reservoir.

However, due to the lack of drill rig accessibility to install piezometers in the valley floors, there is insufficient data to map where the transition occurs on site.

Surface water drainage from the plateau to the local streams is through ephemeral first and second order gullies. The smaller gullies discharge into the major streams from elevated stream beds after sufficient rain, whilst the majority of rain would infiltrate into the plateau and swamp soils and weathered sandstone.

Recharge to the shallow, and subsequently the deeper regional groundwater system, would occur over an extended delay of months to years. It would occur after the meteoric water has soaked through the plateau's soil and bedrock, with the majority of water discharging from temporary seeps in the swamps and creek beds along the preferential horizontal flow regime in the Hawkesbury Sandstone.

The predominantly horizontal flow regime and restricted vertical recharge is essentially determined by the:

- horizontally bedded strata with preferential flow along bedded zones with coarser grain size,
- claystone/mudstone banding at the base and tops of sedimentary facies which restrict vertical migration and enhance horizontal flow at the base of the more porous unit,
- fracture zones enhancing horizontal flow through the strata, and;
- bedding planes or unconformities located immediately above finer grained sediments or iron rich zones.

Groundwater seepage to the local streams can occur at isolated iron stained seeps along the creek beds, where low volume and variable duration seeps discharge for a few days to weeks after significant rainfall. The seeps are generally located at the interface between coarser and underlying finer sandstone or shale/ sandstone interfaces which restrict vertical flow through the bedrock and enhance lateral flow. Most observed seeps in the local streams are anticipated to flow at less than 1L/sec.

The current interaction between surface water, perched and regional groundwater systems is postulated to be that pre-mining conditions prevail in that during wet periods there is a net contribution of groundwater to the surface system, while in dry conditions there is a net loss of surface water, with the resulting surface flow depending on the relative balance between seepage baseflow and stream outflow.

Mapping of the stream reach over the proposed workings indicates Cataract Creek is an ephemeral, "losing" stream in its first order headwater tributaries to approximately 25m downstream of the Longwall 1 tailgate edge, then becomes perennial downstream of that point where a seepage face is present in a 3m high sandstone rock face, down to its junction with Cataract Reservoir.

The surface water and shallow groundwater system is currently interpreted to be hydraulically isolated from the Bulli Seam workings in areas where only overlapping Bulli and Balgownie secondary extraction is present, although may not be separated where the overlapping workings of the Wongawilli Seam (Longwalls 4 and 5) have also been mined.

At present there are local scale aquifer systems at Wonga East over the subsided zone of the Bulli, Balgownie and Wongawilli Seam workings.

It is assessed an upper fractured unit is present from surface to approximately 20m below ground, which transitions into an elevated horizontal permeability zone caused by vertical bedding dilation, which does not necessarily contain a hydraulically connected, subsidence enhanced, vertical permeability component. This zone subsequently transitions into a sequentially higher permeability zone in the goafed and overlying deeper lithologies which can have a higher potential hydraulic connection to the Wongawilli Seam workings.

The Hawkesbury Sandstone and Bulgo Sandstone groundwater systems are not interpreted to be hydraulically separated in the valley of Cataract Creek where the Bald Hill Claystone is eroded through to the Bulgo Sandstone, downstream of the freeway. In addition, they may not be separated where the sandstone may have locally enhanced permeability due to its lack of lithostatic pressure where it has limited or no overburden, or where the Bald Hill Claystone has been fractured by subsidence.

The creeks and perched swamps are separated from the underlying regional groundwater system by a profile of unsaturated strata.

5.9 Groundwater Dependent Ecosystems and Upland Swamps

5.9.1 Groundwater Dependent Ecosystems

The proposed mining is located within the Sydney Basin Sedimentary Rock Groundwater System as described in the NSW State Groundwater Dependent Ecosystems Policy (SGDEP) (DLWC, 2002) which has its associated dependent ecosystems.

The SGDEP recognises four groundwater dependent ecosystems types in NSW, namely:

- Terrestrial vegetation;
- Base flows in streams;
- Aquifer and cave ecosystems; and
- Wetlands.

Groundwater dependent ecosystems present in the Study Area are:

- terrestrial vegetation, in terms of headwater upland swamps which are susceptible to changes in groundwater seepage inflow rates, the balance between rainfall and evaporation, the effect of bushfires and changes to the erosional regime; and
- baseflows in streams, which can be affected by changes in groundwater seepage inflow rates to a stream and the balance between rainfall and evaporation.

5.9.2 Upland Swamps

Biosis (2014) indicates that thirty-nine upland headwater swamps meet the definition of the Coastal Upland Swamp Endangered Ecological Community in the Wonga East Study Area.

No valley fill swamps are present at Wonga East.

The study highlighted the complexity and variability of the associated vegetation communities, with some swamps having a fully developed, saturated, humic sandy clay matrix up to 1.6m deep, through to essentially dry, shallow sandy clay locations with a high degree of shallow or subcropping sandstone and a thin weathered, colluvial, sandy clay soil profile.

Biosis (2014) identified that seven swamps in Wonga East are considered to be of 'special significance' using OEH criteria.

Field mapping, aerial photography and Lidar interpretation indicated that the Wonga East swamps are predominantly drier, shallower and less spatially continuous than a “typical” humic, saturated swamp (Biosis, 2014).

Upland headwater swamps in the Study Area have relatively small upstream catchments, with their saturation relying on rainfall recharge directly into the sandy sediments, seepage out of upslope Hawkesbury Sandstone and their organic (humic) content.

The storage and water transmission characteristics of the surrounding and underlying Hawkesbury Sandstone is critical in sustaining these environments.

The swamps occur in either headwater tributary valleys that are characteristically derived from colluvial sand erosion from Hawkesbury Sandstone dominated ridgelines or along the riparian zone of the major creeks. They are only located over Hawkesbury Sandstone which provides a low permeability base on which the swamp sediments and organic matter accumulate.

Regional groundwater flow within the Hawkesbury Sandstone is hydraulically beneath, and separated by approximately 15m from the surficial swamps.

Due to their gentle slope, only the larger swamps can contain small, shallow, poorly defined open channels, which are generally short and located at the downstream reaches, whilst ephemeral patches of saturated sediment can be present in the headwater sections.

The Wonga East swamps are not located near any cliff scarps, as is the case for “hanging” swamps in the Blue Mountains. As such there are no “hanging” swamps (by definition) in the Study Area, except possibly for swamp Ccus4 which is located upslope of a small, 3 - 4m high rock face.

The headwater swamps are predominantly located within gently sloping, shallow trough - shaped gullies, although they can partially extend onto steep slopes, benches or valley sides, where the plateau is not dissected by the Study Area creeks.

The central axes of the swamps are generally saturated after substantial recharge events, though the margins can comparatively dry out after extended dry periods.

The sand and humic material increases the swamp’s water holding capacity and subsequently discharges rainfall infiltration, groundwater seeps and low-flow runoff into the local streams. Rainfall saturates the swamp after storms and with a slow, delayed discharge due to the low slopes when the recharge exceeds evaporation.

Sediments below and laterally lensing into the humic material are variable in nature and can be composed of fine to medium grained sands that can contain clayey bands and comprise a grey to mottled red-orange colour due to insitu weathering.

Detailed impact assessment, including an initial risk assessment, comparative analysis, groundwater assessment, flow accumulation modelling and analysis of strains and potential for fracturing of bedrock, was undertaken on these 'special significance swamps (Biosis, 2014).

Further detailed information on the swamp structure, component lithologies, geomorphology, ecological diversity and terrestrial flora is provided in Biosis (2014).

6. PREVIOUS GROUNDWATER SYSTEM SUBSIDENCE EFFECTS

6.1 Adjacent Historical and Current Mines

6.1.1 Strata Depressurisation

Each of the existing or decommissioned adjacent underground mines have the potential to interact with the groundwater pressure regime within and adjacent to the proposed Russell Vale Colliery Wongawilli Seam workings.

Excavation of the adjacent underground mines has resulted in localised depressurisation of the Bulli Seam and overburden, which has altered regional groundwater flow toward each of the workings.

Combined pressure losses from the decommissioned, existing and proposed BHP Billiton (BHPB) operations (Appin, Westcliff and Northcliff) and Peabody's Metropolitan Colliery to the north of Cataract River were predicted in the revised groundwater model (Heritage Computing 2010A) to have the following potential drawdowns in the Wollongong Coal lease after 31 years of operation:

- negligible drawdown in the mid Hawkesbury Sandstone;
- 1 - 3m in the lower Hawkesbury Sandstone;
- 5 - 20m in the upper Bulgo; and
- 10m in the Bulli Seam.

The ultimate shape of the depressurised surface will be governed by the prevailing hydraulic properties of the coal measures, connectivity of strata through jointing and fracturing and the cumulative impacts of the regional mines.

The increased or decreased permeability changes along the fault trace that separates the BHP lease to the north and Wollongong Coal lease area to the south, together with the up to 90m lithological displacement may effectively compartmentalise the Wollongong Coal lease area from the BHPB workings, thereby reducing the cumulative depressurisation effect on the lease area.

After 31 years of mining, regional groundwater levels over the BHPB workings were modelled to recover at a rate depending on the remaining water held in storage in the coal measures, the hydraulic properties of subsided overburden, rainfall recharge and any seepage discharges to local streams (Heritage Computing, 2010).

6.1.2 Loss of Stream Flow

Due to the highly localised effects of subsidence on streams overlying subsided workings, there is anticipated to be no transmitted effects on streams within the Wollongong Coal lease from the adjacent BHPB workings as they are either down gradient of the lease, or are in a completely separate watershed on the northern side of the Cataract River.

6.1.3 Loss of Bore Yield

There are no private bores or wells registered with the NSW Office of Water (NOW) within the Study Area.

6.1.4 Changes in Groundwater Quality

No measureable change in groundwater quality has been reported, or is anticipated, within the Study Area as a result the existing, decommissioned or proposed underground workings adjacent to the Wollongong Coal lease.

The previous operators of Russell Vale Colliery, as well as the decommissioned BHPB Cordeaux and Corrimal Collieries to the south and the BHPB Bulli bord and pillar mine to the east have undermined the catchments of Lizard, Wallandoola, Cataract and Bellambi Creeks, as well as the Cataract River (upstream of Cataract reservoir).

Up to 1.3m of subsidence was generated by extraction of the Bulli Seam in the 200, 300, 500 series longwalls to the west of and beneath Cataract Reservoir (SCT Operations, 2014) in the Wonga West Area as shown in **Figure 8**.

Subsidence monitoring over the 200 series longwalls, which consisted of 190m wide panels and 35m wide chain pillars, was limited. However the same layout in the 300 series panels to the north resulted in 0.9m of subsidence. Longwall mining generated a maximum vertical subsidence of 1.1m for 155m wide longwalls with 30m wide pillars, whilst the up to 205m wide panels in Cordeaux Colliery with 30m wide chain pillars generated up to 1.3m of subsidence (SCT Operations, 2014).

No publicly available pre and post mining surveys of groundwater levels or groundwater quality are known to be available over the BHPBIC Cordeaux, Corrimal or Bulli mine workings.

6.2 BHP Bulli Colliery Short Walls

Three 80 - 86m wide short walls (1SW, 2SW, 3SW) with 67m wide pillars were mined in the Bulli Seam adjacent to and under Cataract Reservoir in the Bulli Colliery between 1983 and 1986 for a 230 - 340m depth of cover and 1.9 - 2.6m seam thickness.

A major NE-SW dyke zone with 2 x 5m wide doleritic dykes cutting across the workings corresponded to a pronounced surface lineament, however no evidence of the dyke was seen at surface. The dykes typically had minimal associated seepage into the workings.

During mining the workings were typically “dry” (Holla, L. Barclay, E. 2000).

Monitoring of two piezometer arrays installed to the base of the Bulgo Sandstone and the Bulli Seam near the workings indicated that the vertical permeabilities[a] were generally very low (Bulgo Sandstone horizontal hydraulic conductivity of 7.5×10^{-8} – 1.2×10^{-9}m/s) and that the extraction did not have a significant effect on the vertical permeability of the overburden with the maximum subsidence of 127mm and strains being less than 2.25mm/m.

An upper perched aquifer zone in the Hawkesbury Sandstone showed no response to subsidence, whilst the Bald Hill Claystone and upper Bulgo Sandstone showed a slow response to panel extraction, whilst the lower Bulgo Sandstone showed a pronounced response (Reid, P. 1991).

[a] Considered here to be synonymous with hydraulic conductivity

6.3 Russell Vale Colliery 500 Series Longwalls

The 500 Series Panels were part of the last area mined within the Bulli Seam in Wonga West. Three monitoring locations where installed over the 500 series panels as shown in **Figure 8**.

P501, which is a multi-level vibrating wire array that was installed using a single bore for each VWP intake, and P502, which was installed using nested VWP intakes in one borehole and grouted single vibrating wire piezometers were installed over Panel 502.

P501 and P502 are located over Panels 501 and 502 respectively, whilst P514 is located over Panel 514. All three piezometers are adjacent to Cataract Reservoir.

Regular monitoring of P501 and P502 began in December 1992 and August 1993 respectively, whilst P514 began in November 1998. The piezometer locations are shown in **Figure 8**.

Figure 8 Vibrating Wire Piezometer P501, P502 and P514 Locations

Studies over Longwall panels 501 and 502 by Singh R. N. and Jakeman, M. (2001) indicated that for the 115m wide longwalls with 65m wide pillars and 400 – 440m depth of cover, seepage from the walls or overlying goaf was too small to measure. It should also be noted that the eastern portion of the panels underlie Cataract Reservoir and that the Bellambi West Colliery at the time was referred to as a "dry" pit.

A combined study over Longwall 514 at Bellambi West in 1998 using micro seismic monitoring (CSIRO, 2000) and an open standpipe piezometer indicated that the majority of fracturing was concentrated in the Coalcliff and Scarborough Sandstones, to approximately 100m above the Bulli Seam. Vibrating wire piezometer monitoring between

Longwalls 501 and 502 indicates that the hydraulic integrity of the Bulli Seam and the Hawkesbury Sandstone was not adversely affected (Seedsman, R,W. & Kerr, G, 2001).

P501 is a 338m deep multi-level vibrating wire piezometer array that was installed with intakes in the:

- Hawkesbury Sandstone at 110mbgl;
- Bulgo Sandstone at 174mbgl, 228mbgl and 274mbgl; and
- Scarborough Sandstone at 328mbgl (0m AHD).

However, only data from a single Bulgo Sandstone at 228mbgl (100m AHD) and Scarborough Sandstone at 328mbgl (0m AHD) were available for this study.

This VWP array was installed using sand filters surrounding the transducer intakes with cement grout placed between intakes zones. Commentary from the time of installation (R Byrnes, pers comm.) suggests that bridging of the mid section sand intakes may have occurred during grouting and that the cables were placed under load and had dropped most likely as the sand and grout settled. It is suspected that this led to seals between Bulgo and Scarborough sandstones being compromised.

This is important to note as the VWP water levels within the Scarborough Sandstone overlying 501 Panel prior to extraction are equivalent to the overlying Bulgo Sandstone. This was noted when longwall extraction had occurred immediately to the west in the 200 and 300 series Longwall Panels (**Figure 8**) during the mid to late 1980's and immediately to the east in Longwall Panels 1 – 9 which were mined earlier effectively leaving the 500 series panels as an island surrounded by undermined areas..

The initial rise in pressure before each piezometer is undermined is due to overburden compression that occurs ahead of the retreating longwall. The overburden initially deforms in compression just before subsidence fracturing occurs, which then causes a sudden drop in groundwater pressure heads as the system re-equilibrates to the secondary porosity generated by the fracturing. The effect of rising pressure heads is generally more prevalent at the start of a longwall panel and reduces as the panel advances.

As shown in **Figure 9**, intake P5, which is installed at 226m below surface (100m AHD) in the Bulgo Sandstone, initially had its head pressure fall as the intake equalised with the hydrostatic and lithostatic pressures in the overburden to approximately 277m AHD following installation. As the panel approached the piezometer, the pressure gradually increased then fell sharply to around 263m AHD as the piezometer was undermined Pressures continued to fall slightly due to continued mining of the area to a low of 248 m AHD in September 1996. Since September 1996, pressures have recovered slightly and then have remained relatively static around 255 to 260m AHD.

As the panel approached P501, pressures within the vibrating wire transducer in the Scarborough Sandstone (P2) initially dropped in excess of 120m to 165m AHD. Just after undermining, the Scarborough Sandstone in P501 indicated a 20m rise in head which was attributed to compression of the strata ahead of the longwall face. Pressure heads then dropped to approximately 0m AHD within the Scarborough Sandstone which effectively became depressurised to at least the depth of the VWP instrument.

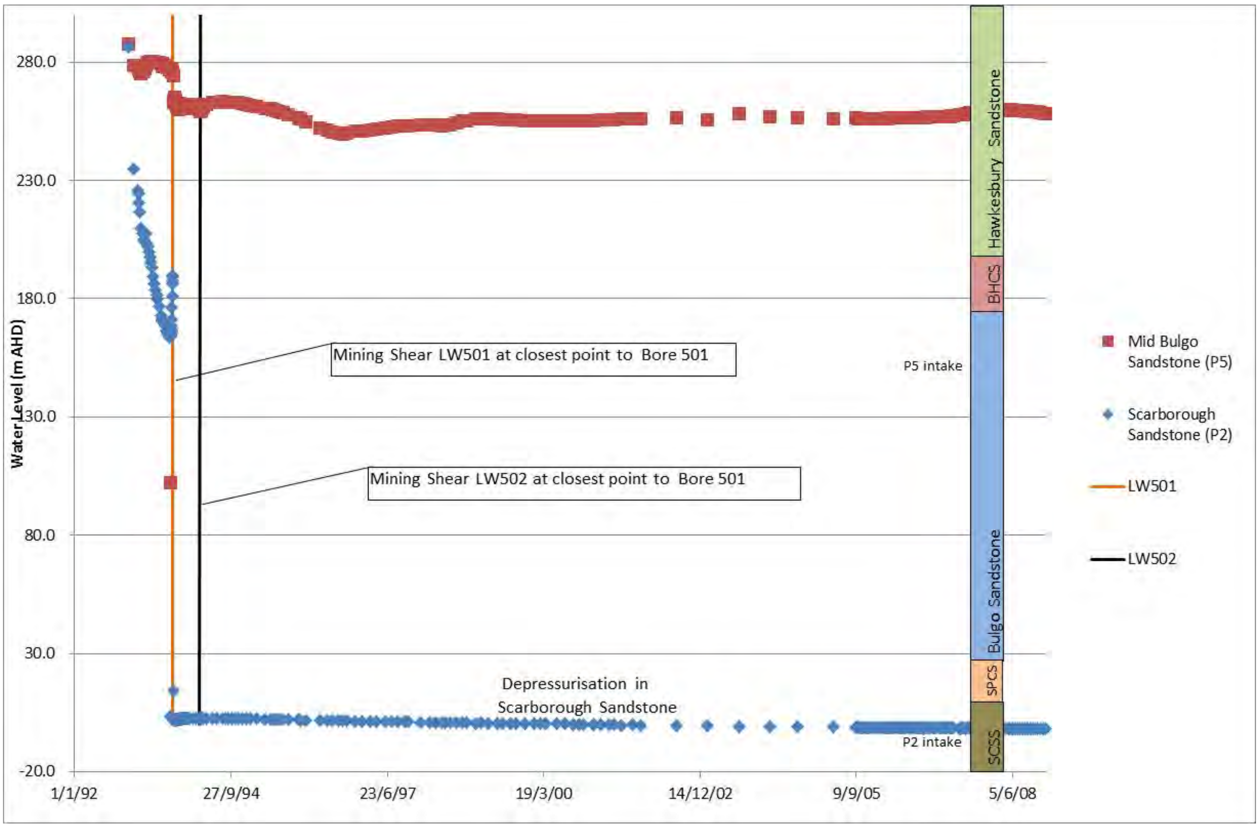


Figure 9 Longwall 501 Water Pressures

At P502, 5 piezometers (P11, P12, P13, P14 and P15) are installed in individual bores in a nested arrangement. The intakes for P12 and P13 were installed 240m above the base of the Bulli Seam in the Upper Bulgo Sandstone. When the piezometers were undermined, groundwater pressures in this piezometer fell by around 18m to 20m around March 1994, to approximately 258m AHD. P13 then recovered up to around October 1996 to approximately 280m AHD. Piezometer P12 stopped functioning after it was undermined.

Since October 1996, as shown in **Figure 10**, water pressures indicated by P13 in the Upper Bulgo Sandstone have varied between 280 and 290m AHD which is similar to the pressures in the overlying Hawkesbury Sandstone until they responded to the rainy period around April / May 2007.

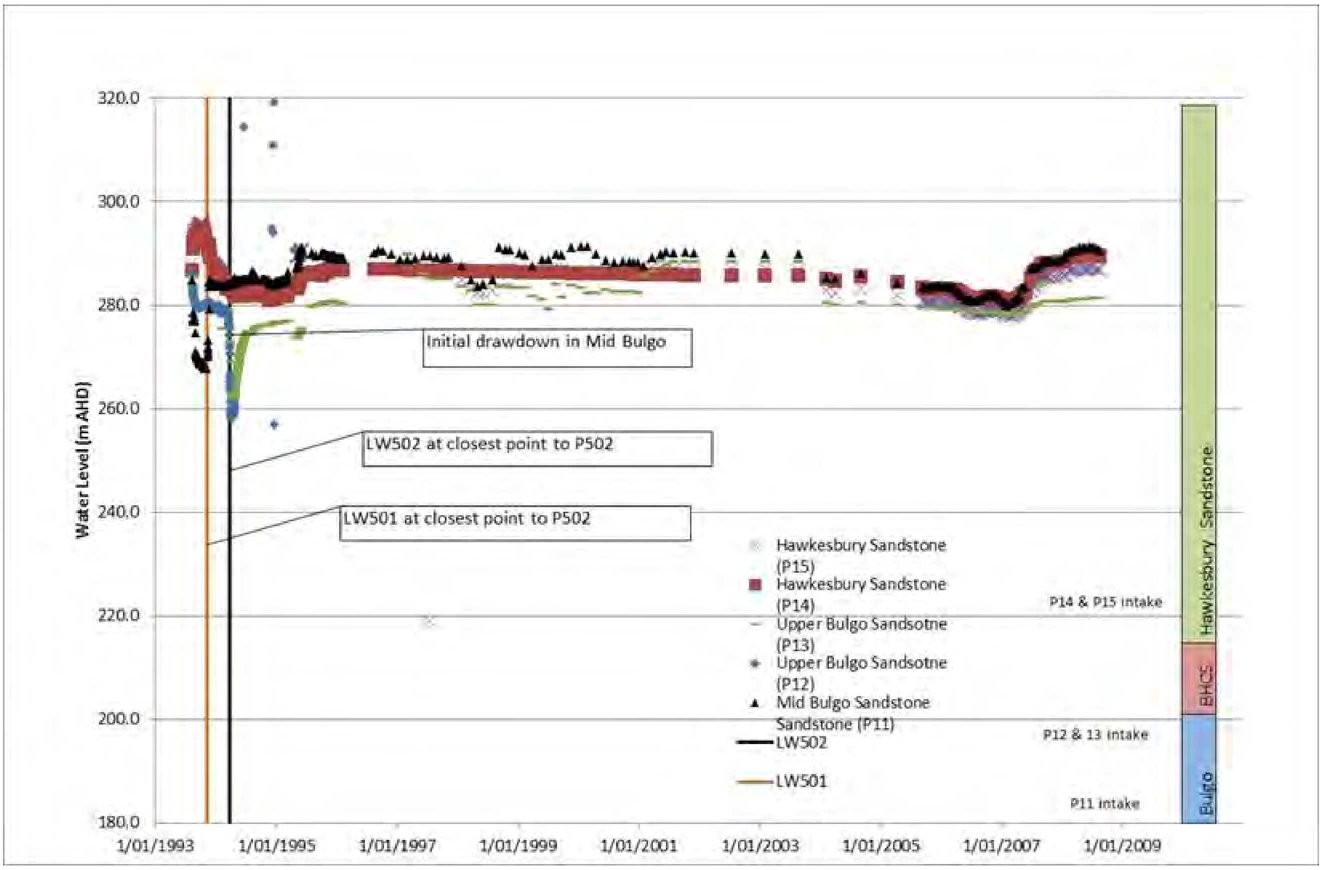


Figure 10 Longwall 502 Water Pressures

Intakes P14 and P15 were installed at 100m below surface in the Hawkesbury Sandstone. When the piezometers were undermined with the progression of LW501, both piezometers fell by around 10m between October 1993 and April 1994 to approximately 282m AHD, then P15 recovered up until around October 1996 to approximately 286m AHD.

Both P14 and P15 responded with falling pressures during the drought then rising pressures after the rainy period began in April 2007.

Piezometer P11 was installed within the Bulgo Sandstone and showed slightly different reactions to the longwall progression. P11 falls 18m to 268m AHD as LW501 passed its closest point and then the core casing appeared to fail. Water levels recovered to 284m AHD similar to P14 and P15. P13 survived the Panel 501 progression and water levels fell approximately 8m, tracking identically to that of the underlying Bulgo Sandstone (P12). P13 levels then drop by approximately 20m to 258m AHD prior to the bore casing appearing to fail. Water levels then recover to eventually mimic other Hawkesbury Sandstone piezometers. Water levels have remained essentially static, ranging between approximately 282m and 288m AHD, with a rise in pressures following the start of the rainy period around April 2007.

Monitoring over the 110m wide Panels 501 to 509, indicated a maximum subsidence of 202mm, with maximum tensile / compressive strain of 0.8mm/m and 0.4mm/m.

Groundwater pressure monitoring indicated that over Panels 501 and 502, vertical interconnected fracturing extended for less than 153m above the Bulli Seam, with a low permeability connection from the lower Bulgo Sandstone to the Bulli Seam goaf. It was interpreted that linked vertical fracturing was unlikely to have extended up into the mid Bulgo Sandstone, however it was potentially affected by horizontal bed separation (Seedsman Geotechnics, 1998).

The open standpipe piezometer P514 (GW102223) was installed to 191m below surface with an intake between 160-188mbgl in November 1998 within the lower Hawkesbury Sandstone and the Newport Formation over the 150m wide, 310-380m deep Panel 514.

As shown in **Figure 11**, since installation, P514 had a wavering water level between approximately 19m and 34m below surface, then essentially fell from 21 to 30m below surface between April 2001 and March 2007 due to the drought.

The standing water level then rose following the start of the rainy period around April 2007 by approximately 10m from 30m to 20m below surface.

The P514 piezometer became blocked between July and August 2009 and was no longer able to be used for equipment access to the water table.

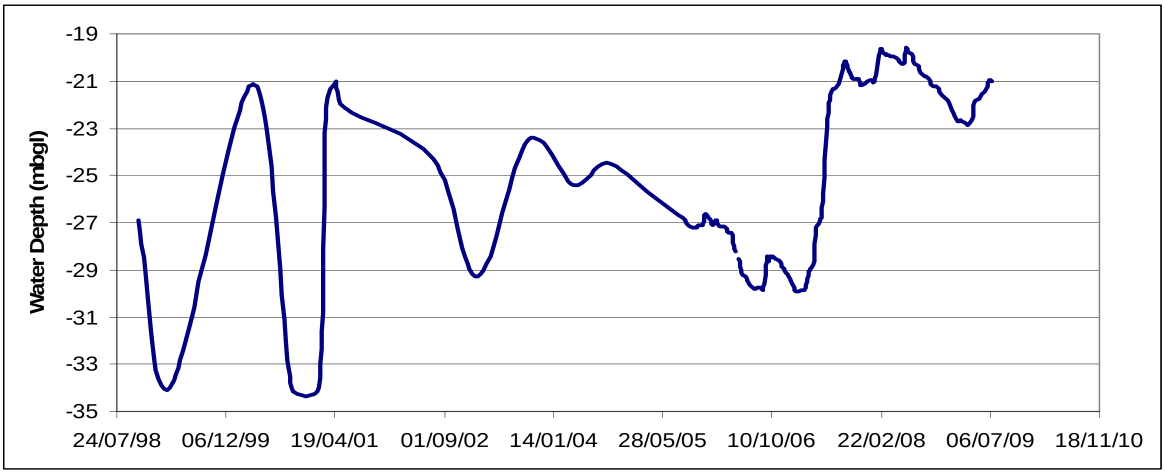


Figure 11 Piezometer 514 Groundwater Levels

6.4 Russell Vale Colliery Wongawilli Seam Longwalls 4 and 5

A vibrating wire piezometer array (GW1) and an open standpipe piezometer (GW1A) were installed adjacent to LW4 and LW5 in late September 2012. GW1 is located 190m east of LW4 and 175m south of LW5, whilst GW1A is located 280m east of LW4 and 125m south east of the LW5 secondary extraction area.

The piezometers are in an area where the Bulli seam has previously been mined by Bulli Seam bord and pillar, as well as pillar extraction, Balgownie Seam longwall extraction.

GW1 was drilled to 170.1mbgl into the Scarborough Sandstone, whist GW1A was drilled to 27m into the Bulgo Sandstone, with numerous fractures observed in GW1.

Neither bore intersected the Hawkesbury Sandstone or Bald Hill Claystone in their upper strata.

Eight vibrating wire piezometers were installed in GW1, with its location shown in **Figure 12.**

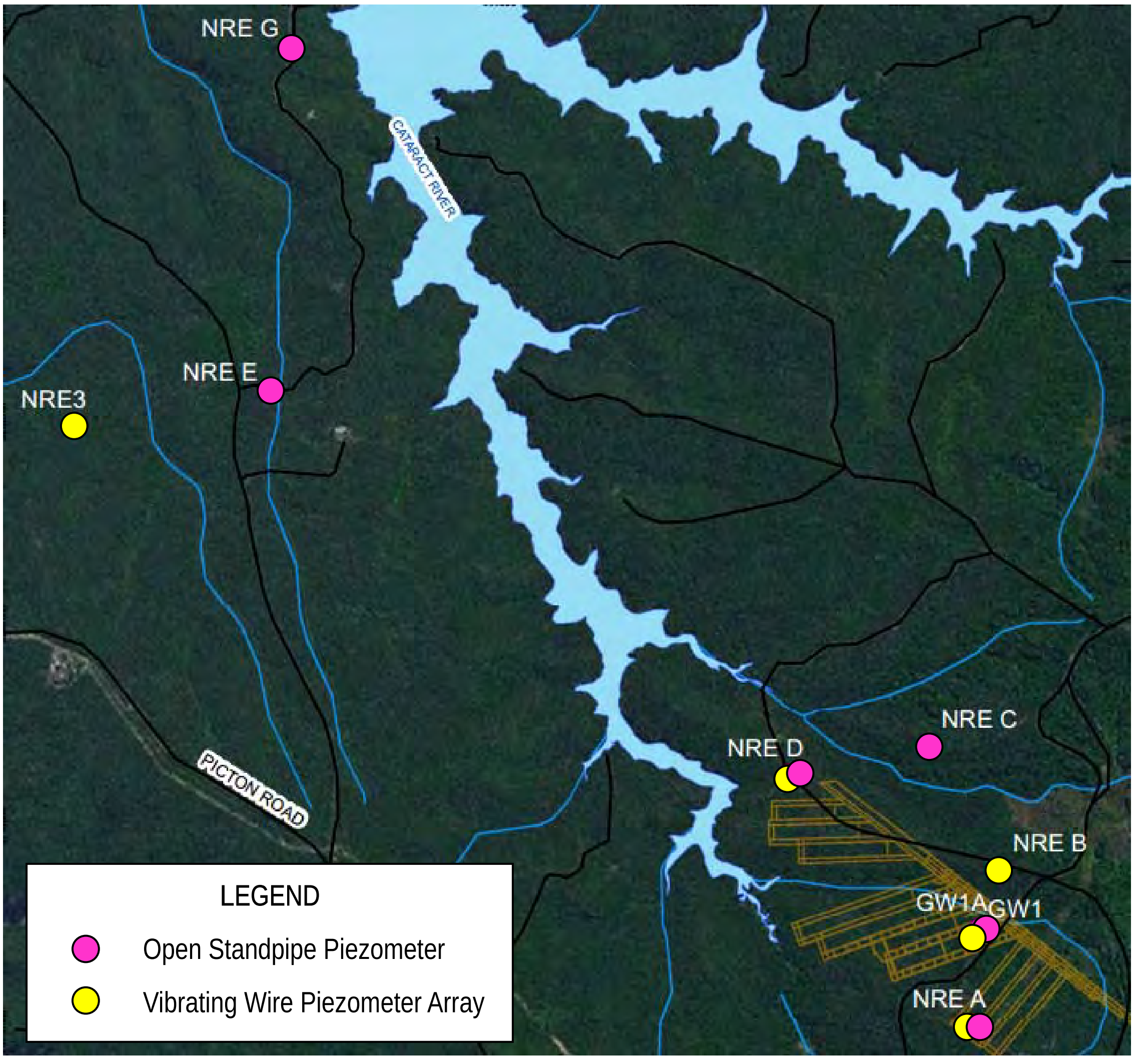


Figure 12 Russell Vale Colliery Piezometer Locations

The results indicate there is a restriction to downward flow in the upper Bulgo Sandstone.

Below the third VWP (45mbgl), the pressure gradient diverges from hydrostatic, which is consistent with low level downward flow. At approximately 140mbgl a reduction in pore pressure was observed with increasing depth consistent with the top of a more hydraulically connected fracture network above the Balgownie Seam longwall goaf.

A hydrostatic pressure gradient represents the rate of increase in water pressure that would be expected in a connected body of water where there is no vertical flow. A pore pressure gradient that is reduced below hydrostatic indicates downward flow, with the rate being dependent on the hydraulic conductivity of the strata.

The pressure profile indicates that the vertical flow rate is likely to be relatively insignificant in comparison with rainfall recharge, but the magnitude of downward flow indicated by this profile depends on the hydraulic conductivity of the overburden strata.

Packer testing in GW1 indicates the Bulgo Sandstone has regionally elevated hydraulic conductivities due to the previous mining related subsidence fracturing in the area, along with gradually reducing permeability with depth, where the strata has not been subsided, whilst the Stanwell Park Claystone has lower permeability than the overlying Bulgo Sandstone or the underlying Scarborough Sandstone (SCT Operations, 2012) as shown in **Figure 13**.

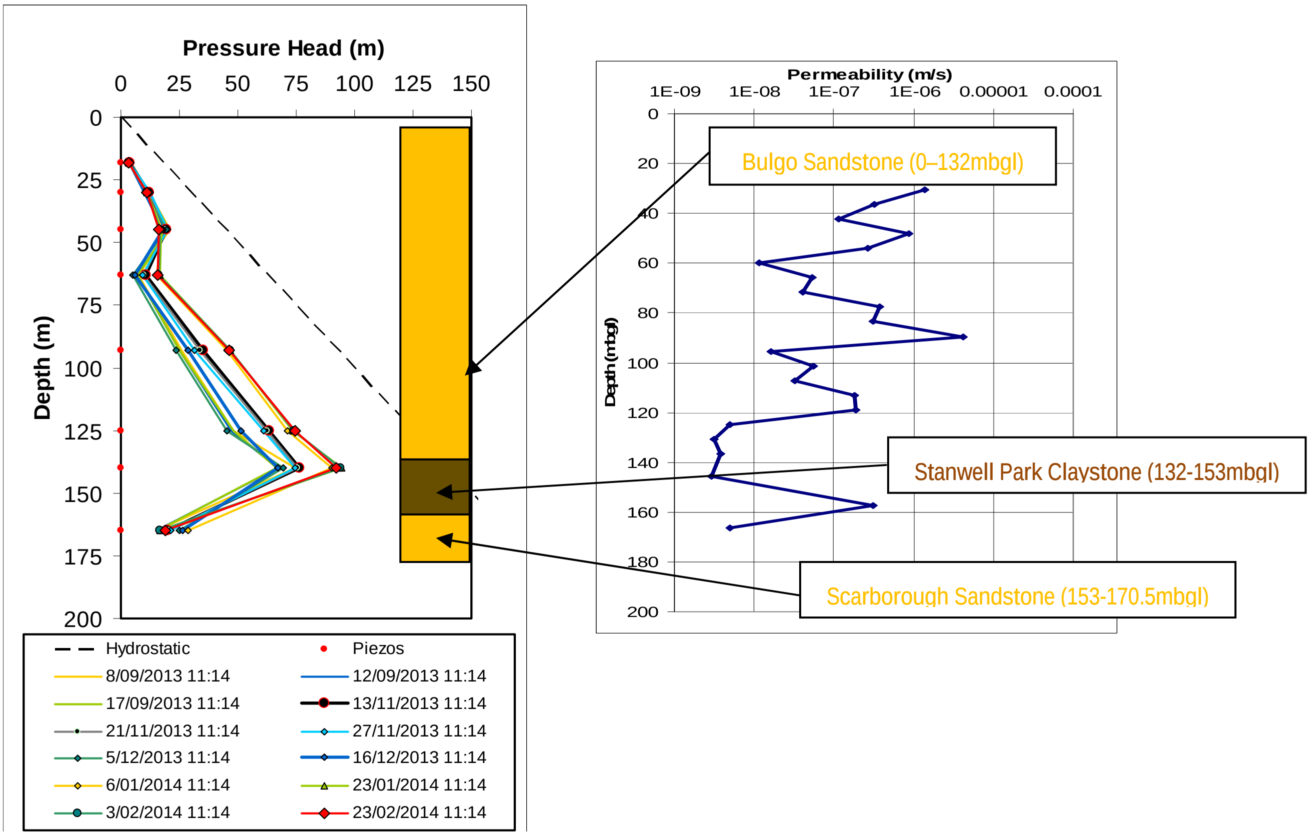


Figure 13 GW1 Pressure Head and Packer Test Data

The phreatic surface through NRE-A, GW1 and GW1A to Cataract Creek indicates the groundwater surface essentially mimics the ground surface, and that the creek has a "losing" relationship to the regional groundwater in its upper headwaters or during extended dry periods.

It should also be noted that the <1.0m wide, highly weathered dyke D8, which is located between GW1 and Longwall 4 does not appear to be acting as a groundwater flow barrier.

The following sections are a compilation of relevant findings from a groundwater and mine water balance study conducted by SCT Operations (2014).

6.4.1 GW1

Vibrating wire piezometer GW-1 was installed in September 2012 after completion of Longwall 4 and is located above the goaf of Longwall 7B in the Balgownie Seam where the Hawkesbury Sandstone has been completely eroded.

The bore is approximately 175m from Cataract Creek, 345m from the northern end of Longwall 4 and 125m from the finishing corner of Longwall 5.

The piezometric pressure profile in GW-1 indicates there are two groundwater systems in the LW4 / LW5 area, with a near surface perched water table and a second deeper groundwater system, both within the Bulgo Sandstone with a possible limited vertical hydraulic connection between the two.

Figure 14 shows that the phreatic surface of the perched water table, as indicated by the 18mbgl intake, is close to, although above the level of Cataract Creek (approximately RL300m).

The 30mbgl intake is near the level of Cataract Creek (RL300m) whilst the 45mbgl intake is below the creek, between 298.9 and 289.3mAHD.

During the period of monitoring to date only the lower two piezometers have correlated responses to rainfall and the effect has not been strong.

There is a slight reduction in the level of the phreatic surface in all three shallow piezometers which commenced soon after Longwall 5 started and continued throughout the period of mining LW5. The long term downward trend from the start of LW5 is considered to be a result of mining and the reactivation of a possible basal shear plane at or below the level of Cataract Creek and extending into the hillside that may have originally been natural, although may have been reactivated or formed during previous mining in the Balgownie Seam and LW4.

The approach of LW5 appears to have caused a reduction in the level of the phreatic surface that is still nominally above the level of Cataract Creek at 18m below the surface (RL300m) but is lower than the creek at 30m and 45mbgl. The effect of mining LW5 appears to have been to slightly elevate the horizon separating a flow gradient toward Cataract Creek from the flow gradient toward the mine, in effect increasing slightly the potential for flow from Cataract Creek toward the mine via the deeper strata. The surface strata is still indicated as having a flow gradient toward the creek in the 18mbgl intake VWP, but this gradient has been reduced slightly by mining LW5.

The uppermost piezometer at 18m below the surface does not change significantly over time or show much response to rainfall but this may be because it is operating at very low pressures and is close to dry.

The 30m piezometer is steady prior to the start of LW5, possibly because of an extended dry period prior to installation, but coincident with the start of LW5 and an intense rainfall event. There is a clear response to rainfall that continues afterwards.

The phreatic surface indicated by the 30m piezometer was initially several metres higher than the RL300m level of the nearest location in Cataract Creek, but with the mining of LW5, the phreatic surface indicated is 299.5m or about half a metre below the level of the nearest point on Cataract Creek. In other words, at the 30m depth horizon in GW-1 (about 12m below the level of Cataract Creek) the hydraulic gradient is slightly away from Cataract Creek toward the mine.

The deepest of the three shallow piezometers at 45m shows a more muted response to rainfall but shows the strongest decline in head of the three with a 9.6m fall since the start of mining LW4.

The relative water levels indicated by each of the piezometers indicates a slight downward gradient, suggesting downward flow into the lower groundwater system and the change in gradient indicates the downward gradient has increased during the period of mining LW5.

The shallow water levels may be hydraulically connected to Cataract Creek, possibly via a horizontal shear horizon located just below the level of Cataract Creek.

The hydraulic conductivity of this connection is such that rainfall recharge from the surface is able to flow back into Cataract Creek but mining increased the gradient toward the mine, particularly in the deeper strata.

Figure 14 also shows that the deeper groundwater table has clearly responded to the later stages of mining LW5. As the longwall approached within about 400m of the piezometer, there was a drop in pressure that was greater with depth below surface.

Mining then ceased for a period, recommenced and then the longwall finished. Each time the longwall advance was halted, the pore pressure recovered to pre-mining levels. Following the completion of LW5, the pore pressures recovered to higher than pre Longwall 5 levels.

This is thought to be due to mining slightly increasing the strata pore space, causing the pore pressure to be temporarily reduced. Inflow from above and possibly laterally allowed the pore pressures to recover to above pre-LW5 levels, possibly as a result of enhanced vertical connectivity caused by mining induced ground movements.

The volumes involved in this process are likely to be transitory but may have caused a temporary period of increased recharge from Cataract Creek.

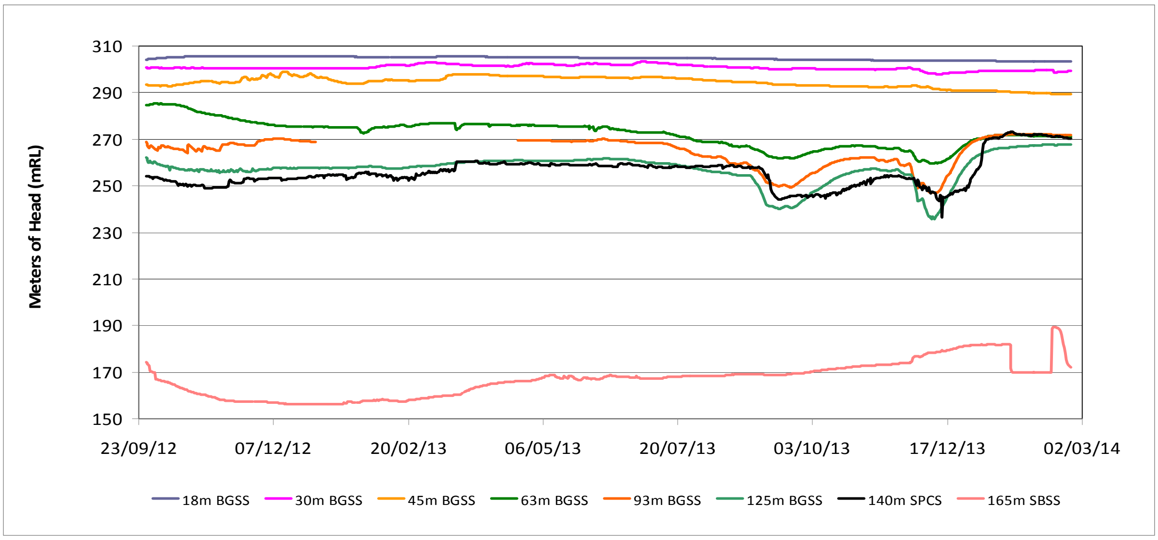
There is still a downward hydraulic gradient toward the mine evident throughout the Bulgo Sandstone but the flows appear to be of a low magnitude based on mine inflow records. The low flow would be consistent with the low hydraulic conductivity of only slightly disturbed strata.

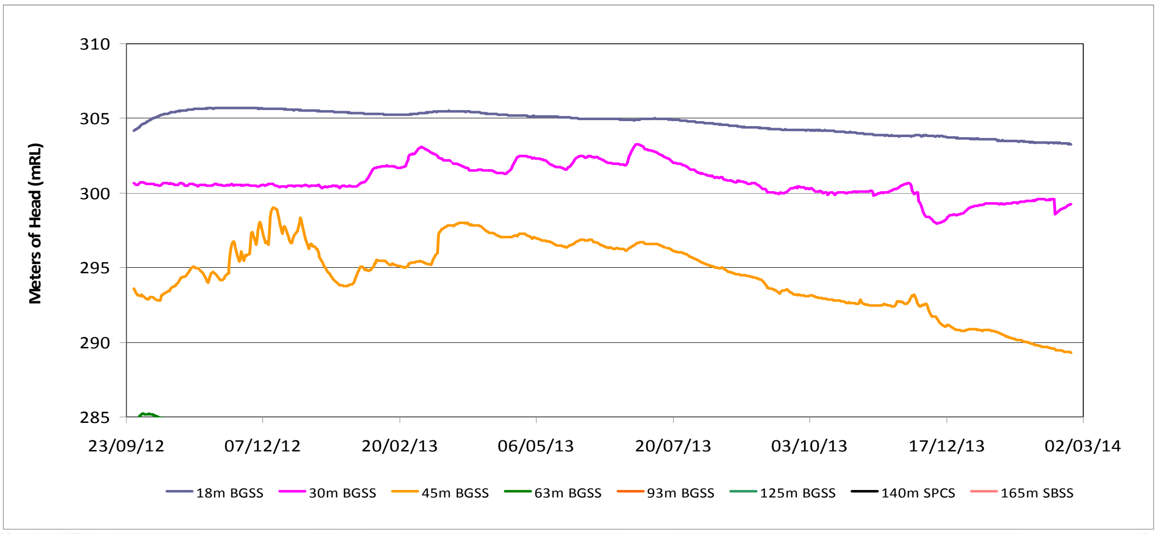
The piezometric profile in GW-1 shows the height above the mining horizon where there is depressurisation below hydrostatic. By implication, the vertical height above an existing mined void is where there is sufficient downward flow into the mine that the pressure profile can no longer be maintained. Extrapolation indicates that the point of zero pressure has been inferred at a depth of approximately 170m below surface in the Scarborough Sandstone (SCT Operations, 2014A).

The Bulli Seam is nominally 2.2m thick but mining in this area did not involve full extraction.

It is possible that the effective height of mining in both seams could be 2.0m and that the Tammetta (2012) approach could provide a basis to estimate the height of depressurisation above the most recent panel mined if the combined mining height is assumed.

Further measurements in a multi-seam mining environment are planned to confirm this single data point.





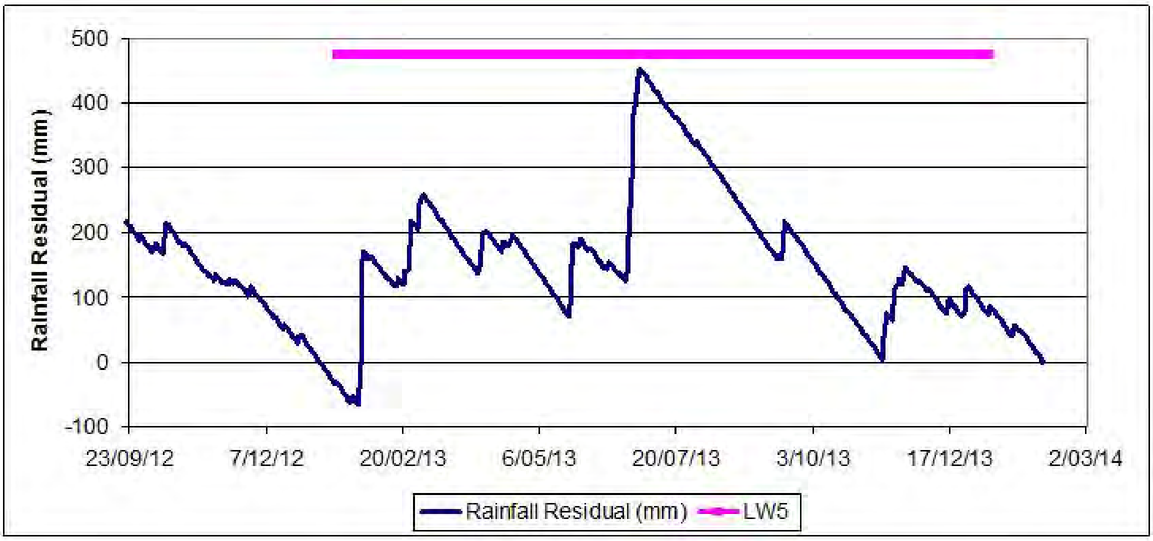


Figure 14 GW1 Groundwater Levels and Rainfall Residual Curve

6.4.2 Open Standpipe Piezometer GW1A

Open standpipe piezometer GW-1A was installed to a depth of 27m in September 2012 after completion of Longwall 4. It is located above the goaf of Longwall 7B in the Balgownie Seam where the Hawkesbury Sandstone has been completely eroded and is installed at the same stratigraphic depth in the Bulgo Sandstone as the 30m intake in the vibrating wire piezometer array in bore GW1.

The bore is located between the VWP piezo (GW1) and Cataract Creek, which is approximately 105m to the north east, 400m from the northern end of LW4 and 485m from the finishing corner of LW 5.

The piezometric pressure profile in GW1A is essentially the same as the 30mbgl VWP intake water level within the Bulgo Sandstone.

Figure 15 shows the water level in GW1A is near the level of Cataract Creek (RL300m) with a correlated, although not strong, similarity to rainfall recharge.

There is a slight reduction in the phreatic surface which commenced soon after LW5 started and continued throughout the period of mining LW5. The long term downward trend from the start of LW5 is considered to be a result of mining and the reactivation of a possible basal shear plane at or below the level of Cataract Creek and extending into the hillside that may have originally been natural, although may have been reactivated or formed during previous mining in the Balgownie Seam and LW4.

The approach of LW5 appears to have caused a reduction in the phreatic surface coincident with the start of LW5 and an intense rainfall event. There is a clear response to rainfall that continues afterwards.

The phreatic surface was initially several metres higher than the RL300m level of the nearest location in Cataract Creek, but with the mining of LW5, the phreatic surface indicated is 299.5m or about half a metre below the level of the nearest point on Cataract Creek. In other words, at the 30m depth horizon in GW-1 (about 12m below the level of Cataract Creek) the hydraulic gradient is slightly away from Cataract Creek.

The water in GW1A may be hydraulically connected to Cataract Creek, possibly via a horizontal shear horizon located just below the level of Cataract Creek.

The hydraulic conductivity of this connection is such that rainfall recharge from the surface is able to flow back into Cataract Creek.

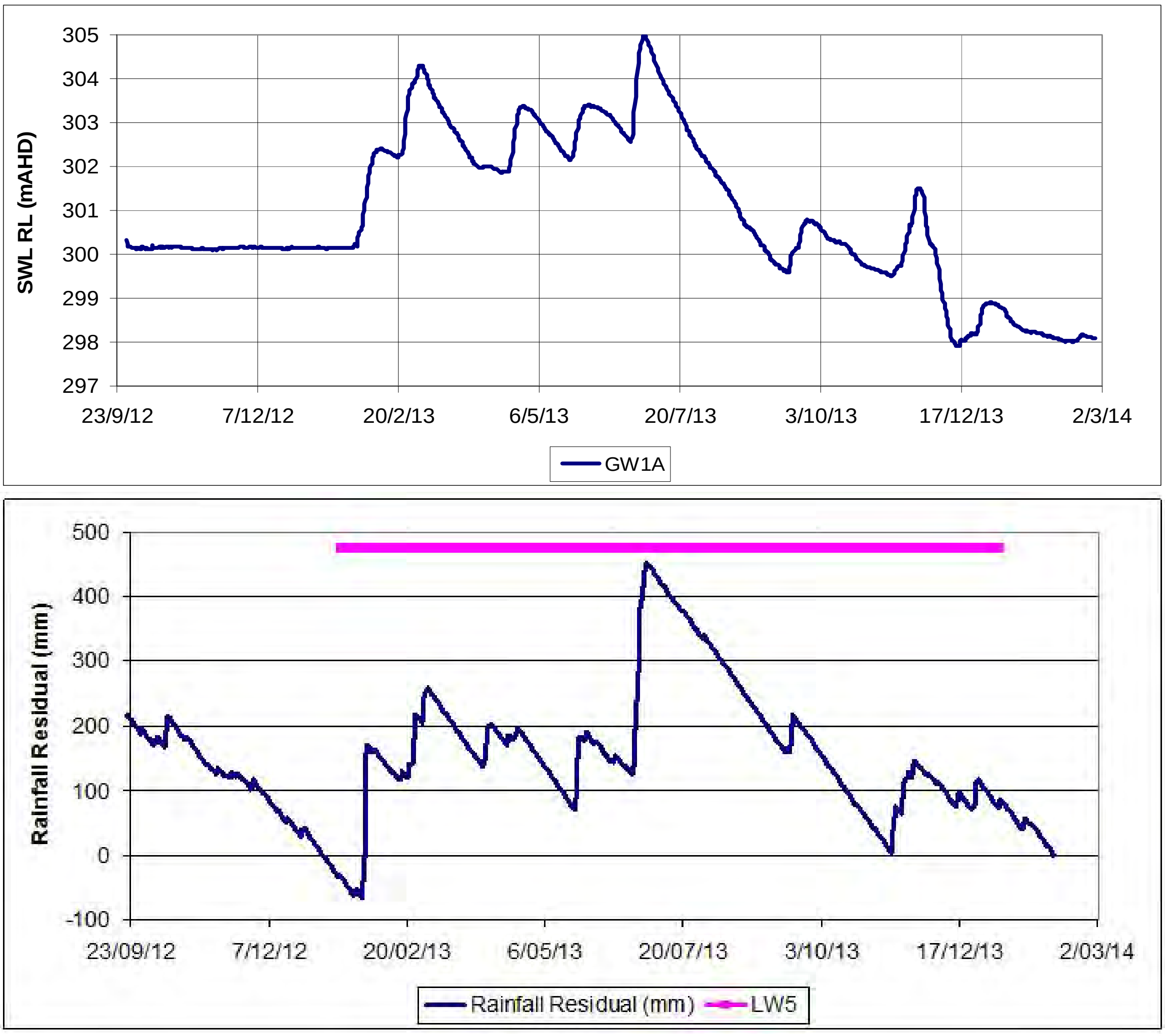


Figure 15 GW1A Groundwater Levels and Rainfall Residual Curve

7. POTENTIAL STRATA DEFORMATION AND ASSOCIATED GROUNDWATER EFFECTS

7.1 Horizontal Strata Shear Zone Formation

Based on studies conducted in the Southern Coalfield at the BHPB Appin Colliery, Sandy Creek waterfall (Walsh R.W, et al 2014), Waratah Rivulet at the Peabody Coal Metropolitan Colliery (Mills, K.W. 2007) and the Wollongong Coal Wonga East study area, SCT Operations Pty Ltd (2014) have inferred that lateral movement of hillsides in toward the valley floor and associated horizontal to sub-horizontal shearing of the strata is possible.

The lateral shear mechanism occurs naturally in valleys, however it may be exacerbated by dilational hillslope shearing movement from the hillslopes toward the valley floor associated with mining induced subsidence as shown in **Figure 16**.

This mechanism is inferred to occur where lateral shear movement, which is not necessarily associated with pre-existing bedding plane or strata discontinuities, is mobilised following periods of intense rainfall.

At Russell Vale, the horizontal shearing of pre-existing natural bedding planes and vertical joints is inferred to have occurred in association with mining induced subsidence and hillslope dilational movement following extraction of the Balgownie and Bulli Seams.

The inferred shear (or shear planes) may have been re-mobilised following extraction of Longwalls 4 and 5 in the Wongawilli Seam, particularly after the heavy rain period in early to mid 2014.

SCT Operations (2014) infer that the main shear plane may be located between 6 – 10m below the valley floor and may extend from the creek bed, under the subsided hillslope within the zone of subsidence for up to approximately 400-450m away from the creek.

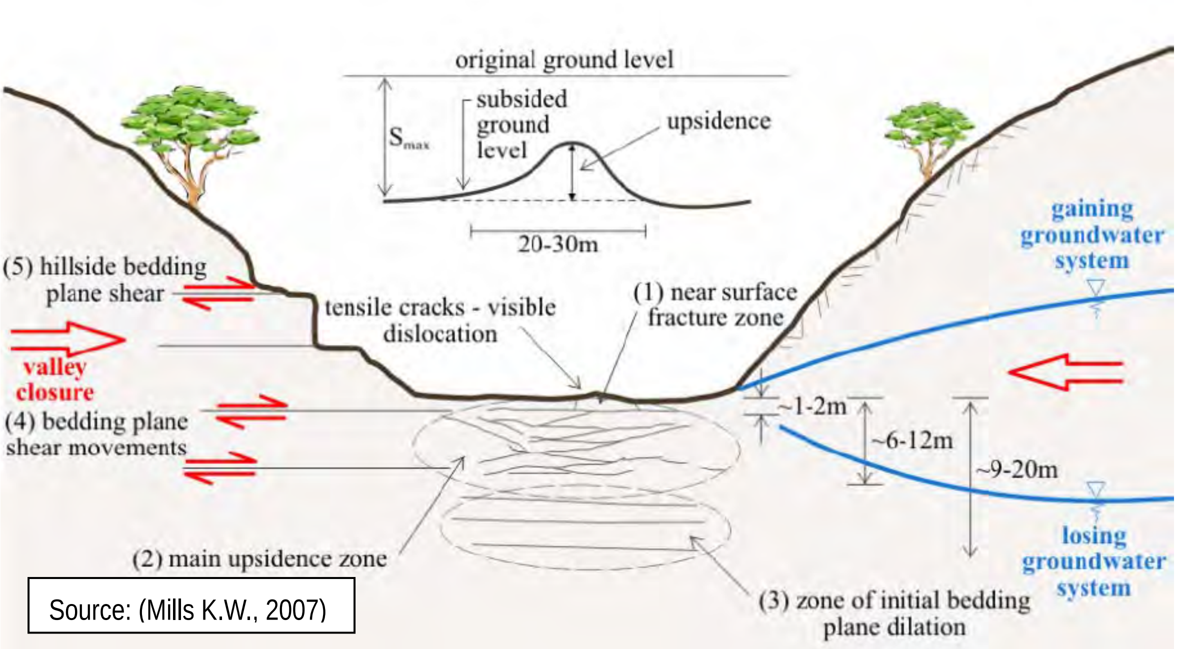


Figure 16 Conceptual Valley Closure Shearing

A definitive assessment of the location, presence and complex nature of the potential shear zone/s is not possible with current field / drilling data at Russell Vale in the valleys overlying subsided areas at Wonga East.

7.2 Tammetta (2012) Theory of Strata Depressurisation

A method for the potential empirical estimation of the height of depressurisation over the centre of single seam longwall panels, for ordinary situations, has been developed by Tammetta (2012). However, its applicability to multiple seam extraction situations has not been defined as yet.

The method and empirical estimation of depressurisation has been modified for use in the current assessment, as a base case scenario, by applying the geometry of the most recent mined panel and the combined thickness of all seams that have been mined.

The empirical equation (Tammetta, 2012) for the height of complete groundwater drainage above centre panel for continuously sheared longwall panels given by *H* (in meters) is:

$H = 1438 \ln(4.315 \times 10^{-5} u + 0.9818) + 26$

where $u = wt^{1.4}d^{0.2}$, and:

t = extracted seam thickness (m)

w = width of the secondary extraction workings (m)

d = overburden thickness (m).

In the equation, *H* depends only on the geometry of the mine opening (*w* and *t*) and the overburden thickness (*d*).

Overburden strata geology appears to play no role in the empirical equation (Tammetta, 2012) however other practitioners question this assumption (Seedsman, R.W. pers comm.).

The value of *H* is a maximum over the centre of a panel and decreases toward the chain pillars, where it is up to 70% smaller, and may reduce to zero in some circumstances, which is facilitated by the lower hydraulic conductivity over the chain pillars compared to the centre of the panel.

The value of *H* in the following situations is smaller than maximum *H* for ordinary locations for various reasons and is inappropriate for use in estimating maximum *H* above:

- chain pillars of continuously sheared panels, with either a panel on one side only or panels on both sides;
- the centre line of pillar extraction being undertaken in room and pillar panels; and
- above the centre line of continuously sheared panels under flowing rivers or saturated high-permeability alluvium.

From a groundwater perspective, the longwall caving process creates two distinct zones above a continuously sheared panel: the collapsed zone and the disturbed zone.

According to Tammetta (2012), the collapsed zone is interpreted to be parabolic in cross section and reaches from the mined seam to a maximum height equal to *H* over the centre of a panel as shown in **Figure 17**.

Tammetta (2012) interpreted this zone to be severely disturbed and drained to atmospheric groundwater pressure as a result of overburden caving and is subsequently unable to maintain a positive pressure head and behaves as a drain while the mine void is kept dewatered.

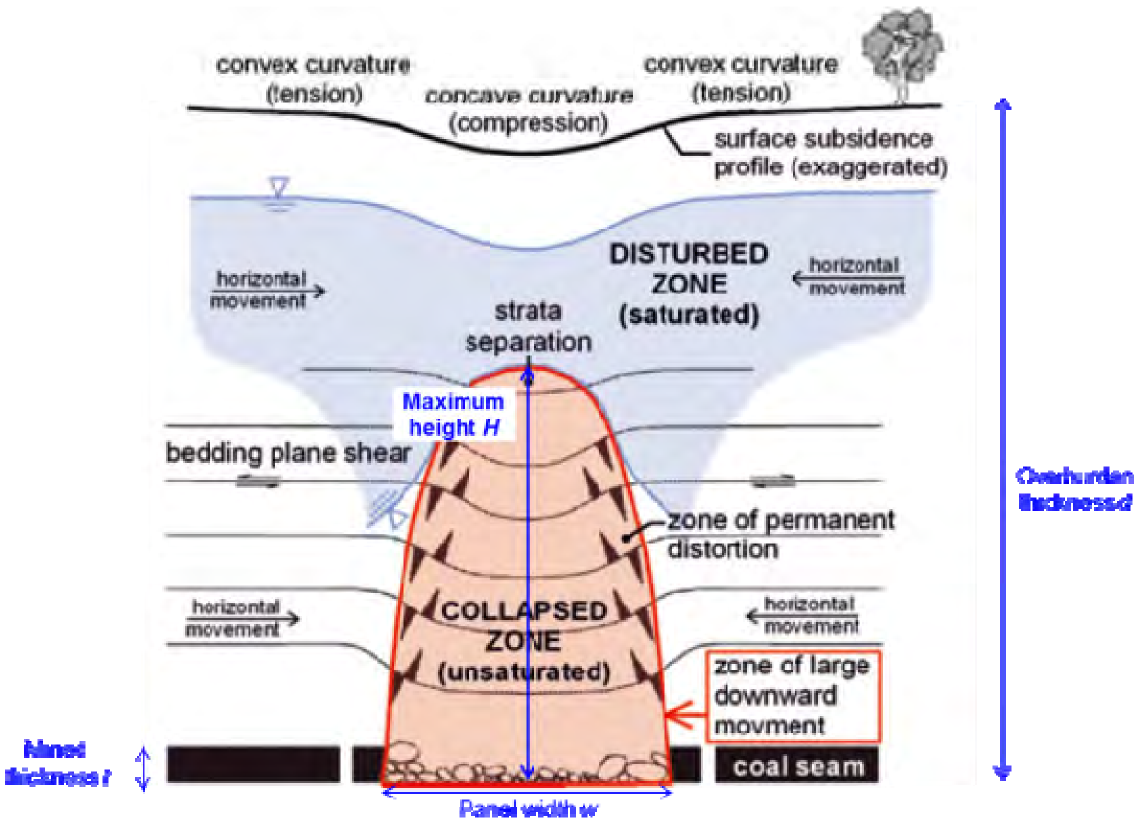


Figure 17 Conceptual Ground Deformation (Tammetta, 2012)

Within this zone, the matrix of rock blocks may continue draining for extended periods, however, the defects will immediately transport this water downward to the mine void.

Groundwater flow will not be laminar and Darcy's equation is unlikely to be obeyed.

The disturbed zone overlies the collapsed zone, where positive groundwater pressure heads are maintained over most of the zone. Limited data for long-term groundwater behaviour in this zone suggest that hydraulic heads remain relatively stable, except for immediate lowering associated with drainage of lower strata and minor increases in void space after caving. Groundwater flow will be laminar, and Darcy's equation is likely to be obeyed.

De-saturation in the disturbed zone occurs above the chain pillars. Here, *H* is smaller than over the centre of a panel and may reduce to zero if the pillar is flanked by one panel only. *H* above the pillars is likely to be more strongly dependent on *d* than for the centre panel and will probably also be dependent on the pillar width.

The Bald Hill Claystone is not anticipated to act as a semi-confining layer between the Hawkesbury Sandstone and Bulgo Sandstone aquifers where it is partially eroded in the mid valley of Cataract Creek, to the east of Cataract Reservoir over the proposed Wonga East workings, or where subsidence fracturing and associated depressurisation has passed through the Bald Hill Claystone.

8. HYDROGEOLOGICAL INVESTIGATIONS

Drilling, piezometer installation, low flow pump out tests, falling head tests, packer tests and installation of open standpipe and vibrating wire piezometers, as well as groundwater level and water chemistry monitoring were conducted within the Study Area from 1992 to the present.

The majority of drilling and monitoring conducted after July 2009 was used to provide input data for the development of a groundwater model and assessment of the hydrogeological characteristics of the:

- upland swamps;
- Hawkesbury Sandstone,
- Narrabeen Group lithologies, and
- Illawarra Coal Measures.

To date, groundwater investigation in the Study Area has involved the installation of:

- 8 open standpipes, and;
- 7 vibrating wire array piezometers,

as shown in **Figure 18**, with drilling extending to 335m below surface.

Drilling was contained within the Wollongong Coal lease area, although the groundwater model domain extends out to include the adjacent BHPB lease areas and current / decommissioned / proposed workings as well as peripheral areas within the major watersheds outside of the lease.

Details of relevant open standpipe piezometers are presented in **Table 3**, whilst geological logs and piezometer construction details were outlined in Geoterra (2012).

Under clause 18 and Schedule 5 of the *Water Management (General) Regulation 2011*, which was gazetted on 30 June 2011, an access licence is not required for monitoring bores.

Piezometers installed prior to that date were licensed by Wollongong Coal.

All relevant approvals from the Sydney Catchment Authority were obtained prior to drilling.

Discussions with the DoPI appointed reviewer for this assessment have indicated the groundwater data utilised is suitable for the groundwater modelling conducted for this study (Tammetta, P. pers comm.)

Table 3 Hawkesbury Sandstone Open Standpipe Piezometer Hydraulic Parameters and Standing Water Levels

Bore	Install. Date	E	N	Collar RL mAHD	Mining Domain	Total Depth (m)	Screen Interval (mbgl)	Standing Water Level (mbgl)
NRE-A (VWP)	21/11/09	303692	6196033	376.18	Wonga East	47	24 - 47	19.21 – 22.37
NRE C	3/12/09	303233	6198797	362.72	Wonga East	24	18 – 24	12.82 – 14.31
NRE D	6/11/09	301870	6198509	348.83	Wonga East	52	40 - 52	27.21 – 30.73
NRE E	23/10/09	296727	6202286	329.24	Wonga West	29	17 - 29	11.57 – 11.91
NRE G	20/10/09	296949	6205678	363.03	Wonga West	53	36 - 53	29.63 – 30.51
NRE3	5/12/09	294803	6201954	359.27	Wonga West	60	48 - 60	39.22 – 39.34
P514	1/11/98	297917	6204280	308.23	Wonga West	191	160 - 188	20.0 – 34.0
GW1A	22/8/12	303742	6196983	311.7	Wonga East	27	21 - 27	24.0

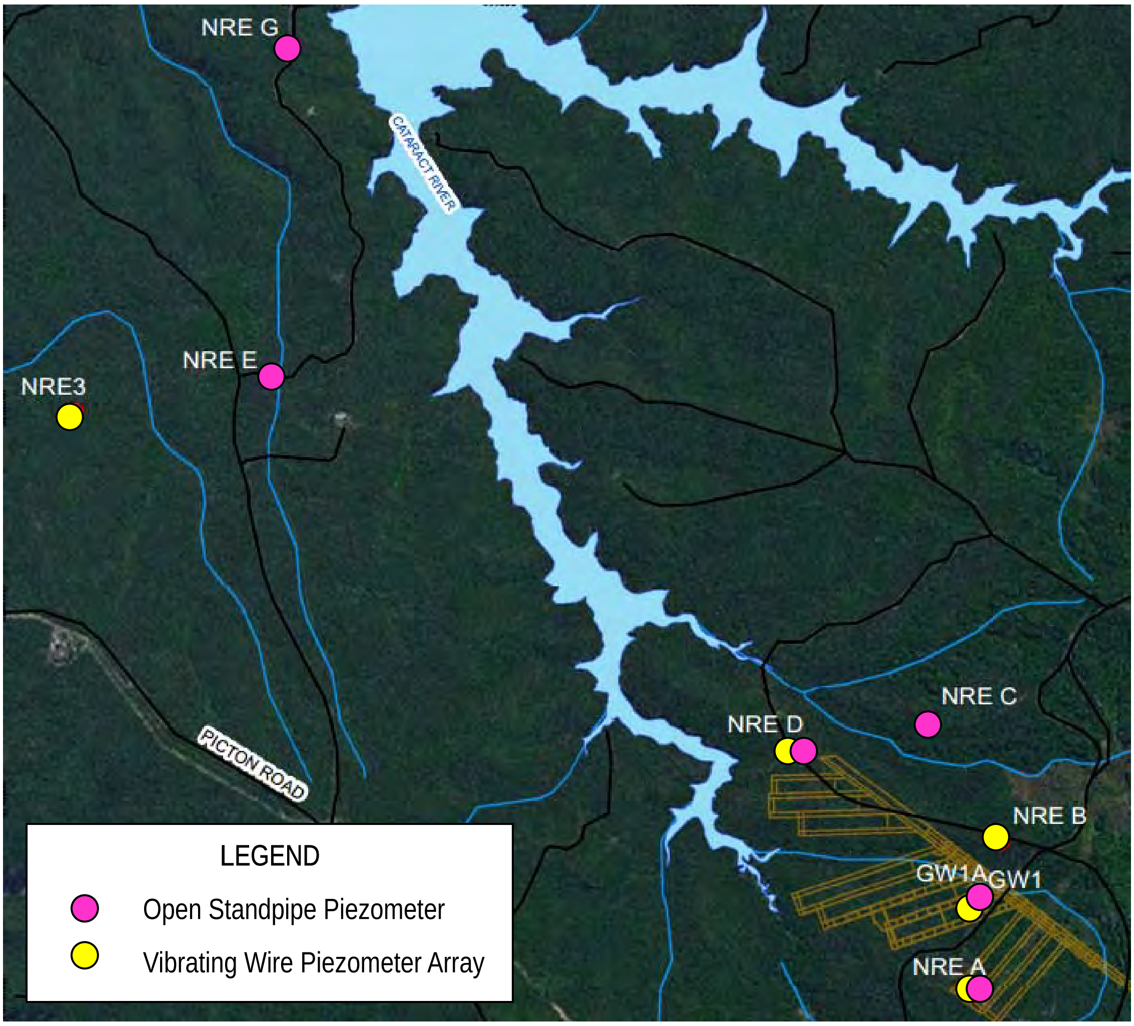


Figure 18 Russell Vale Colliery Piezometer Locations

It should be noted that where VWP arrays are installed, as shown in **Table 4**, the bores were sealed to surface with cement / bentonite.

Table 4 Vibrating Wire Piezometer Bores

Piezometer	E	N	Collar RL (mAHD)	Total Depth (mbgl)	Intakes (mbgl)
NRE-A VWP	303680	6196034	376.23	153	45(mid HS) 60(low HS) 75(up BS) 140(mid BS)
NRE B	303939	6197567	372.69	170	27.5(low HS) 43(up BS) 63(mid BS) 168(SPCS)
NRE D VWP	301875	6198493	348.0	176	33(mid HS) 60(low HS) 73(BHCS) 135(mid BS)
NE3	294794	6201945	360.23	281	100(mid HS) 130(low HS) 155(NP) 255(low BS)
P501	298771	6201855	326.18	335	110(HS) 174(up BS) 226(mid BS) 274(low BS) 325 (SS)
P502	298598	6202049	319.32	218	90(P14 & P15 low HS) 167(P12 & P13 up BS) 218(P11,mid BS)
GW1	303693	6196913	318.2	165	18 (BS) 30 (BS) 45 (BS) 63 (BS) 93 (BS) 125 (BS) 140 (SPCS) 165 (SS)

NOTE: HS - Hawkesbury Sandstone NP - Newport Formation BHCS - Bald Hill Claystone BS - Bulgo Sandstone SPCS - Stanwell Park Claystone SS - Scarborough Sandstone

8.1 Basement Hydraulic Properties

Low flow (<0.16L/sec) pump out tests of less than 45 minutes duration were conducted in all open standpipe piezometers seated in the upper to middle Hawkesbury Sandstone as outlined in Geoterra (2012).

Packer tests over 5.5m intervals were conducted in 6 bores to 281m below surface (SCT Operations, 2009).

As detailed in (Geoterra, 2012), the average packer test hydraulic conductivity of the Hawkesbury Sandstone varies from 0.01m/day in the upper section to 0.0003m/day in the mid section and 0.0008m/day in the lower horizon.

The Bald Hill Claystone averages 0.03m/day whilst the upper Bulgo Sandstone averages 0.007m/day and the mid Bulgo Sandstone averages 0.0004m/day (Geoterra, 2012).

Based on a combination of on-site tests as well as assessment of regional studies (Heritage Computing, 2010) hydraulic conductivities in the BHPB Bulli Seam proposed workings region vary from 0.03m/day to 1E-6m/day, whilst the western region around Tahmoor (Geoterra, 2009) ranges from 9.3E-6m/day to 1.6E-9m/day. The Dendrobium workings range from 8.6E-1m/day to 8.6E-5m/day (GHD, 2007).

Site specific test work, as well as reference to adjoining field and modelling groundwater studies in the Southern Coalfields, were used as hydraulic parameter inputs to the Study Area groundwater model.

Figure 19 shows the range of hydraulic conductivities available from the Study Area and adjoining Southern Coalfield study sites.

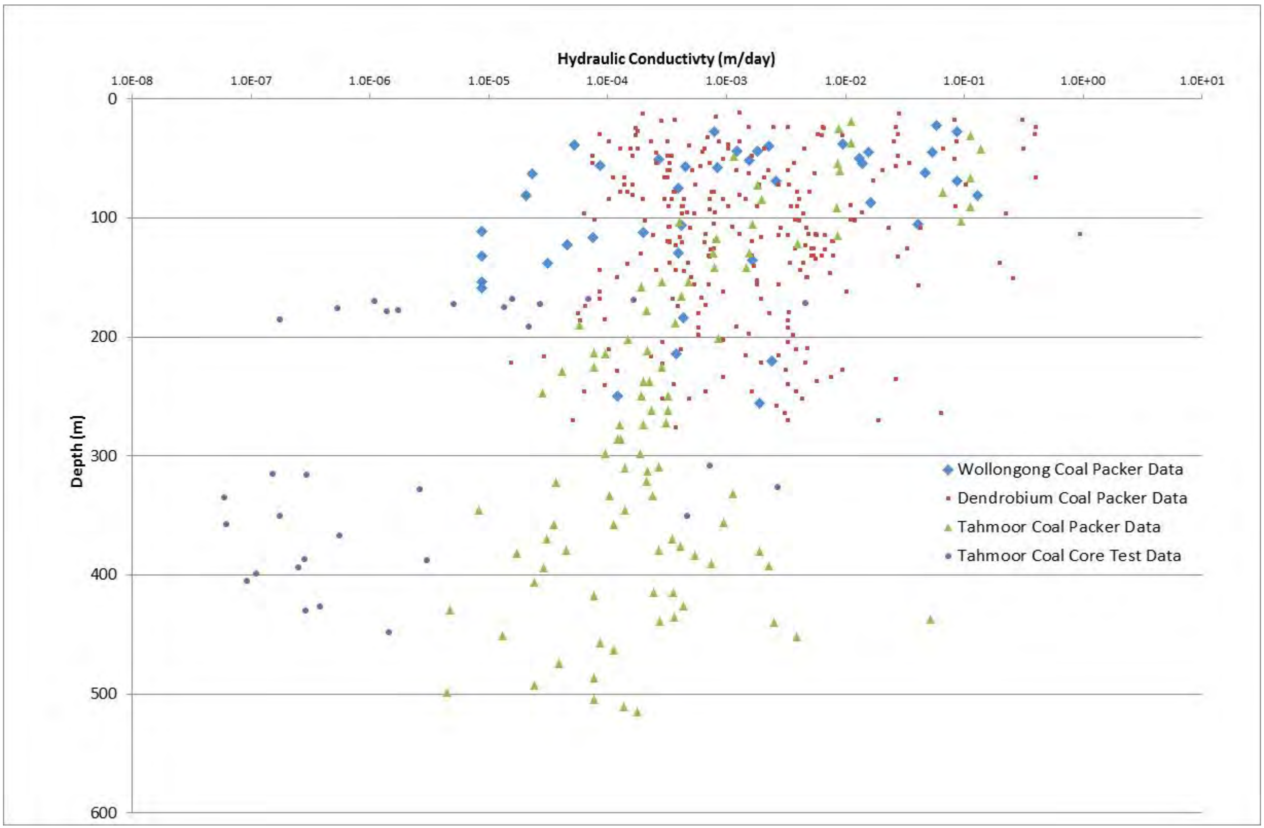


Figure 19 Selected Southern Coalfield Hydraulic Conductivities

8.2 Hawkesbury Sandstone Open Standpipe Water Levels

Water level variability has been measured in open standpipe piezometers that were installed in the upper Hawkesbury Sandstone as shown in **Figure 13** and **Table 5**.

Table 5 Open Standpipe Piezometer Water Level Variability

Piezometer	Drilling First Water Intercept (mbgl)	Water Level Range (mbgl)	Water Level Variability (m)
Wonga East			
NRE-A (VWP)	24.0	1.25 – 21.68	20.43
NRE C	18.0	6.32 – 13.06	6.74
NRE D	40.0	1.99 – 10.5	8.51
GW1A	24.0	6.97 – 13.6	6.63
Wonga West			
NRE E	17.0	10.41 – 11.63	1.22
NRE G	36.0	25.86 – 30.51	4.65
NRE3	48.0	6.97 – 39.55*	35.28*

NOTE: NRE3 piezo appears to not be correctly sealed

The monitoring data indicates that the Wonga East piezometers are generally more responsive to rainfall than at Wonga West, as shown in **Figure 20** with the variability principally due to the degree of subsidence and overburden fracturing that has occurred over the Wonga East workings.

Note that the high water level variability in NRE3 is unusual, and is probably due to incomplete sealing of the surface casing annulus, which allows overland surface water runoff to enter the casing and “artificially” raise the standing water level in the piezometer.

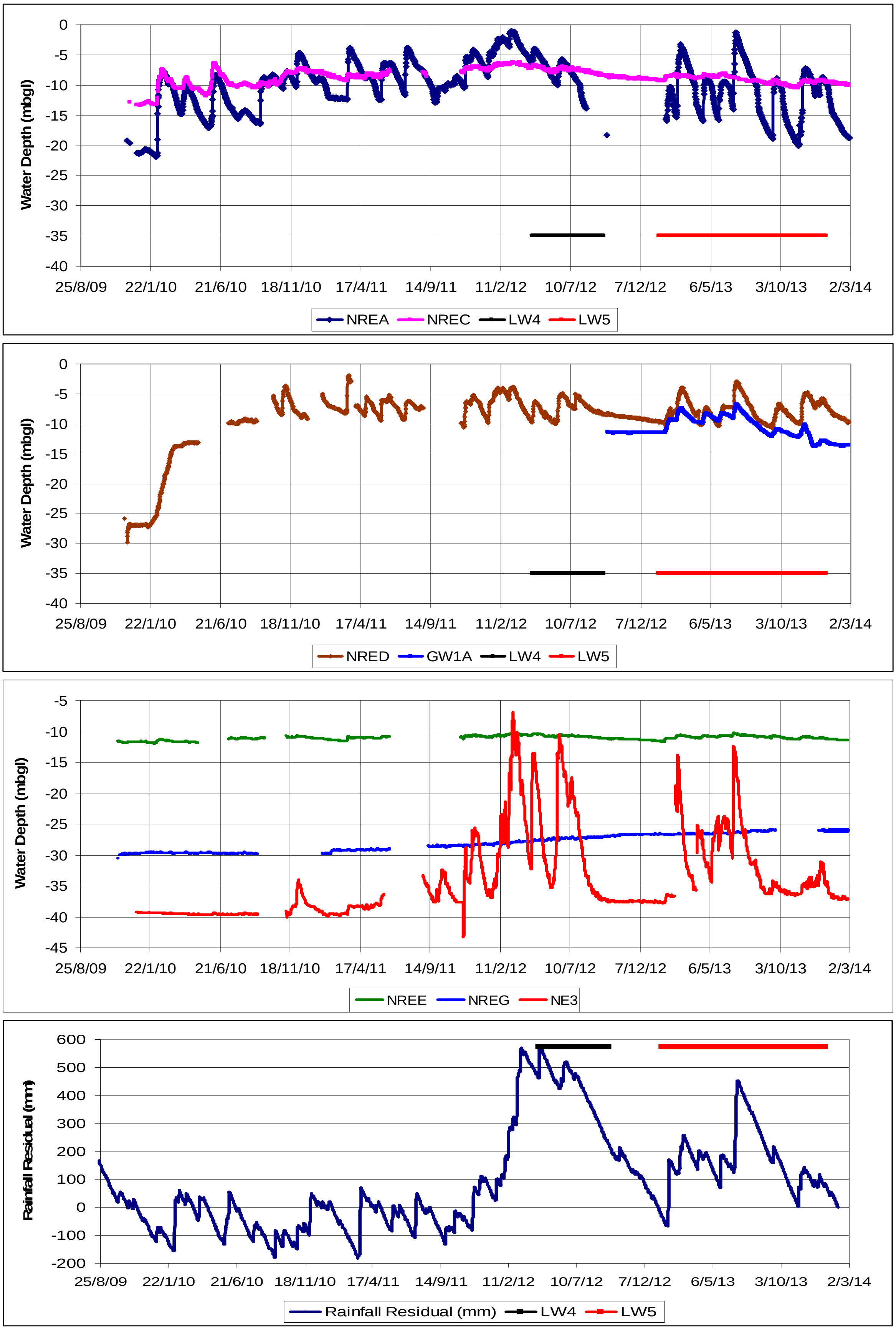


Figure 20 Shallow Sandstone Water Levels, Rainfall Residual and Longwall Extraction

8.3 Multi Level Piezometers

Multi level piezometers have been installed at selected depths between the Upper Hawkesbury Sandstone and the Stanwell Park Claystone since July 2009 in four bores at Wonga East and one at Wonga West as summarised in **Table 6**.

Table 6 Vibrating Wire Piezometers

Piezometer Intake Depth (mbgl)	Location / Formation	Piezometer Intake Depth (mbgl)	Location / Formation
NRE-A (VWP)	**(Wonga East)**	**NRE-B**	**(Wonga East)**
45	Mid Hawkesbury Sandstone	**27.5**	Lower Hawkesbury Sandstone
60	Lower Hawkesbury Sandstone	**43**	Upper Bulgo Sandstone
75	Upper Bulgo Sandstone	**63**	Mid Bulgo Sandstone
140	Lower Bulgo Sandstone	**168**	Stanwell Park Claystone
NRE-D (VWP)	**(Wonga East)**	**NRE-3**	**(Wonga West)**
33	Mid Hawkesbury Sandstone	**100**	Mid Hawkesbury Sandstone
60	Lower Hawkesbury Sandstone	**130**	Lower Hawkesbury Sandstone
73	Bald Hill Claystone	**155**	Newport Formation
135	Mid Bulgo Sandstone	**255**	Lower Bulgo Sandstone
GW1 (Wonga East)			
18	Upper Bulgo Sandstone	**93**	Mid Bulgo Sandstone
30	Upper Bulgo Sandstone	**125**	Lower Bulgo Sandstone
45	Upper Bulgo Sandstone	**140**	Stanwell Park Claystone
63	Mid Bulgo Sandstone	**165**	Scarborough Sandstone

NOTES: mbgl metres below ground level

Vibrating wire piezometers arrays were also installed in 1992 as part of an investigation of the 500 series longwall subsidence and groundwater response in piezometers P501, P502 and 514 (Singh R.N, Jakeman, M. 2001). These earlier piezometer arrays augment the latter VWP installations at Wonga East and Wonga West.

A contour plot of the regional upper Hawkesbury Sandstone piezometric surface based on data from the open standpipe and upper vibrating wire piezometer intakes as well as assumed water levels in the base of valleys and along Cataract Reservoir is shown in **Figure 21**.

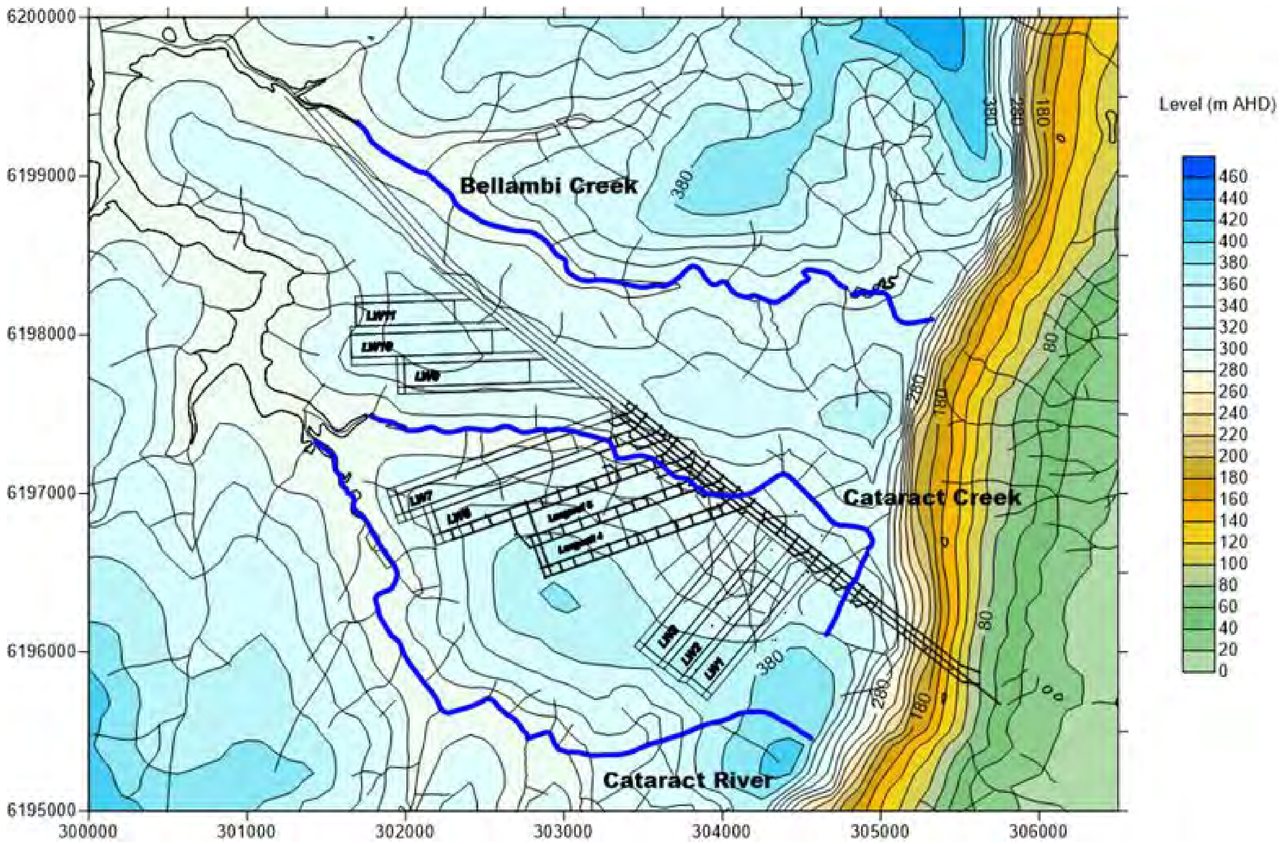


Figure 21 Russell Vale Colliery Phreatic Surface Groundwater Contours

The plot indicates a general flow at Wonga East from the escarpment to the Cataract Reservoir.

8.3.1 Comparison of Observed to Predicted Height of Strata Depressurisation

Comparison of the observed vibrating wire piezometer strata pressure profiles shown in **Figure 22**, to the predicted extent of the zone of depressurisation, according to the adapted Tammetta (2012) empirical method, indicates the method overestimates the observed height of depressurisation at Wonga East in GW1, as summarised in **Table 7**.

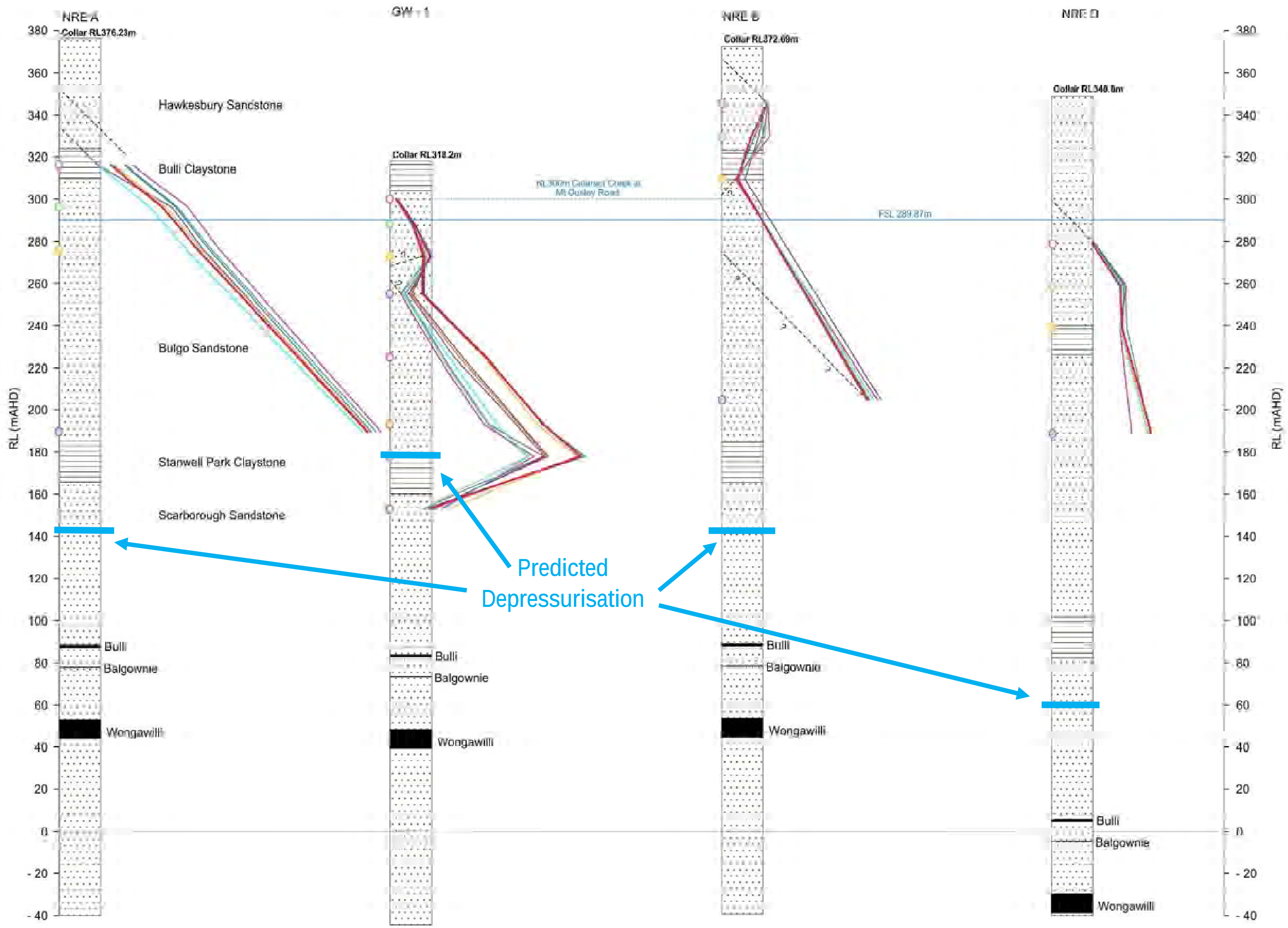


Figure 22 Wonga East Stratigraphy, Vibrating Wire Piezometer Installations and Head Pressures

It should be noted, however, that only GW-1 has been installed deep enough into the overburden to assess the height of depressurisation and that, as it is located approximately 500m off to the side of Longwall 4 and 250m from the edge of Longwall 5, use of this VWP data does not fulfil a tacit assumption in the Tammetta (2012) theory.

The theory assumes the depressurisation prediction location is directly over the centre of the subject secondary extraction workings.

Nevertheless, the available site data indicates the Scarborough Sandstone remains saturated, whereas the strata underlying the Bulli and Balgownie Seams have been dewatered due to earlier mining activities.

Table 7 shows that comparison of the theoretical versus actual height of depressurisation can not be ascertained in NRE-A, B and D as the lowest VWP transducer in each bore is not deep enough to measure the actual top of the "depressurisation" zone.

Comparison of the predicted versus actual depressurisation height is also complicated by the observation that although a VWP array may not directly overlie the centre of secondary extracted workings, most of the installed VWPs lie in close proximity to the edge of extracted workings and the depressurisation "halo" from the subsided strata over those workings affects the monitored overburden strata pressures in the VWPs.

GW1 however, does have deep enough instrumentation in the Scarborough Sandstone, and can be used to estimate the predicted "depressurisation" zone as a result of mining Longwalls 4 and 5 in the Wongawilli Seam.

Groundwater pressures have partially recovered in GW1 since the completion of LW5 and the Scarborough Sandstone remains saturated at least to the depth of the installed vibrating wire transducer.

Table 7 Comparison of Predicted and Observed heights of Depressurisation

Piezometer	Mining Height (Bulli / Balgownie / Wongawilli) Total (m)	Mining Width (Bulli / Balgownie / Wongawilli) Maximum (m)	Overburden Thickness From Top of Lowest Mined Seam (m)	Observed Height of Depressurisation Above Top of Lowest Mined Seam (m)	Predicted Height of Depressurisation Above Top of Lowest Mined Seam (m)
NRE-A*	0	0	295	<110	n/a
NRE-B**	2.2	100	285	<115	56
NRE-D**	2.2	100	345	<185	57
GW-1***	2.5	190	275	100 - 130	136

NOTES * NRE-A does not directly overly any workings, but is within close proximity to the edge of extraction in the Bulli and Balgownie secondary extraction areas

** NRE-B and NRE-D directly overly Bulli Seam extraction only

***GW-1 directly overlies Bulli + Balgownie Seam extraction, although is in close proximity to triple seam extraction from LW4 and LW5

The commentaries in the following sections on vibrating wire piezometer monitoring observations are an adaptation from the text, and also relate to the diagram in SCT Operations (2014) shown in **Figure 22.**

8.3.2 Wonga East NRE-A (VWP)

Piezometer NRE-A (VWP) is located on a ridge in the Hawkesbury Sandstone in an area where there are only first workings in the Bulli Seam (approx 285 mbgl), nearby longwall mining in the Balgownie Seam and no nearby mining in the Wongawilli Seam.

Figure 22 shows the pressure profile measured on the four piezometers installed in the bore indicate a hydraulic gradient that is close to hydrostatic with the indicated phreatic surface varying from 15m to 30m below surface (RL360m to RL345m).

The hydrograph in **Figure 23** indicates a response to short term rainfall trends consistent with the full column being vertically connected through the Hawkesbury Sandstone, the Bald Hill Claystone and approximately 75m into the Bulgo Sandstone as a result of mine subsidence.

There is some slight muting of the pressure response at 140m below surface in the Lower Bulgo Sandstone, but the immediacy of the response in all the piezometers indicates there is a high degree of vertical connectivity and that the Bald Hill Claystone is not acting to reduce vertical downward flow at this location.

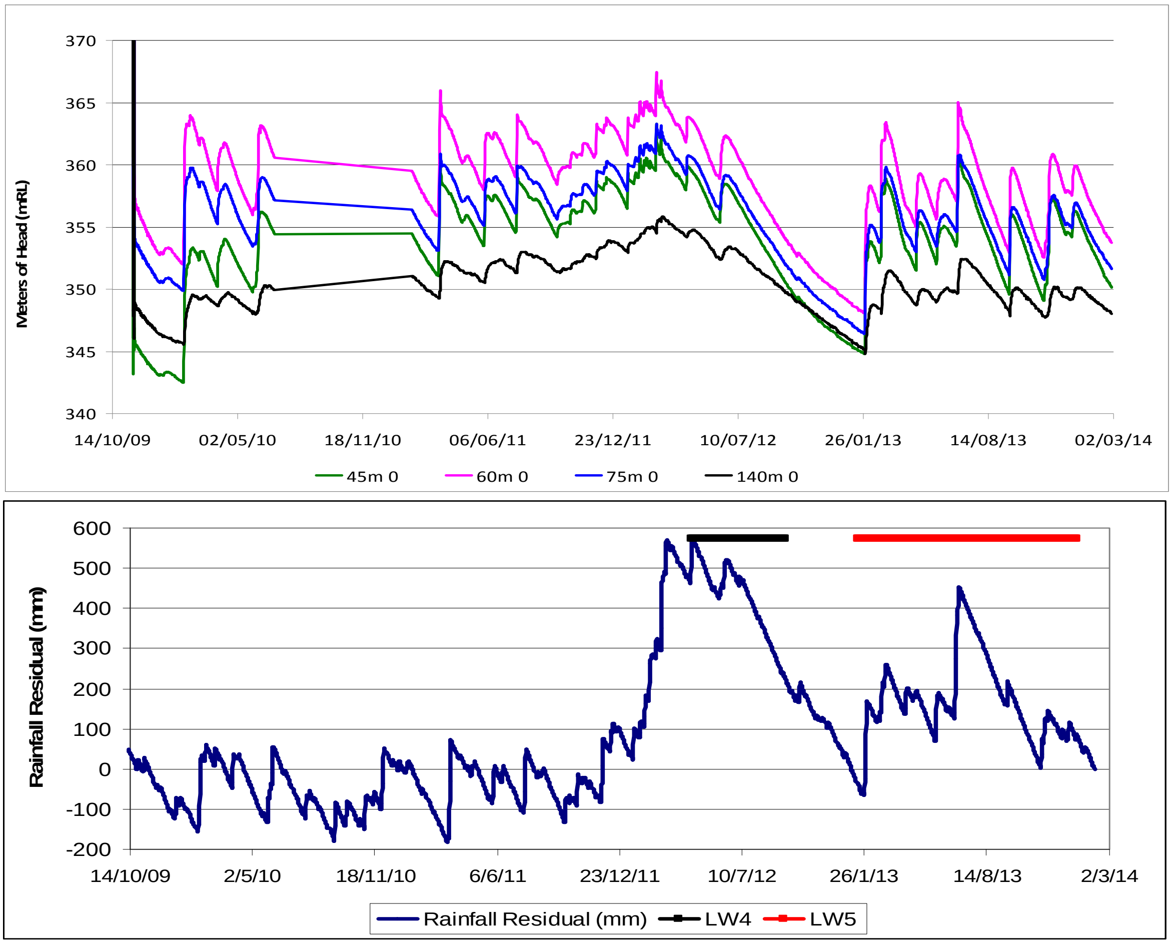


Figure 23 NRE-A VWP Water Levels, Rainfall Residual and Longwall Advance

The individual piezometers indicate approximately the same response to rainfall recharge, with a slight trend of decreasing head with depth consistent with downward flow gradient from the surface toward the mining horizons. Given the high vertical conductivity indicated by the rainfall response, the presence of a downward hydraulic gradient indicates a strong potential for this area to be a source of inflow into the mine, particularly if the height of depressurisation above the mining horizon interacts with the zone of elevated vertical connectivity from the surface.

Although it is possible that the piezometer array was not properly sealed and the borehole annulus may contribute to the vertical conductivity, the downward trend with pressure does not support this. It should also be noted that NRE-A (VWP) is located on the same topographic ridge where horizontal stretching on the surface of Mount Ousley Road and open cracks in the adjacent terrain have been observed.

There were also pre-existing tension cracks close to the site of NRE-A (VWP) during mining of Longwall 3 in the Balgownie Seam. The high level of vertically connected cracking and consequently a high level of vertical conductivity observed in NRE-A (VWP) is considered to be a result of the presence of vertical fractures and opening of existing joints caused by horizontal tensional stretching of the shallow overburden (SCT Operations, 2014).

A second piezometer is proposed in this area in the near future and will help confirm the depth of elevated vertical conductivity.

The elevation of the phreatic surface at the NRE-A (VWP) site ranges from RL340m to RL360m which is at the level of the upper headwaters of Cataract Creek near the site and is likely to be contributing to an intermittent to perennial base flow into Cataract Creek.

Although there is a vertical hydraulic gradient downward toward the mine at NRE-A (VWP) and by implication some flow, there is also lateral flow into Cataract Creek, which is the primary control on the phreatic surface.

A significant observation from NRE-A (VWP) is that with the high level of vertical connectivity associated with tensional (stretching) movements caused by subsidence to a depth of at least 140m, the potential for downward flow into the mine is likely to be greatest directly below the tensional zone along the ridge top.

This piezometer string was installed well before the commencement of Longwall 4 on 22/4/12 and so there is a relatively long baseline of rainfall events prior to a series of high intensity rainfall events in early 2012 and the commencement of mining Longwall 4.

There is a clear reduction in piezometric pressure response after the start of mining Longwall 4 and this has continued through into Longwall 5. Close examination of the step change in the correspondence between rainfall and piezometric head change shows that rainfall prior to the start of Longwall 4 may have contributed to the inferred initial lateral hillside movement toward Cataract Creek.

The effect of the inferred lateral hillside movement, which was induced by a combination of high rainfall as well as previous historical and recent mining activity in the Wongawilli Seam, has been to reduce the head of the background phreatic surface by about 5 - 10m after March 2012.

Rainfall events appear capable of recharging the phreatic surface to pre - 2012 levels, but the level drops back more quickly to baseline levels. The volume of water stored in several large cracks observed during routine subsidence monitoring on the ridge above

Longwalls 4 and 5 soon after the start of mining Longwall 5 may be sufficient to account for the additional inflow volumes into the mine soon after the start of Longwall 5.

8.3.3 Wonga East (NRE-B)

As shown in **Figure 18**, piezometer NRE-B is located on a ridge to the north of Cataract Creek in an area where there has been secondary workings in the Bulli Seam but no mining in the Balgownie or Wongawilli Seams.

The piezometric profile at monitoring location NRE-B as shown in **Figure 22** indicates a perched water table under the ridge that is drawn down to zero at an elevation above Cataract Creek. It is difficult to draw many conclusions from the single pressure reading at 168m depth below surface in the Bulgo Sandstone, but this single value is consistent with a groundwater level at about 100m below the surface or 30m below the base of Cataract Creek. The upper two piezometers in the Hawkesbury Sandstone respond slightly to long term rainfall trends (**Figure 24**), but the correlation is much less clearly evident in NRE-B compared to NRE-A (VWP).

Although there has been some mining below this site in the Bulli Seam, extraction of coal has been much less systematic compared to the southern side of Cataract Creek where eleven longwall panels were mined in the Balgownie seam. Pore pressures in the Hawkesbury Sandstone are perched well above the level of Cataract Creek and the Cataract Reservoir.

The pore pressure in the Bulgo Sandstone is below the 289.87mAHD Full Supply Level (FSL) of Cataract Reservoir.

The NRE-B data indicates that there is a downward hydraulic gradient, but that the hydraulic properties of the intact strata are sufficiently low in the undisturbed strata so that there is almost no vertical downward flow component.

The response to long term rainfall trends even at relatively shallow depths within the Hawkesbury Sandstone is muted and only varies around a long term average by a few metres. There is a slow downward trend evident in the lower Hawkesbury Sandstone at 43m and the Bulgo Sandstone at 168m from about July 2011, but there is not clear a reason for this trend and it is not replicated in the piezometer located vertically between the two that are trending downward.

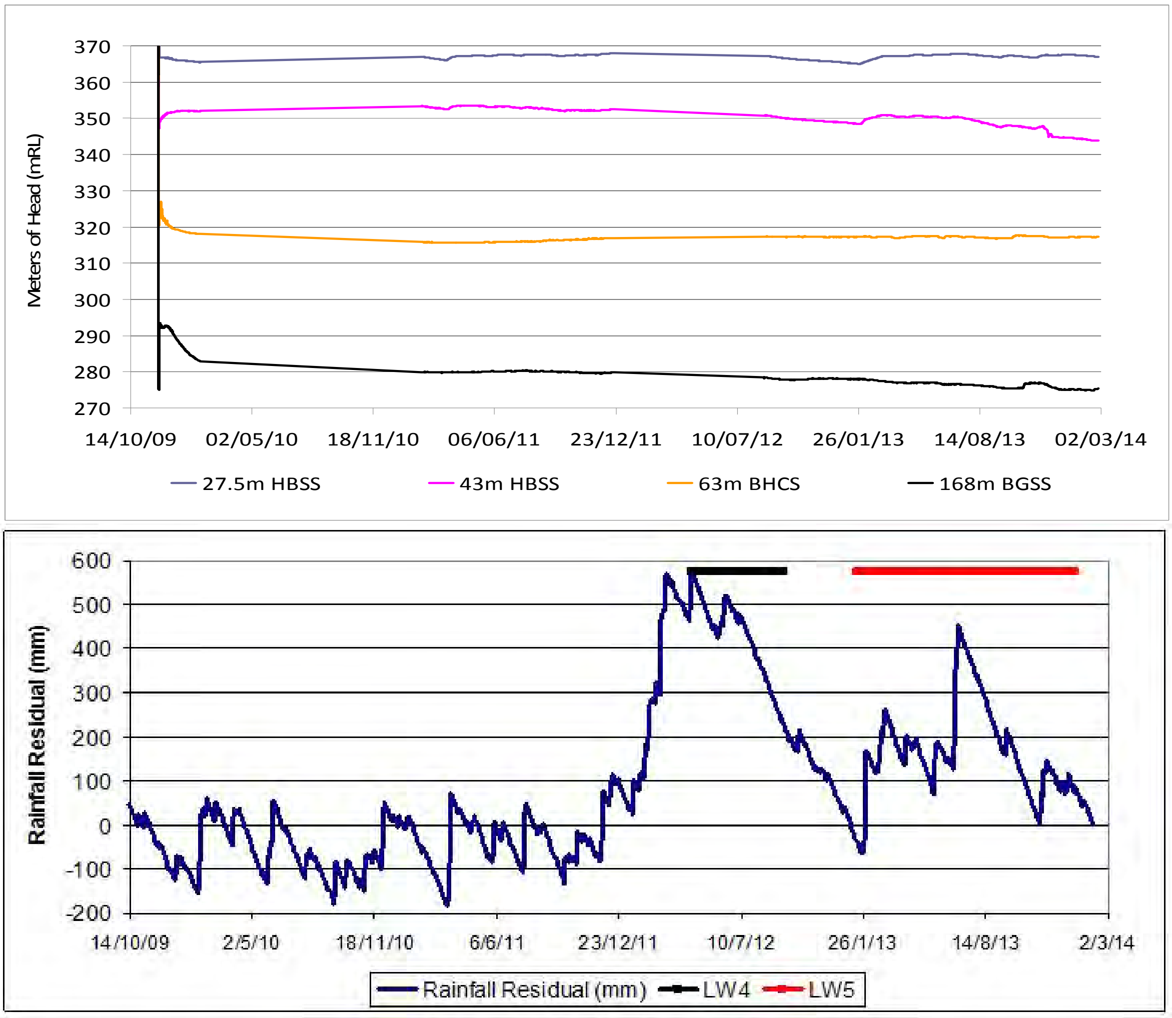


Figure 24 NRE-B VWP Water Levels, rainfall Residual and Longwall Advance

8.3.4 Wonga East NRE-D (VWP)

The vibrating wire piezometer array in bore NRE-D (VWP) is located approximately 540m to the east of Cataract Reservoir.

As shown in **Figure 18**, the borehole is located further west along the ridge to the north of Cataract Creek from NRE-B. The strata dips to the west so the equivalent geological units are about 75m lower at NRE-D (VWP) compared to NRE-B. There have been some limited secondary workings in the Bulli Seam but no mining in the Balgownie or Wongawilli Seams.

The piezometric profile at NRE-D as shown in **Figure 22** indicates the phreatic surface in the Hawkesbury Sandstone under the ridge is only slightly above the Full Supply Level (FSL) of Cataract Reservoir (RL289.87m). The pore pressure in the Bald Hill Claystone is drawn down 20m below FSL and the pore pressure in the Bulgo Sandstone is drawn down about 60m below FSL.

This profile indicates a downward hydraulic gradient, however, the mine pump-out records indicate there is very limited vertical flow down into the Bulli Seam workings so the in-situ vertical hydraulic conductivity appears to be limiting the downward flows to the low levels observed underground.

The graph also shows there is a positive head from the VWP intake at NRE-D 70HS and the open standpipe piezometer intake (NRE-D).

The piezometric pressure in the Bald Hill Claystone and Bulgo Sandstone that are below hydrostatic and below the level of Cataract Reservoir indicates there is a downward hydraulic gradient towards the mine in these units. The possible correlation with the changes in water level in Cataract Reservoir indicates there may be a connection between NRE-D (VWP) and the reservoir even at a distance of 540m.

The VWP array responses show a slight correlation with long term rainfall, particularly in the lower two intakes as shown in **Figure 25**.

In addition to the low rainfall deficit correlation, there may be an indistinct correlation with the level of Cataract Reservoir and the Bald Hill Claystone intake (NRE-D 110BHCS).

The possible correlation indicates that there may be limited lateral connectivity between the reservoir and NRE-D vibrating wire piezometer, potentially along a horizontal to sub-horizontal shear plane at a level just below the base of Cataract Reservoir (estimated in this area to be at about RL282m).

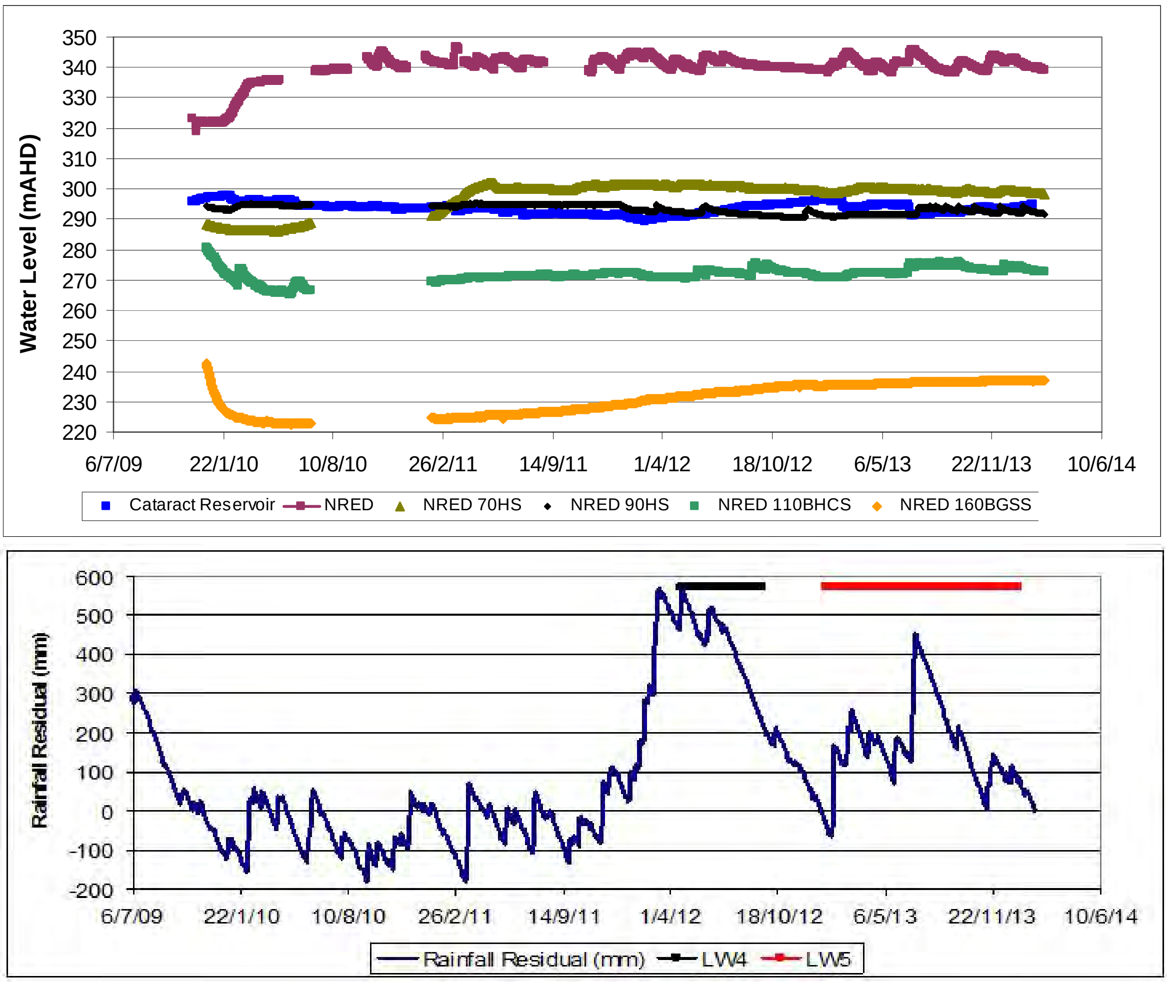


Figure 25 **NRE-D Water Levels, Rainfall Residual, Cataract Reservoir Level and Longwall Advance**

There is a hydraulic gradient away from the mine towards the reservoir in the Hawkesbury Sandstone and a hydraulic gradient from the reservoir back toward the mine at the Bald Hill Claystone and Bulgo Sandstone horizons.

The very low levels of inflow observed into the Bulli Seam indicate the hydraulic conductivity of the strata must be sufficiently low to limit any significant inflows into the mine to low levels despite this apparent possible connection.

8.3.5 Wonga West (NRE-3)

The head pressure vertical profile for NRE3 as shown in **Figure 26**, which is located at Wonga West near the southern lease boundary, indicates essentially hydrostatic pressure gradient from 100mbgl (Upper Hawkesbury Sandstone) to 155mbgl (Lower Hawkesbury Sandstone), with a decrease away from hydrostatic from 155mbgl to the Bulgo Sandstone at 255mbgl, which has not stabilised and is gradually reducing further.

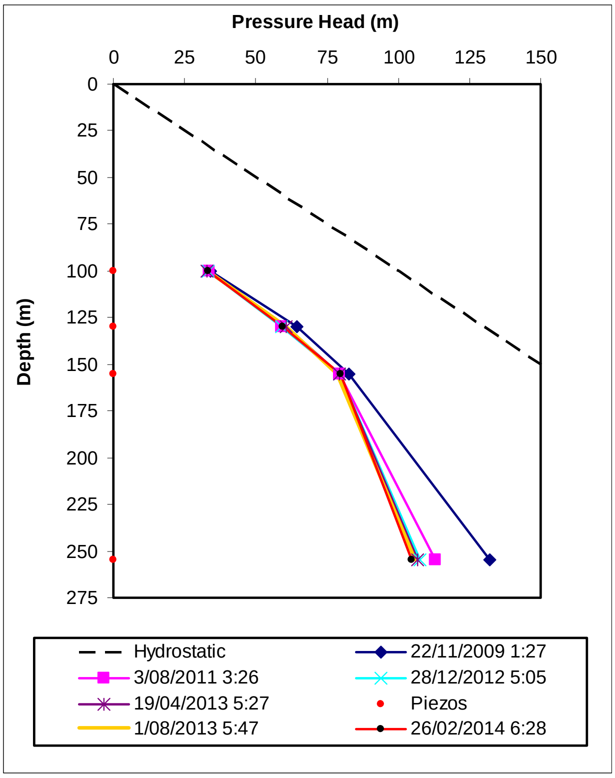


Figure 26 Wonga West NRE-3 VWP Head Pressure Profile

As shown in **Figure 27**, NRE-3 has limited response to rain events, with relatively stable pressures noted in the mid and lower Hawkesbury Sandstone (100 and 130mbgl) and in the Newport Formation (155mbgl), whilst the lower Bulgo Sandstone (255mbgl) is gradually depressurising presumably due to ongoing depressurisation associated with the historic mining of the Bulli Seam that has occurred to the west of cataract reservoir.

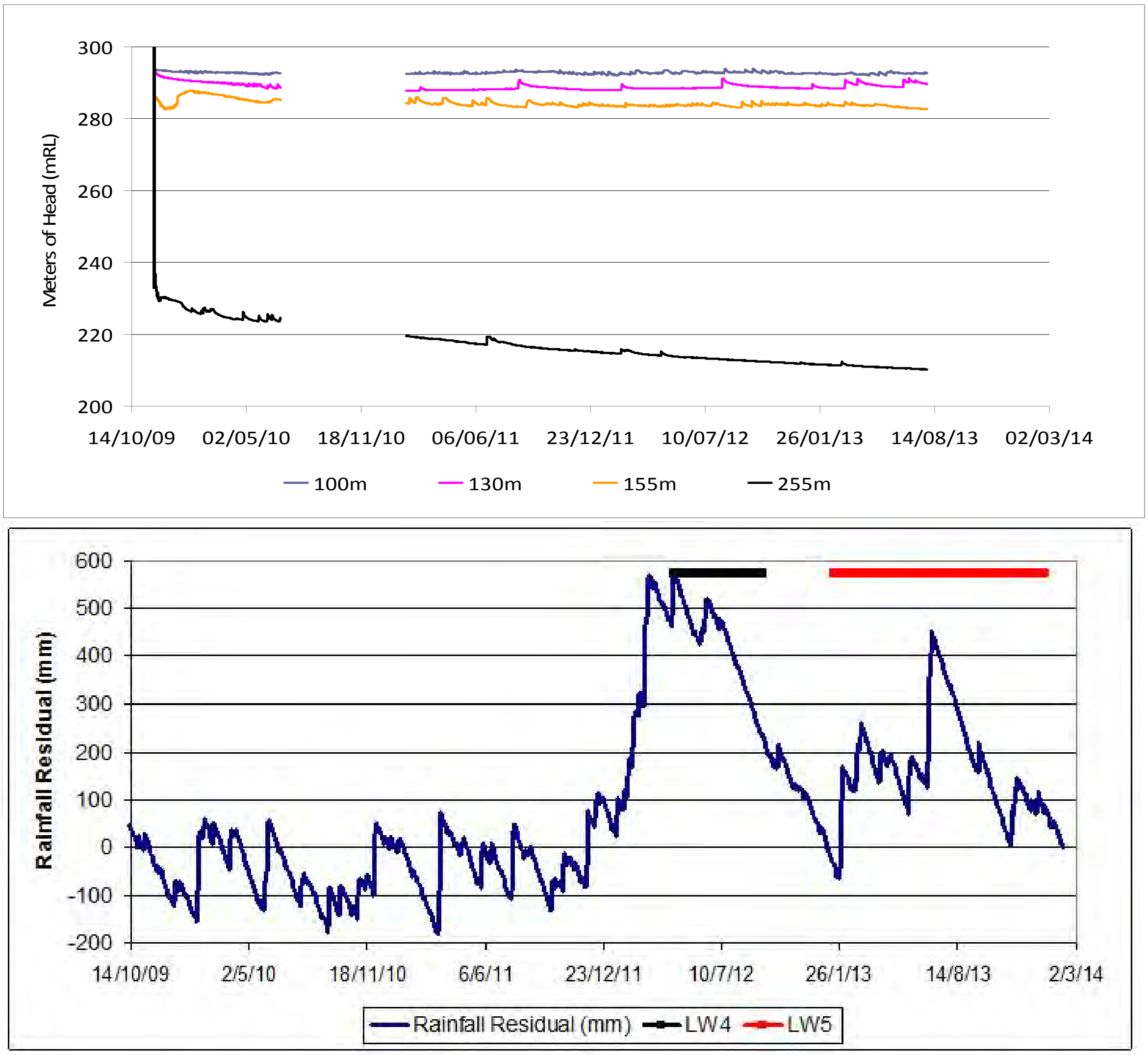


Figure 27 Wonga West NRE-3 VWP Water Levels, Rainfall Residual and Longwall Advance

8.4 Mine Water Pumping

This section outlines an adaptation of a mine water balance and groundwater assessment conducted by SCT Operations (2014).

All three seams dip to the west towards a low point in the 200 series longwall panels.

The natural pathway for water flow underground is from the outcrop on the Illawarra Escarpment down to the low point in the 200 series longwall panels. However, because of the irregular nature of the lease boundaries and the various panels within the mine, there are numerous underground storages created where water is impounded behind coal barriers within the mine and between mines.

Water flowing from up dip flows into these underground storages until they become full and overtop allowing flow to continue down into the lowest point in the mine. Over time, all the storage areas have filled up and so any additional flow occurs through a chain-of-ponds along each of the barriers. A similar process is occurring in the adjacent Old Bulli and Corrimal Collieries.

The current groundwater make from the Wongawilli Seam workings at Wonga East is approximately 1.05ML/day (383.3ML/year) as shown in **Figure 28**.

Based on considerations of how this flow has developed over time and where it has reported to in the mine, the current water make is estimated to comprise:

- 0.3ML/day from pre LW4 mining development headings in the Wongawilli Seam.
- 0.2ML/day for pre LW4 up dip inflow from upgradient adjacent workings in the Bulli and Balgownie Seams.
- 0.1ML/day additional inflow from mining Longwall 4.
- 0.5ML/day from mining Longwall 5.

8.4.1 200 and 300 Series Longwalls West of Cataract Reservoir

It is assessed there is no free drainage through the Bald Hill Claystone at Wonga West, as the existing workings are currently depressurised and essentially dry, although ponded water is present in a syncline in the central, southern section of the 200 series longwalls near as well as within the BHPB Cordeaux workings (S Wilson, pers comm.).

Monitoring of mine water pump-out from workings to the west of Cataract Reservoir, along with observations from underground supervisors (SCT Operations, 2014) indicate there is no short term increase in mine water make from the current workings following significant rain in the Lizard and Wallandoola Creek catchments.

Monitoring of water level trends in piezometers over the 200 and 300 series longwalls indicates the upper Hawkesbury Sandstone does not have an enhanced response to rainfall recharge.

8.4.2 Current Workings East of Cataract Reservoir

It is assessed there is no free drainage into the existing workings to the east of Cataract Reservoir as they are currently depressurised and essentially dry apart from a few small ponding areas at the down dip end of the old workings where the dewatering pump is not able to extract the water, until it “spills” into a downgradient section of the workings (SCT Operations, 2014).

Monitoring of water pump-out from the Wonga East workings indicates there is no observed associated short term increase in mine water make from the current Wonga East workings following significant rain in the Cataract Creek, Cataract River or Bellambi Creek catchments.

Based on available mine water balance records, the average daily groundwater inflow extracted from Russell Vale Colliery was 0.2 ML/day prior to extraction of LW4 and 1.05ML/day after extraction of LW5.

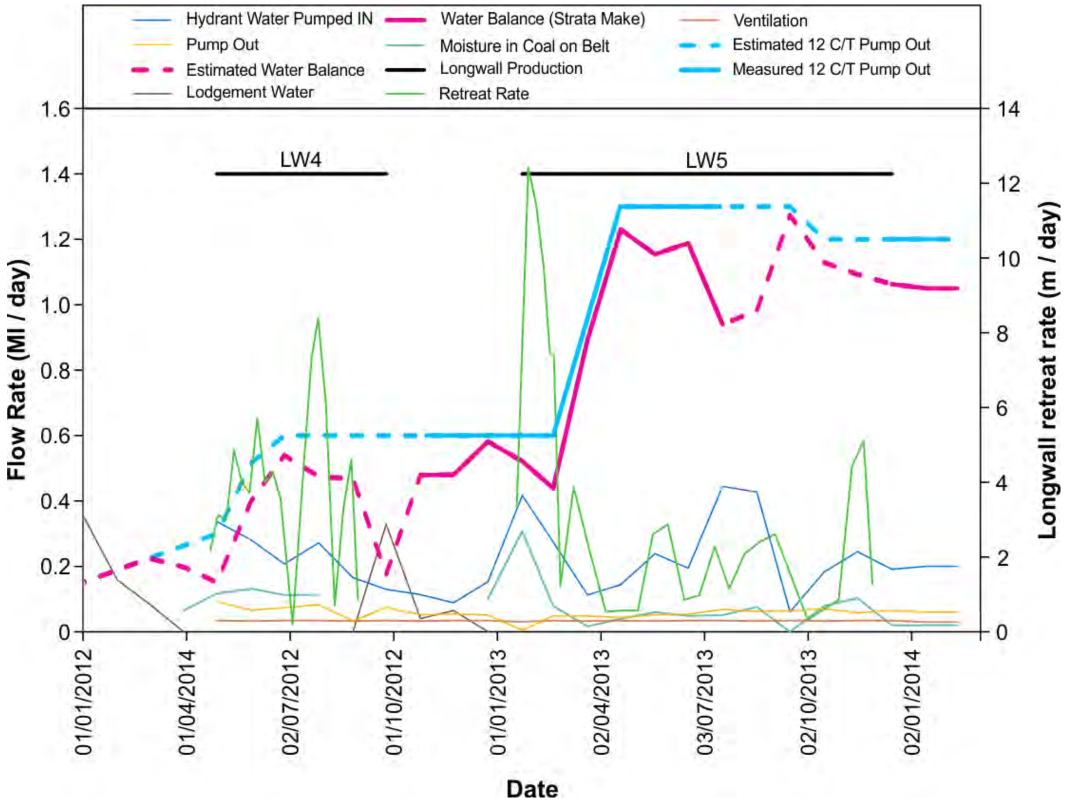


Figure 28 Russell Vale Colliery Groundwater Extraction and Rainfall

8.5 Groundwater Chemistry

Groundwater in the Hawkesbury Sandstone at Wonga East ranges from 76 - 776µS/cm with a pH from 3.2 – 6.8 as shown in **Figure 29**.

The moderate pH acidification and low salinity indicate meteoric rainfall recharge into the Hawkesbury Sandstone, with the salinity and pH range being typical of similar lithologies in the Southern Coalfields.

On the basis that the shallow groundwater discharges through seeps into the local streams, monitoring indicates the groundwater salinity is generally within the acceptable range for potable water, however it is predominantly outside the ANZECC 2000 South Eastern Australia Upland Stream criteria for pH and can be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines for:

- filtered copper, lead, zinc and aluminium (where the pH exceeds 6.5, which rarely occurs), as well as;
- total nitrogen and total phosphorus.

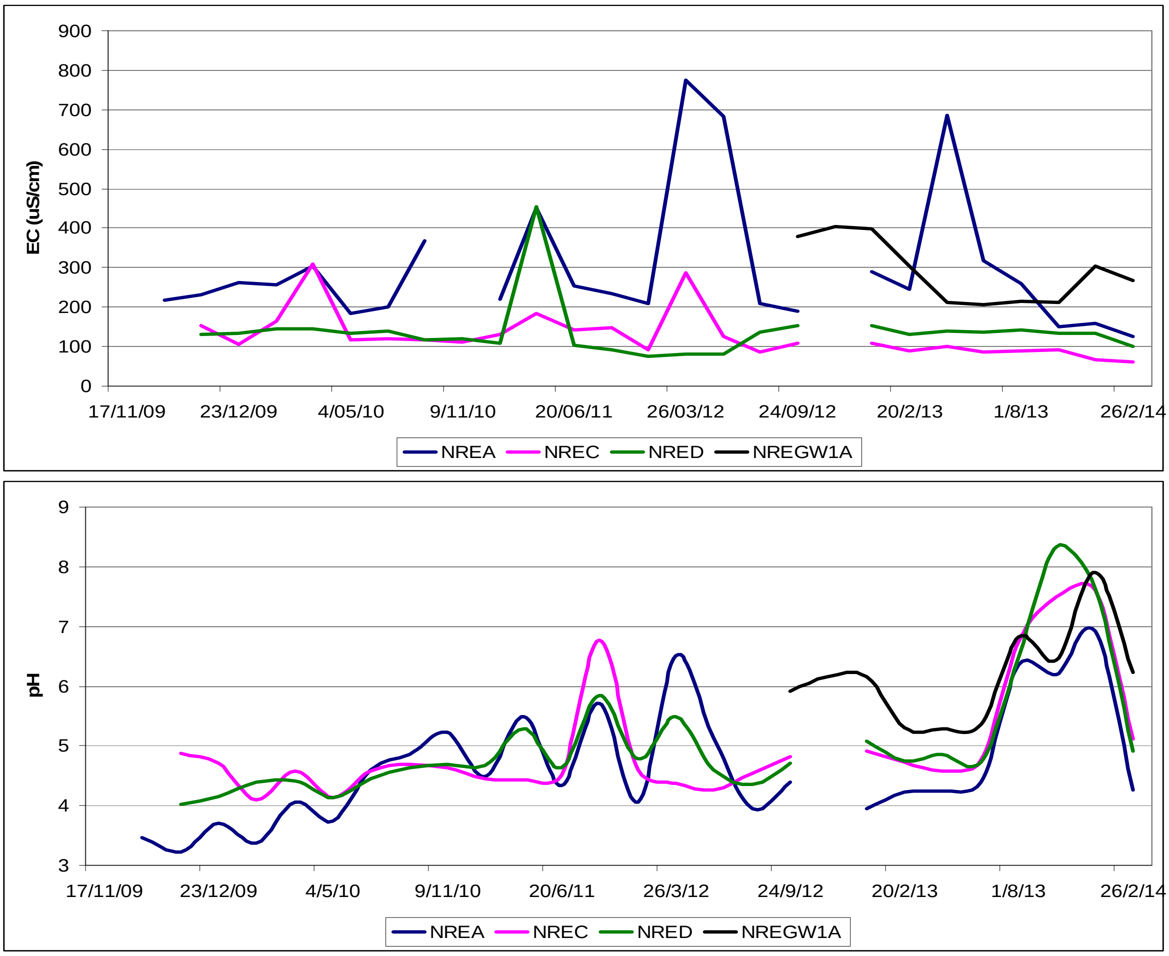


Figure 29 Wonga East Hawkesbury Sandstone Salinity and pH

Further detailed analysis of groundwater chemistry in the Wonga East area is contained in Geoterra (2014A).

9. GROUNDWATER MODELLING

Assessment of the current and potential mining related impacts due to extraction of the proposed Wonga East Wongawilli Seam longwalls on groundwater systems involved a revised conceptualisation of the local groundwater flow processes, measurement of hydraulic parameters in the field, and revised simulation using computer based mathematical modeling with MODFLOW SURFACT, imposition of changes brought about by the proposed extraction and assessment of the resulting impacts.

A previous FEFLOW based groundwater model and associated interpretation was reported in Geoterra (2012B). The previous report assessed the proposed mining in both the Wonga West and Wonga East areas, prior to revision of the mine plan to the current PPR.

The current MODFLOW SURFACT modelling was conducted to incorporate more recent drilling results and groundwater monitoring and to focus on the revised mine layout in the PPR Wonga East mining domain.

The model structure, modelling approach and simulations generated by Groundwater Exploration Services (GES) in association with Geoterra Pty Ltd and SCT Operations Pty Ltd are detailed in the following sections, with the potential groundwater impacts summarised in **Section 10.**

The groundwater model is of Moderate Complexity (under the MDBC Guidelines) with a Class 2 Confidence Level (under the NWC guidelines). It provides an assessment of the existing groundwater system status and predicts the potential effects from extraction of the proposed workings.

The key objective of this groundwater model is to simulate the current and proposed mining activities within the Wongawilli Seam in the Wonga East area and to understand the effects to groundwater and surface water environment in a local and regional context. There is extensive pre-existing depressurisation from the existing workings at Russell Vale, as well as the adjoining Cordeaux, Corrimal and Bulli mines resulting from mining activities over many decades. This includes the area immediately surrounding the Wong East proposal and also in a regional context. There has been a long period of hiatus in terms of mining activities in the Wonga East area with the extraction of the Balgownie Seam at Wonga East occurring in the 1970's.

There is also very little in the way of groundwater level data which show mining related impacts prior to Wongawilli Seam development given the amount mining activities which have historically occurred. The only known data available related to Wonga West Bulli Seam mining activities particularly in the 500 series panels. It was the monitoring of impacts of these panels in 1993 which led to the development of the model to begin transient modelling early enough to incorporate this data.

Hence the model includes stress periods which include the period in the Wonga West workings where the 500 series panels were active and monitored from early 2003 (Year 0), up to the current period, then after the end of extracting Wonga East, then up to 100 years after mining has finished in Wonga East.

Some uncertainty is present due to the lack of direct field measurement of post subsidence hydraulic conductivities applied to represent sedimentary formations above the existing workings, except at the vibrating wire piezometer bore site GW1 where packer tests were conducted.

In addition, assumptions were incorporated regarding the interactive effect of adjoining mines and workings within the overall Study Area.

The spatial relationship of the proposed and the existing workings within the model domain are shown in **Figure 30.**

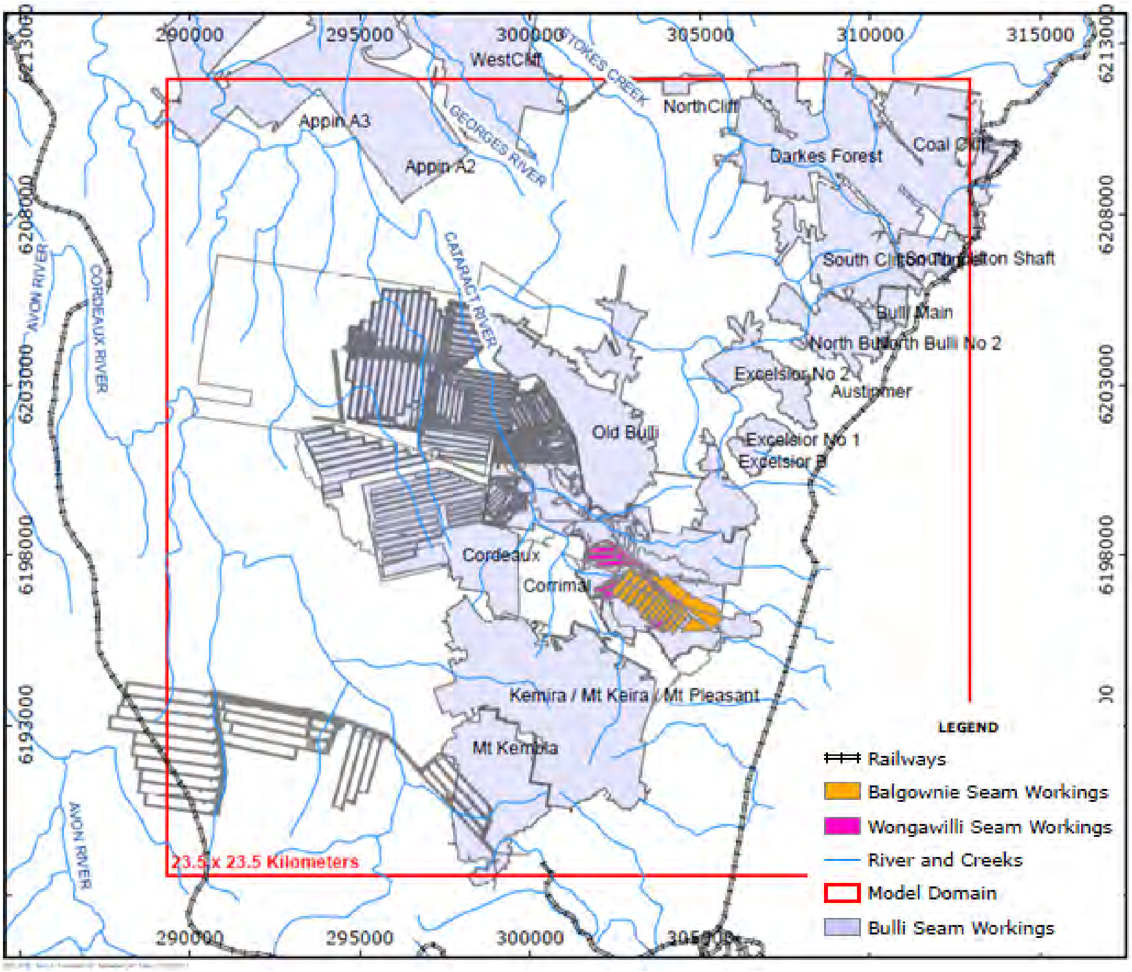


Figure 30 Russell Vale and Adjoining Mining Areas

It should be noted that the modelling requires simplification of the groundwater system in regard to lithological thicknesses, their hydraulic properties and applied stresses including previous subsidence, rainfall infiltration, creek leakage and underground seepage.

It is also challenging, within the model limitations, to represent steep hydraulic gradients above the mine workings and the potential for zero pore pressure horizons.

9.1 Conceptual Hydrogeological Model

A conceptual model of the Study Area hydrogeological regime has been developed based on a review of existing hydrogeological data as described in **Section 8** and shown in **Figure 31**, and was based on the Southern Coalfield 1:100,000 geology mapping, mine seam mapping and geological drill logs that are available from within the Russell Vale lease area.

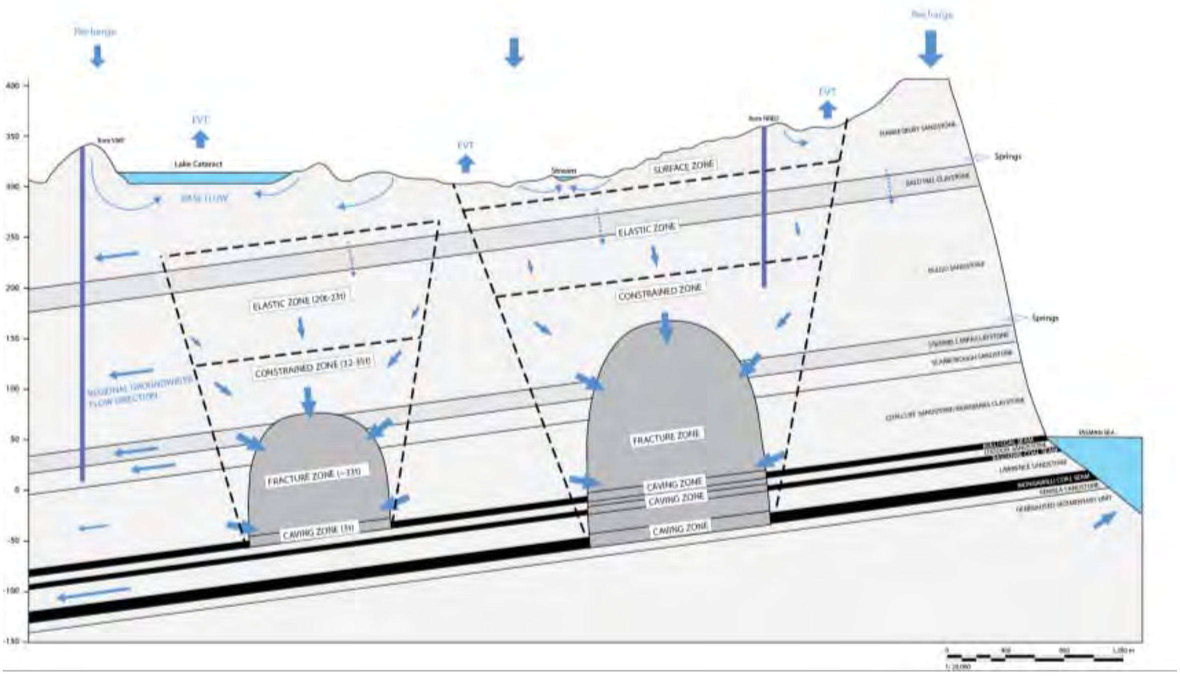


Figure 31 Conceptual Groundwater Model

Input data has also been gathered from geological and hydrogeological assessments undertaken for the Appin, West Cliff, Dendrobium and other Southern Coalfield mine lease areas.

Lithological layer depths and thicknesses within the Russell Vale lease area were based on in-situ piezometer and coal exploration drilling results within the Russell Vale lease area and from drilling data sourced from other projects.

Six conceptual groundwater sub-domains are present:

- intermittent to ephemeral, hydraulically disconnected (perched) upland swamps which provide baseflow to the local streams ;
- a perched, ephemeral weathered Hawkesbury Sandstone profile which provides baseflow to the local streams.
- the deeper Hawkesbury Sandstone, which is hydraulically separated from the overlying Quaternary sediments and weathered sandstone perched aquifers as well as from the underlying Bulgo Sandstone at Wonga West, although not at Wonga East, both before and after subsidence. Following mining, as has been observed in the piezometers to the east of the reservoir, the water levels exhibit a heightened response to recharge, or increased recharge due to the higher porosity, as well as interconnected permeability of the aquifer;
- the Narrabeen Group sedimentary lithologies which have already been locally fractured and depressurised above the existing workings up to the mid to lower Bulgo Sandstone, and are anticipated to be fractured and partially depressurised over the proposed Wongawilli Seam longwall workings up to the mid to upper Bulgo Sandstone;

- the Illawarra Coal Measures, containing the Bulli, Balgownie and Wongawilli Seam aquifers, which have also been fractured and depressurised by the existing workings and will be locally fractured and depressurised by the proposed workings, and;
- the sedimentary sequence underneath the Wongawilli Seam.

The model was set up with 18 layers to represent both the existing lithological and Bulli / Balgownie Seam subsidence affected areas, and to account for the anticipated change in hydraulic properties following extraction of the proposed workings within the Wongawilli Seam.

The existing Russell Vale Colliery workings within the model in the Bulli seam were assumed to be partially flooded in the central southern section of the longwalls to the west of Cataract Reservoir, as well as in the Cordeaux workings, and partially in the Bulli Colliery bord and pillar workings.

This is based on reported ponded areas within the Bulli Seam in the Wonga West area and estimated ponding levels within the Corrimal workings. Drain cell stages were limited to elevations above the seam for allowing ponding to occur. Wonga West drains were limited to -140m AHD and Corrimal was limited to -95m AHD. This has led to minor ponding within the seam and has removed dry cells from these areas. However, the levels are marginally higher than the base of the layers and have not led to wholesale flooding in any area.

Where the workings were dry they were modelled with seepage boundaries with head levels set to the elevation of the mine floor to simulate atmospheric pressure.

The adjoining Cordeaux and Bulli workings were assumed to be separated from Russell Vale Colliery by at least a 40m wide intact coal barrier.

9.2 Model Layers

Eighteen layers are conceptualised for the purpose of numerical modelling as shown in **Table 8**.

The major sandstone formations (Hawkesbury and Bulgo) are split into multiple layers in order to reproduce natural or mining-induced vertical hydraulic gradients.

In the mid-reach of Cataract River, the Hawkesbury Sandstone and underlying Newport / Garie Formation and the Bald Hill Claystone have been eroded away within drainage channels to enable exposure of the Bulgo Sandstone. Where this occurs, the appropriate hydraulic parameters have been propagated into overlying layers where each unit outcrops.

As a result, although Layer 1 is dominated by the upper Hawkesbury Sandstone, it also contains the Newport / Garie Formation, Bald Hill Claystone and upper Bulgo Sandstone in the eroded reach of Cataract Creek.

Similarly, but to a sequentially lesser degree, the mid and lower Hawkesbury Sandstone in Layers 2 and 3 are also eroded in the reach of Cataract Creek near the freeway, so these layers also contain the Newport / Garie Formation, Bald Hill Claystone and upper Bulgo Sandstone.

Layer 4, which predominantly contains the Bald Hill Claystone, can also contain the upper Bulgo Sandstone in the eroded reach of Cataract Creek.

All subsequent underlying layers contain only one lithology.

Table 8 Model Layers

Layer	Unit
1	Upper Hawkesbury Sandstone + NGF + BHCS +UBS
2	Mid Hawkesbury Sandstone + NGF + BHCS +UBS
3	Lower Hawkesbury Sandstone + NGF + BHCS +UBS
4	Bald Hill Claystone +UBS
5	Upper Bulgo Sandstone
6	Mid Bulgo Sandstone
7	Mid Bulgo Sandstone
8	Lower Bulgo Sandstone
9	Stanwell Park Claystone
10	Scarborough Sandstone
11	Wombarra Claystone
12	Coal Cliff Sandstone
13	Bulli Seam
14	Loddon Sandstone
15	Balgownie Seam
16	Lawrence Sandstone
17	Wongawilli Seam
18	Kembla Sandstone and Below

NOTE: NGF = Newport / Garie Formation BHCS = Bald Hill Claystone UBS = Upper Bulgo Sandstone

9.3 Boundary Conditions

The model areal extent has been chosen so that the peripheral boundary conditions are of a sufficient distance from the proposed Wonga East mining domain to significantly reduce the potential for a change in flow conditions across the model boundaries as a result of the Project.

The boundary conditions at the periphery of the model consist of:

- constant head boundaries representing active mining areas in the Wongawilli Seam including Appin (to the north) in the Bulli Seam and Dendrobium to the south;
- general head boundaries representing the coast line to the east of the escarpment and coastal plain;

- no-flow boundaries at topographic divides representing the western boundary of the model domain;
- historic mining areas, principally within the Bulli Seam, as represented by the Drain Package in MODFLOW SURFACT, have been conceptualised to remain as regional hydrogeological sinks, and;
- drainage channels which were simulated using the River Package. River stages were set 1m above base of surficial layer to allow the package to act as drainages, with their conductance set to $5m^2$/day to allow the aquifer hydraulic properties to control leakage to and from the model. Sydney Catchment Authority reservoirs, Lake Cataract and Lake Cordeaux were also simulated utilising River Package with levels set at 290m AHD and 305m AHD respectively.

The Cataract and Cordeaux reservoirs were represented with static (Steady State) River Package boundary cells.

Groundwater pressures or standing water level data from piezometers within the Study Area were used as a basis for initial conditions, whilst groundwater levels over the Cordeaux and Bulli workings were approximated, as no direct data was available.

Direct measurements of hydraulic parameters from bores within the Wollongong Coal lease were used, and where data was unavailable, approximated parameters were sourced from studies over the BHPB workings to the north (Heritage Computing, 2010).

Underground dewatering was represented by inclusion of the proposed mine voids in the Bulli, Balgownie and Wongawilli Seams through the use of drains as well as incorporating the associated changes in overburden hydraulic parameters in the overlying sedimentary units due to subsidence.

9.4 Recharge and Evapotranspiration

Recharge was set at 2% of rainfall from Woonona station data across elevated terrain west of the escarpment and to 4% over the escarpment and coastal plain, as was used in the Bulli Seam Operations modelling (Heritage Computing, 2010).

Evapotranspiration was applied uniformly to the model with rate of 0.005 m/d and an extinction depth of 4m.

9.5 Grid

A variable cell size is employed across the model domain.

A grid size of 250 x 250m occupies the periphery of the model domain, reducing to 100m x 100m nearer to the Wollongong Coal lease area, then to 50m x 50m over most of Wollongong Coal Lease area.

The grid was further reduced to 50m x 25m in an east – west alignment that overlies the main channel of Cataract Creek.

While the potential impacts from the mining activities relate to regional scale effects, experience has shown that providing more detailed grid discretisation has no significant impact on predicted mine inflows or groundwater levels as long as a mine plan can be appropriately represented.

However, the adopted grid refinement allowed for improved detailing of the mine plan scheduling and increased accuracy surrounding the baseflow effects in creeks overlying the Project.

The changes in grid size obeyed the 50% convention rule regarding changes between grid size between rows and columns with minimum ratio of cell size change being 0.75 (Environmental Simulations Inc. 2009).

9.6 Mining Schedule

The adopted mining schedule for development and the extraction of the panels within the Bulli and Wongawilli seams is shown in **Table 9**.

The model start date is 1/1/1993, whilst the calibration period is from 1/1/1993 to 28/2/2014. This includes the 500 series panels in Wonga West within the Bulli seam in 1993 and the initial mine development in the Wongawilli Seam at Wonga East, which began in early 2011. The interim period included a large hiatus where no significant mining activities occurred.

The period of predictive analysis occurs from 28/2/2014 to 28/8/2018 with the completion of LW3. The recovery period includes the subsequent 200 years to 1/1/2220.

Detailed time stepping has been used to simulate the Wongawilli Seam development and mining progression in the Wonga East area is shown in **Figure 32**.

In order to investigate the incremental effects of mining, the predicted operational mining impacts and the post mining recovery have been assessed in accordance with the adopted schedule.

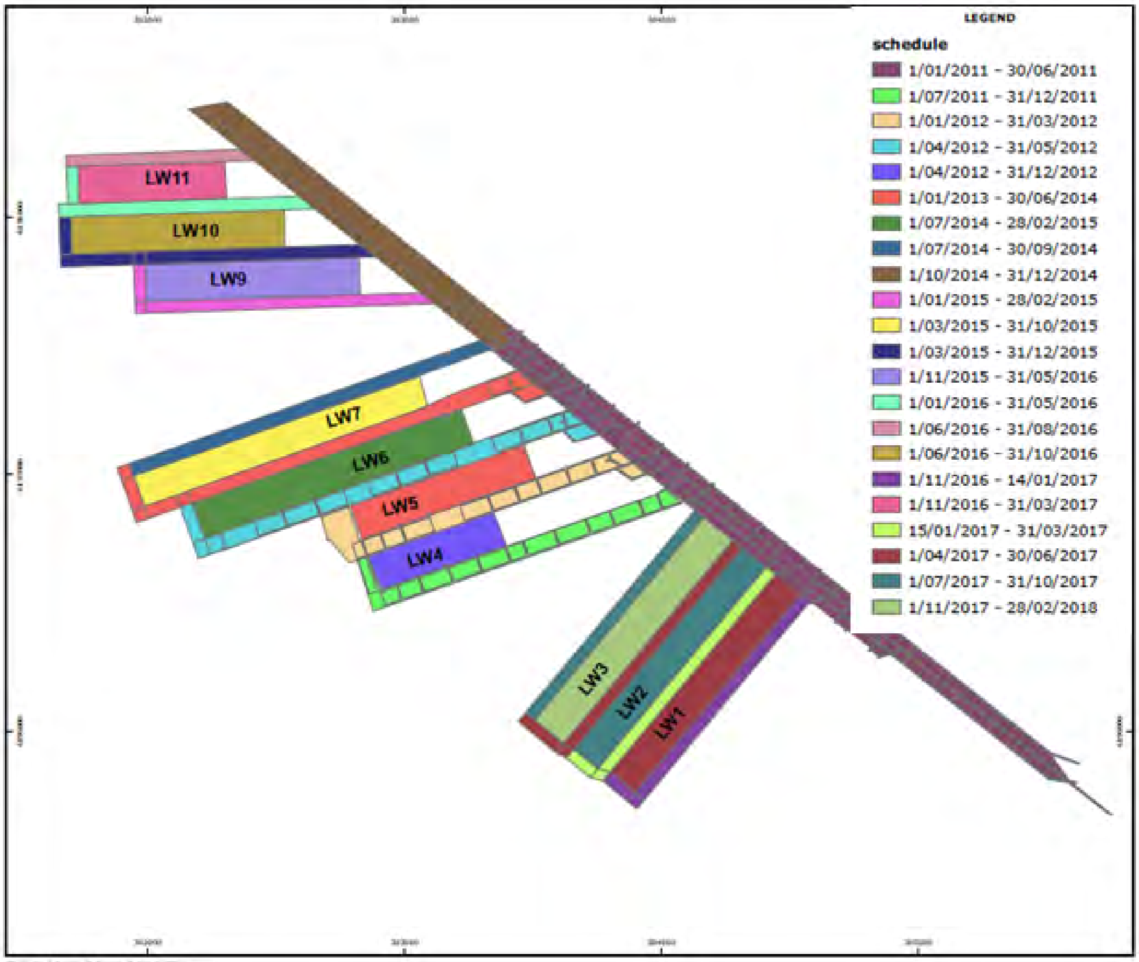


Figure 32 Mining Schedule in Wongawilli Seam

Table 9 Mine Schedules Used for the Impact Assessment

						MINING AREAS / LONGWALLS			
Model Type	**Purpose**	**SP**	**SP_START**	**SP_END**	**SP Length (DAYS)**			**Wonga West**	All Other Bulli Seam Mines
Steady State	'PRE-MINING'	1	01-Jan-91	31-Dec-92	731				
Transient Calibration	HISTORIC	2	1/01/1993	11/07/1993	192				modelled as constant
	HISTORIC	3	12/07/1993	13/12/1993	155			501	
	HISTORIC	4	14/12/1993	18/05/1994	156			502	
	HISTORIC	5	19/05/1994	28/09/1994	133			503	
	HISTORIC	6	29/09/1994	6/02/1995	131			504	
	HISTORIC	7	7/02/1995	19/06/1995	133			505	
	HISTORIC	8	20/06/1995	26/11/1995	160			506	
	HISTORIC	9	27/11/1995	16/08/1996	264			507	
	HISTORIC	10	17/08/1996	25/05/1997	282			508	
	HISTORIC	11	26/05/1997	31/12/1997	220			509	
	HISTORIC	12	1/01/1998	31/12/1998	365			no mining	
	HISTORIC	13	1/01/1999	31/12/1999	365				
	HISTORIC	14	1/01/2000	31/12/2000	366				
	HISTORIC	15	1/01/2001	31/12/2001	365				
	HISTORIC	16	1/01/2002	31/12/2002	365				
	HISTORIC	17	1/01/2003	31/12/2003	365				
	HISTORIC	18	1/01/2004	31/12/2004	366				
	HISTORIC	19	1/01/2005	31/12/2005	365				
	HISTORIC	20	1/01/2006	31/12/2006	365				
	HISTORIC	21	1/01/2007	31/12/2007	365				
	HISTORIC	22	1/01/2008	31/12/2008	366				
	HISTORIC	23	1/01/2009	31/12/2009	365				
	HISTORIC	24	1/01/2010	31/12/2010	365				
	HISTORIC	25	1/01/2011	31/03/2011	90	Mains			
	HISTORIC	26	1/04/2011	30/06/2011	91	Mains			
	HISTORIC	27	1/07/2011	31/12/2011	184	MG4			
	HISTORIC	28	1/01/2012	31/03/2012	91	TG4			
	HISTORIC	29	1/04/2012	31/05/2012	61	TG5			
	HISTORIC	30	1/06/2012	31/07/2012	61				
	HISTORIC	31	1/08/2012	31/08/2012	31		LW4		
	HISTORIC	32	1/09/2012	31/10/2012	61				
	HISTORIC	33	1/11/2012	31/12/2012	61				
	HISTORIC	34	1/01/2013	14/02/2013	45				
	HISTORIC	35	15/02/2013	31/03/2013	45				
	HISTORIC	36	1/04/2013	31/05/2013	61		LW5		
	HISTORIC	37	1/06/2013	31/07/2013	61				
	HISTORIC	38	1/08/2013	14/08/2013	14				

	HISTORIC	39	15/08/2013	31/08/2013	17				
	HISTORIC	40	1/09/2013	14/09/2013	14	TG6			
	HISTORIC	41	15/09/2013	30/09/2013	16				
	HISTORIC	42	1/10/2013	14/10/2013	14				
	HISTORIC	43	15/10/2013	31/10/2013	17				
	HISTORIC	44	1/11/2013	14/11/2013	14				
	HISTORIC	45	15/11/2013	30/11/2013	16				
	HISTORIC	46	1/12/2013	14/12/2013	14				
	HISTORIC	47	15/12/2013	31/12/2013	17				
	HISTORIC	48	1/01/2014	28/02/2014	59				
Prediction	IMPACT	49	1/03/2014	30/06/2014	122				
	IMPACT	50	1/07/2014	30/09/2014	92	TG7			
	IMPACT	51	1/10/2014	31/12/2014	92	Mains	LW6		
	IMPACT	52	1/01/2015	28/02/2015	59	MG9			
	IMPACT	53	1/03/2015	30/06/2015	122	TG9	LW7		
	IMPACT	54	1/07/2015	31/10/2015	123				
	IMPACT	55	1/11/2015	31/12/2015	61	TG9			
	IMPACT	56	1/01/2016	29/02/2016	60		LW9		
	IMPACT	57	1/03/2016	31/05/2016	92	TG10			
	IMPACT	58	1/06/2016	14/07/2016	44				
	IMPACT	59	15/07/2016	31/08/2016	48	TG11	LW10		
	IMPACT	60	1/09/2016	31/10/2016	61				
	IMPACT	61	1/11/2016	14/01/2017	75	MG1	LW11		
	IMPACT	62	15/01/2017	31/03/2017	76	TG1			
	IMPACT	63	1/04/2017	30/06/2017	91	TG2	LW1		
	IMPACT	64	1/07/2017	31/10/2017	123	TG3	LW2		
	IMPACT	65	1/11/2017	28/02/2018	120		LW3		
	RECOVERY	66	1/03/2018	31/12/2019	671	**Turn off DRN**	**Turn off DRN**		
	RECOVERY	67	1/01/2020	31/12/2029	3653				
	RECOVERY	68	1/01/2030	31/12/2069	14610				
	RECOVERY	69	1/01/2070	31/12/2119	18261				
	RECOVERY	70	1/01/2120	31/12/2169	18263				
	RECOVERY	71	1/01/2170	1/01/2220	18262				

9.7 Model Implementation

The underground mining and dewatering activity is defined in the model using drain cells within the mined coal seams, with modelled drain elevations set to 0.5m above the base of the Bulli Seam (Layer 13), Balgownie Seam (Layer 15) and Wongawilli Seam (Layer 17).

These drain cells were applied wherever workings occur and were maintained as constant within the Bulli and Wongawilli Seam and implemented in line with mine progression in the Wongawilli Seam. Mining prior to the transient modelling period was simulated as steady state within the Bulli Seam (Layer 13) and Balgownie Seam (Layer 15).

The model set-up involved changing the parameters with time in the goaf and overlying fractured zones directly after mining of each panel, whilst simultaneously activating drain cells along all development headings. The development headings were activated in advance of the active mining and subsequent subsidence. Although the coal seam void should be dominated by the drain mechanism, the horizontal and vertical permeabilities were raised to 10 m/day to simulate the highly disturbed nature within the caved zone.

9.8 Existing Mine Workings

Extensive abandoned mine workings occur regionally within the Bulli seam and extend the length of the escarpment within the model domain as shown in **Figure 30**.

Adjacent to the proposed Project, there are large areas of abandoned Bulli workings to the north and immediately to the south of the Wollongong Coal lease boundary as well as the combined Corrimal / Cordeaux complex to the south in the Bulli seam. The model maintains active sinks using drain cells with invert levels 0.1m representing Bulli Seam workings at the following decommissioned operations:

- Old Bulli;
- Excelsior 1, 2 and B;
- North Bulli;
- South Clifton Tunnel;
- Darkes Forest;
- Coal Cliff;
- Corrimal;
- Cordeaux, and;
- Mt Kembla.

Drain cell invert levels were set at 0.1m above the seam floor and were maintained throughout transient modelling with the exception of small areas in Wonga West at Russell Vale, where drain cell invert levels were raised slightly to mimic reported ponding in some areas. No flooding was indicated in any of these areas as the levels of ponding are not reported to be extensive.

The degree of hydraulic connectivity between the Corrimal / Cordeaux complex and the older mine workings adjacent to the Wollongong Coal lease area is currently unknown and has been assumed in the model to be constrained by hydraulic conductivities of the host strata.

Active mining within the Bulli Seam is occurring in the northern periphery of the model in the form of the BHPB Appin workings. Additionally, active mining is occurring within the Wongawilli seam at Dendrobium at the southern boundary of the model area.

9.9 Fracture and Depressurisation Zone Implementation

The post Wongawilli Seam extraction subsidence parameter distribution was based on a conceptual understanding of longwall mine subsidence geomechanics and fracture development as detailed in SCT Operations (2013).

Layer definition within the model has allowed primary mined coal seams to be represented individually. It also allows the overburden to be subdivided into multiple layers and therefore allows subsidence caving and fracturing effects to be simulated to various heights above each mined seam so that the impact of progressive caving and fracturing associated with the mining is adequately represented.

The fractured zone was simulated with horizontal hydraulic conductivity enhanced by a factor of two, and with vertical hydraulic conductivity enhanced according to a function which varied the vertical hydraulic conductivity field within the deformation zone overlying coal extraction areas and “weighted” the permeability changes based on layer thickness.

Limits for the variability were governed by the predicted fracture height, based on Tammetta (2012) and the pre-determined upper and lower bounds of hydraulic conductivity. These were manipulated to allow the height of depressurisation which follows an empirical equation based on historical data for single seam mining environments to be followed in this multiple seam mining environment.

9.9.1 Height of Fracturing and Associated Zone of Depressurisation

Based on in-situ monitoring, the hydraulic characteristics of strata overlying or adjacent to the extracted Bulli, Balgownie and Wongawilli Seam secondary workings have been altered due to subsidence that may have generated atmospheric depressurisation up to the lower Bulgo Sandstone following extraction of Longwalls 4 and 5 in the Wongawilli Seam.

Where mining in all three seams has occurred, or will occur, there is a potential for interaction between surface water features and the top of the depressurised groundwater zone that is recharged from rainfall and adjacent creeks. The potential may be enhanced if there is interaction between the hillslope basal shear plane that may have been re-activated by subsidence and the top of the zone of depressurisation above each longwall panel.

There is considered to be some potential for interaction between the zone of depressurisation and the basal shear planes in the shallower areas at the northern ends of Longwall 2 and 3 as well as at the northern end of Longwall 7. At the northern end of Longwall 7, the area where three seams have been mined is limited in extent and the height of depressurisation may be less as a result. Further monitoring is planned and has been applied for approval by the SCA to establish the height of depressurisation when all three seams have been mined.

Further in-situ field assessment via installation of additional vibrating wire piezometer arrays is planned in the short term to determine the height of depressurisation above the southern end of Longwall 4, which has also been planned and applied for approval by the SCA, where all three seams have been mined.

To date, the multi-seam estimated height of depressurisation is limited to the one location (GW-1), which is not located over the centre of a Wongawilli Seam longwall (SCT Operations, 2014).

Based on mine water balance monitoring and rainfall observations, free drainage through vertically connected fracturing from the surface streams and in the overall catchment is not apparent over the existing workings at Wonga East (SCT Operations, 2014).

In the groundwater model, it was assumed that the enhanced hydraulic conductivity after extraction of the proposed longwalls could enable free drainage within the goaf and overlying fractured strata, with vertical connective fracturing to the Upper Bulgo Sandstone / Lower Hawkesbury Sandstone.

Plastic deformation with bed delamination, without significantly enhanced vertical hydraulic connectivity was interpreted to be present from the mid / upper Bulgo Sandstone to 20m below surface where overlapping triple seam extraction was not present.

Due to limitations of the model setup capability and the scale of the model, it was not possible to represent any changes in hydraulic conductivity of the thin (<2m) Quaternary alluvial / colluvial and upland swamp profiles in the upper section of model Layer 1.

The predicted height of the depressurisation zone above the lowest mined seam, using the adapted Tammetta (2012) empirical equation, with linear addition of the extracted seam heights, is shown in **Figure 33** for the Wollongong Coal lease area, and for Wonga East in **Figure 34.** The height of separation between the predicted top of the depressurisation zone and the ground surface is shown in **Figure 35**.

It should be noted that although the adapted Tammetta (2012) method indicates the potential height of complete "depressurisation", and the figures indicate the theoretical separation distance from this zone to surface, strata depressurisation can not transgress through unsaturated strata between the surface water system and the underlying, separated, groundwater system. Therefore, the streams and swamps are hydraulically separated from the underlying "depressurisation" zone within the regional groundwater system.

This means that although depressurisation (which is associated with subsidence related fracturing) may be "predicted" to reach the surface, based on the theoretical Tammetta (2012) methodology, the streams and swamps will not necessarily be adversely affected by subsidence, unless connected, enhanced vertical conductivity strata are generated due to subsidence, and extend to the base of the swamps or stream beds.

The partial "depressurisation" zone generally extends higher up into the subsided strata than the "fractured", vertically connected, enhanced hydraulic conductivity zone.

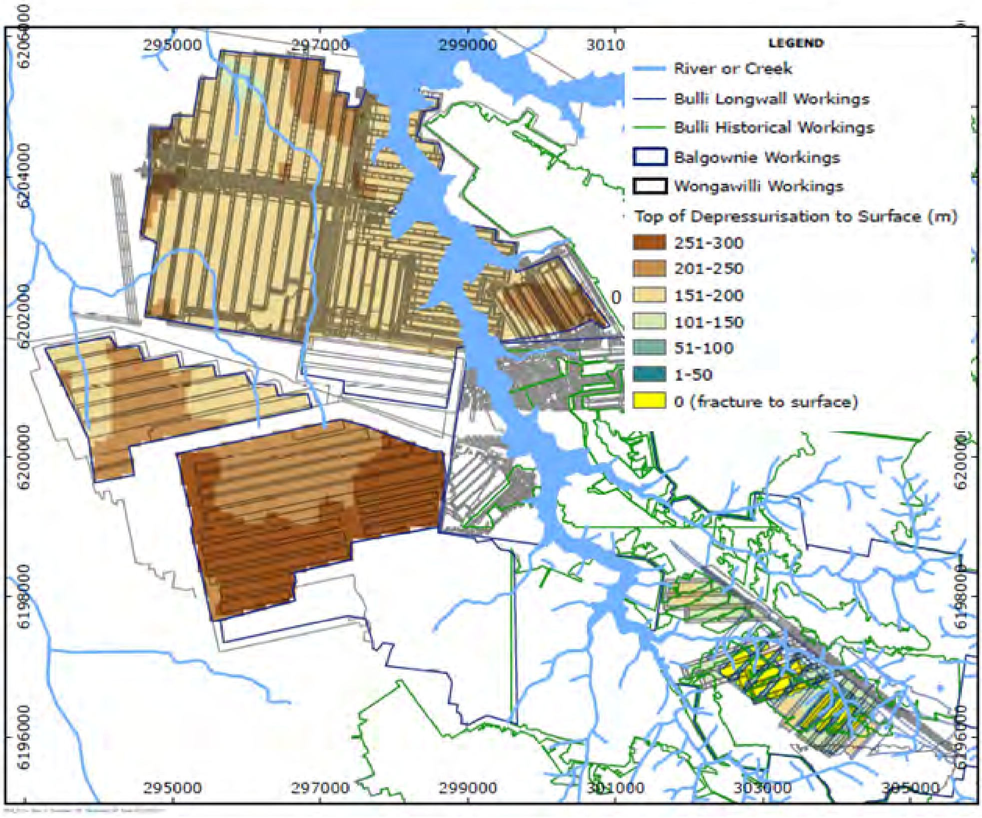


Figure 33 **Predicted Height of Russell Vale Colliery Depressurisation Zone above the Lowest Mined Seam**

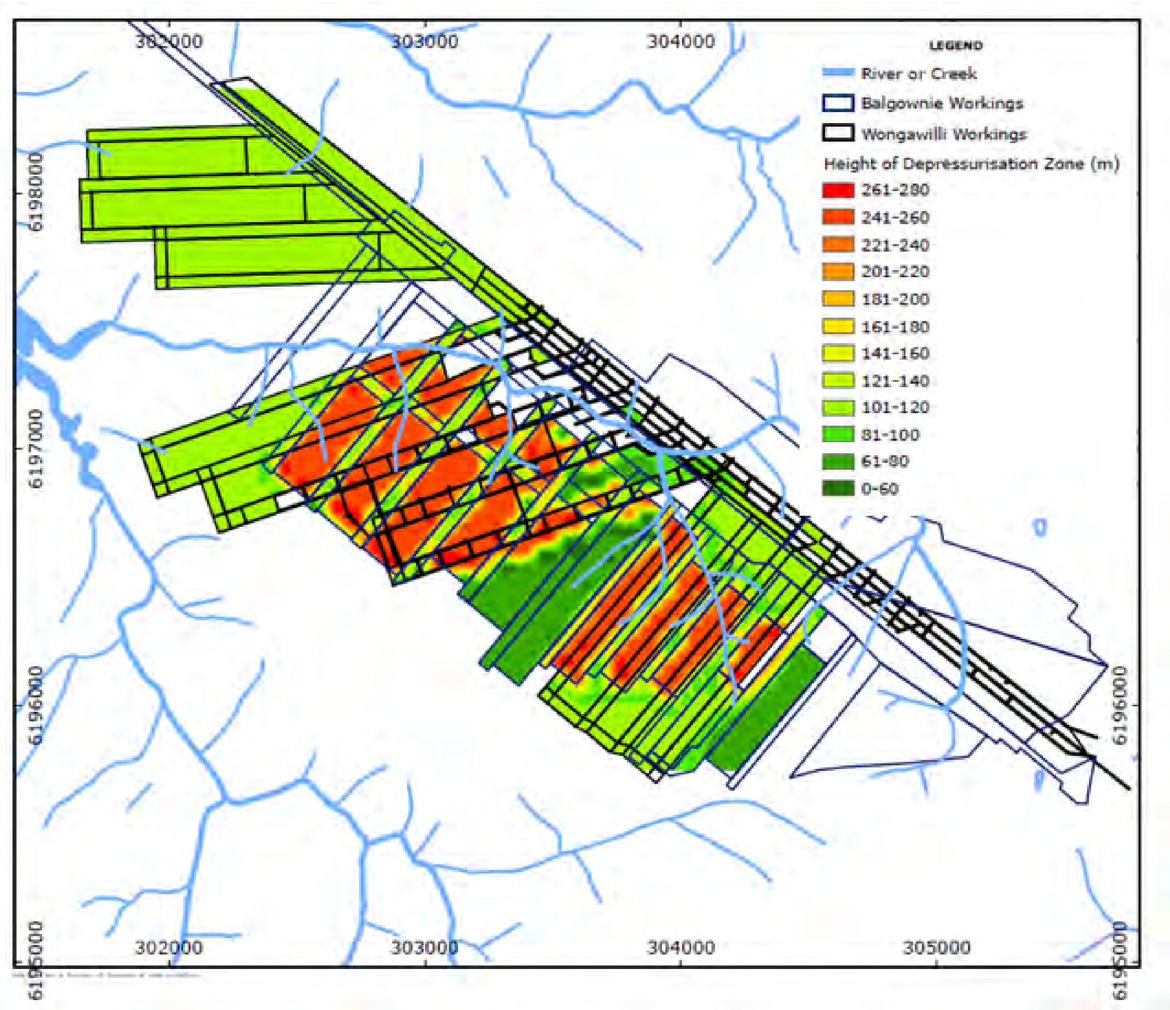


Figure 34 Predicted Height of Wonga East Depressurisation Zone above the Wongawilli Seam

Figure 35 indicates that, based on the inherent assumptions in the Tammetta (2012) empirical method and the adaptation of this equation to multi-seam mining, the depressurisation zone may reach the ground surface over the already extracted Wongawilli Seam Longwalls 4 and 5.

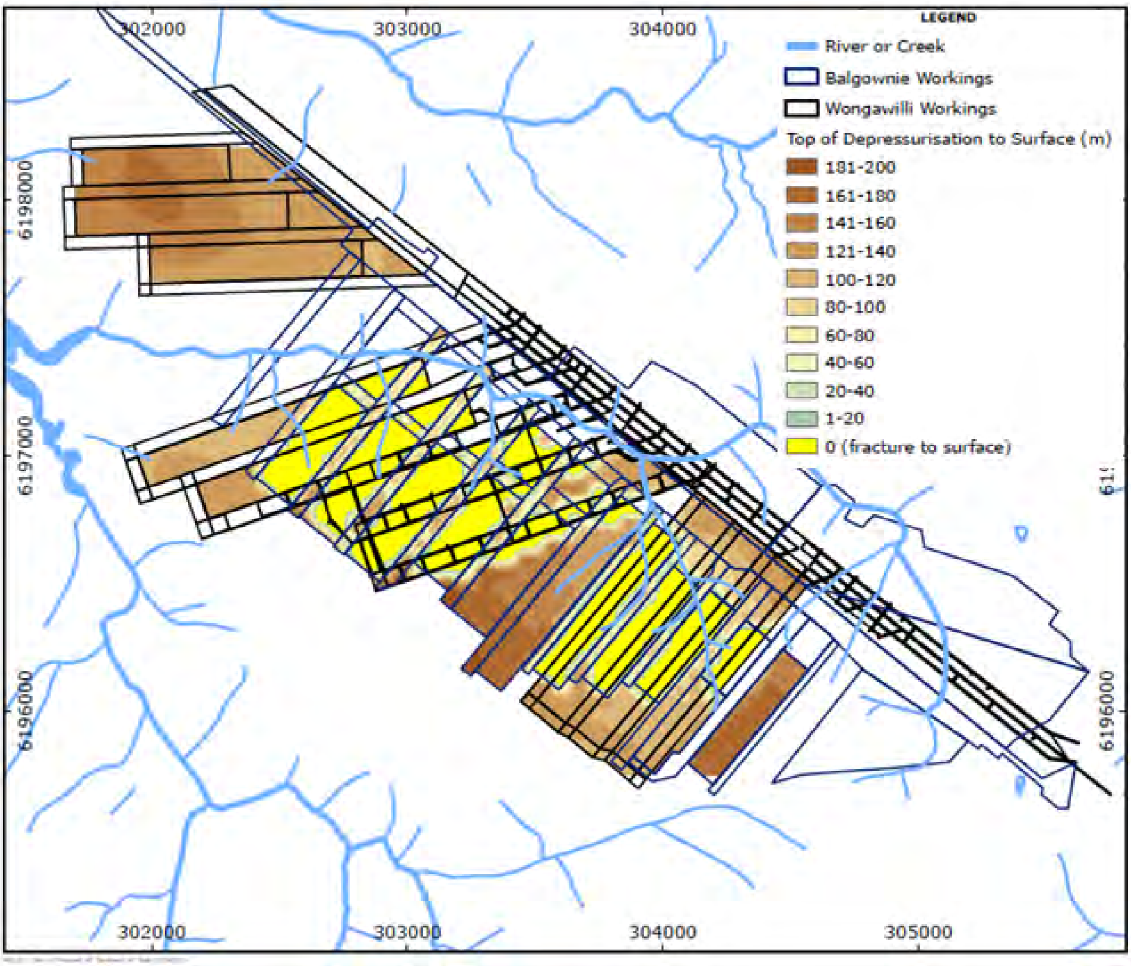


Figure 35 Predicted Height of Separation Between the Top of the Predicted Depressurisation Zone and the Ground Surface

The depressurisation "zone" may also potentially reach the ground surface over the eastern and central sections of Longwalls 6 and 7, but not over Longwalls 9 to 11 (due to the absence of triple seam mining at that location).

The depressurisation zone may also reach the ground surface over the eastern and central sections of Longwalls 1 to 3, where there are stacked, overlying, Bulli, Balgownie and Wongawilli secondary extraction workings.

It should be noted that the adapted Tammetta (2012) method is a conservative assessment of the potential height of depressurisation, and that, although the "atmospheric pressure" depressurisation zone may extend to surface, that does not mean the vertically connected, enhanced permeability, fractured strata will cause a "full" direct connection of surface waters to the mine workings to the degree where total loss of stream flow or swamp water occurs.

This is supported by the observation that although "surface to seam" depressurisation has potentially occurred over the extracted Longwalls 4 and 5 in the Wongawilli Seam (according the adapted empirical Tammetta (2012) model), the overlying swamps have not been observably drained, there are no observable changes to flow or pool levels in Cataract Creek and the mine inflows after Longwall 5 equate to 1.05 ML/day (383.3ML/year).

Of the measured 1.05ML/day mine inflow, 0.1ML/day of inflow is assessed to have occurred due to mining Longwall 4, with 0.5ML/day coming from mining Longwall 5. However the make up component of the inflows from stream flow losses and strata depressurisation is not known.

9.10 Model Calibration

Model calibration involves comparing predicted (modelled) and observed data and making modifications to model input parameters where required, within reasonable limits defined by available data and sound hydrogeological judgment, to achieve the best possible match.

Model calibration performance can be demonstrated in both quantitative (head value matches) and qualitative (pattern-matching) terms, by:

- Contour plans of modelled head, with posted spot heights of measured head;
- Hydrographs of modelled versus observed bore water levels;
- Water balance comparisons; and
- Scatter plots of modelled versus measured head, and the associated statistical measure of the scaled root mean square (SRMS) value.

Due to the complex interactive depressurisation effects of the existing subsidence and adjacent workings on groundwater levels and the predominantly “dry” nature of the Russell Vale workings, model calibration focussed on matching observed and modelled groundwater levels and mine inflows particularly during periods where mining impacts can be observed.

The scaled RMS value is the RMS error term divided by the range of heads across the site and it forms a quantitative performance indicator. Given uncertainties in the overall water balance volumes (e.g. it is difficult to directly measure evaporation and baseflow into the creeks), it is considered that a 10% scaled RMS value is an appropriate target for this study, with an ideal target for long term model refinement suggested at 5% or lower. This approach is consistent with the best practice Australian groundwater modelling guidelines (SKM, 2012).

Calibration was conducted initially as steady state (i.e. calibration to assumed long-term equilibrium conditions) and subsequently transient (i.e. calibration to the impacts of time-dependent stresses such as pumping and or climatic variation).

Steady state calibration was used to compare assumed long term average groundwater levels with groundwater levels prior to the transient calibration period (1993 – 2013).

Subsequent transient or “history match” calibration was conducted using the steady state model to determine initial conditions. The transient calibration period included underground mining in the Bulli Seam in the 500 Series panels in the Wonga West area and more recently in the Wongawilli Seam.

Transient calibration was to a degree restricted by the lack of monitoring locations within Permian aquifers. Attention was placed on achieving a level of inter-connection of underground mining areas to match the assessed drawdown response seen, particularly in the monitoring points over the 500 series longwall panels.

9.10.1 Calibration Targets

The model compares target values against model results and interpolates results in both space and time to compute an error or residual. A total of 32 groundwater monitoring locations including standpipes and multi-level vibrating wire piezometers have been used for steady state calibration. A total of 24 monitored horizons from 11 monitoring locations provided a total of 2328 temporal head targets which were included in the transient calibration.

The available monitoring based target points are distributed through the upper overburden layers, with no monitoring present below the Scarborough Sandstone.

Transient groundwater levels were taken from all records at each borehole where data was available. A full list of the calibration targets, including the Layers monitored and a comparison of actual versus modelled groundwater heads is included in Appendix A.

Groundwater inflows to active mining areas provide a valuable calibration measure and are critical for achieving a robust calibration. Historically, water balance records and, particularly mine inflow records for the Russell Vale Mine lease and other adjacent mining operations, have not been well recorded.

Considerable effort has recently been undertaken by SCT Operations (2014) to better understand water balance variables from data available from which a review of inflows has led to revised water make estimates. It is this data for mine inflows which was utilised during the calibration process.

9.10.2 Steady State Calibration

Steady state (or baseline ‘long term’) calibration was carried out as the first stage of the calibration process.

Given that the hydrogeological environment in this region is highly impacted from historical mining activities, achieving pre-mining steady state conditions was not the focus of the initial steady state modelling, rather it was focused on attaining realistic starting head conditions for transient calibration was the primary objective.

The steady state calibration allowed for initial head distributions in the model layers to be generated and to check assumptions on the conceptual hydrogeological processes.

It is acknowledged that steady state target heads were gathered from monitoring data that has considerable temporal range. However, the limited availability of monitoring data meant this was the best achievable option. Target heads were derived from numerous monitoring periods including 1992 – 1998 and 2007 – 2011. While the appropriateness of this may be questioned, the lack of any monitoring data with sufficient spatial distribution prior to the calibration period provided little opportunity to derive starting heads with any confidence and hence monitoring data with a range of dates was used to derive initial heads.

The steady state model was calibrated to groundwater levels as close as possible to the beginning of 1991, assuming these to be close to long term average groundwater levels.

Figure 3 shows that this year had a stable climate and preceded a period of drought.

In the Wonga East area, transient mining stresses had not occurred since completion of the Balgownie Seam extraction, which was completed in the 1980’s, and hence groundwater levels were assumed to have reached a relatively stable position particularly within shallower stratigraphy where most of the monitoring network is screened.

The pre-mining water levels in all bores have, to some extent, been influenced by the surrounding mining operations over an extended period of time. With this in mind, the steady state model calibration was principally used to provide an acceptable set of starting conditions for the transient calibration model.

Prior to undertaking transient calibration, these models were run in a “pseudo steady state” whereby the steady state model was run in a transient mode for a period of 10,000 days with no transient stress boundary condition variability. This was undertaken to assess the impact of changes to water levels and mine inflows etc. from the influence of storage and potential instability through transition of the hydrographs from steady state to transient model types.

9.10.3 Transient Calibration

Transient calibration against groundwater levels was carried out for the period 1993 to 2013 inclusive, utilising 24 target locations comprised of single screen standpipes and multi-level vibrating wire piezometers.

Although this period covers an extended time where limited to no significant secondary extraction occurred in the Wollongong Coal mine lease (1998 – 2010), it covers two periods where groundwater hydrographs show a response to mining influences.

Following completion of mining in the 500 series panels, apart from some limited areas of pillar extraction, no longwall mining was undertaken within the Wonga West area.

Mining was re-started in the Wonga East area, with development of first workings in the Wongawilli Seam in 2011 followed by extraction of Longwalls 4 and 5 commencing in April 2012.

All mines were represented using conventional drain cell representation.

The RMS value for the calibration period is 5.7m, whilst the scaled root mean square (SRMS) error is 2.6% (within the target range of 10%). The SRMS value is the RMS value divided by the range of heads across the site, and forms the main quantitative performance indicator. This result is consistent with the relevant groundwater modelling guideline (SKM, 2012).

The scatter diagram of measured versus modelled potentiometric head targets is plotted in **Figure 36** and it can be seen that the model is reasonably well balanced against the targets (i.e. there is no systematic under or over prediction). However, there are some significant departures from the matching curve and these can be attributed to bore failures during mining progression.

However, to some degree, this statistical measure is positively influenced by the transient data points in the GW1 VWP that is screened within the Scarborough Sandstone. This is the case even with its poor match due to the low elevation of the piezometer relative to other target monitoring elevations, and its effect in increasing the elevation range of the targets data.

Removal of GW1 from the calibration data set has a positive impact of the calibration statistics although it not overly dramatic. The RMS value for the calibration period would drop to 4.9m if GW1 were excluded.

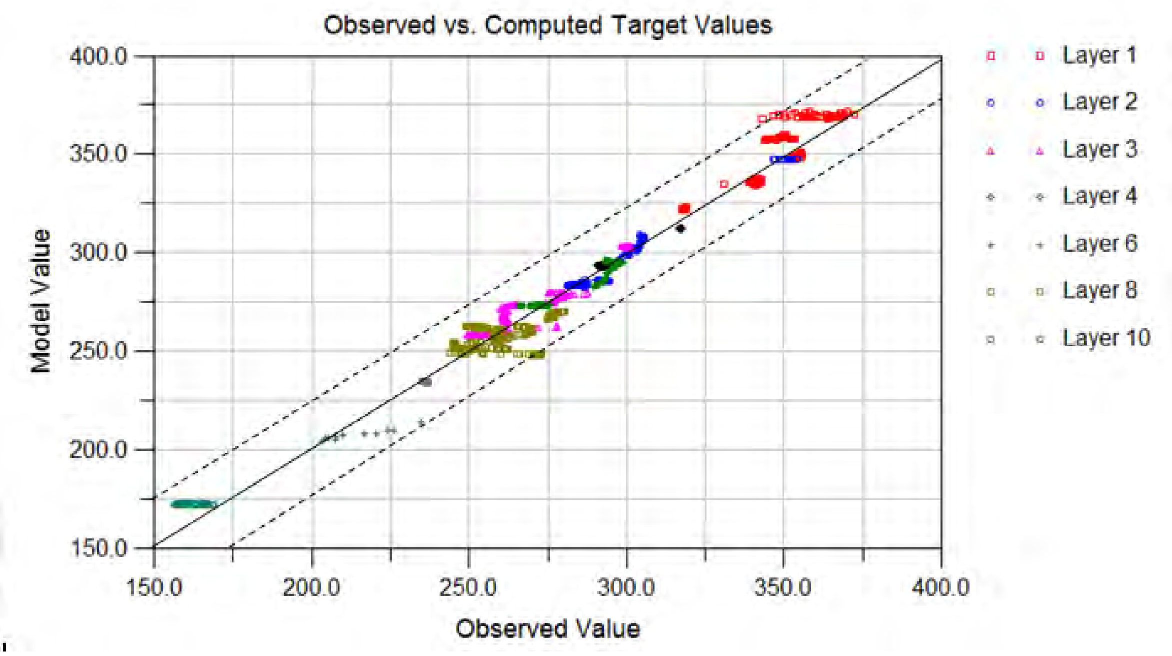


Figure 36 Measured Vs Modelled Potentiometric Head Targets

9.10.4 Calibrated Hydraulic Properties

Table 10 summarises the calibrated hydraulic properties of the modelled layers.

Table 10 Calibrated Hydraulic Properties

Layer	Stratigraphic Unit	Host (kx)	Ss [1/m]	Sy	Fracture Zone (Kz)	Wonga West (Kz)	Wonga East Historic Workings Bulli Seam (Kz)	Wongawilli Longwalls (Kz)
1	Upper Hawkesbury Sandstone	3.00E-02	1.0×10^{-3}	1.0×10^{-2}	1.62E-02			
1	Layer 1 (Coastal Plain)	3.03E-01	1.0×10^{-4}	2.0×10^{-2}	9.58E-02			
2	Upper Hawkesbury Sandstone	5.00E-04	1.0×10^{-4}	1.0×10^{-2}	1.00E-05			
3	Lower Hawkesbury Sandstone	5.55E-04	1.0×10^{-4}	1.0×10^{-2}	6.86E-05			5.00E-04
4	Bald Hill Claystone	2.00E-05	1.0×10^{-7}	1.0×10^{-2}	9.88E-06			2.00E-04
5	Upper Bulgo Sandstone	6.00E-04	1.0×10^{-6}	1.0×10^{-2}	1.00E-04			2.20E-03
6	Upper Bulgo Sandstone	5.00E-04	1.0×10^{-6}	1.0×10^{-2}	2.00E-05			9.00E-04
7	Lower Bulgo Sandstone	9.00E-04	1.0×10^{-6}	1.0×10^{-2}	3.00E-05			1.00E-04
8	Lower Bulgo Sandstone	9.28E-04	1.0×10^{-6}	1.0×10^{-2}	5.00E-06			4.50E-02
9	Stanwell Park Claystone	1.47E-04	1.0×10^{-7}	1.0×10^{-2}	3.00E-06			3.82E-04
10	Scarborough Sandstone	8.00E-04	1.0×10^{-7}	1.0×10^{-2}	1.00E-05			9.72E-03
11	Wombarra Claystone	1.68E-05	1.0×10^{-6}	1.0×10^{-2}	1.50E-06	7.00E-06	4.00E-05	3.14E-03
12	Coal Cliff Sandstone	6.92E-06	1.0×10^{-6}	1.0×10^{-2}	1.00E-06	3.96E-05	3.00E-04	2.36E-03
13	Bulli Seam	3.00E-02	1.0×10^{-6}	1.0×10^{-2}	1.00E-03	0.1		0.1
14	Interburden	1.19E-05	1.0×10^{-6}	1.0×10^{-2}	1.00E-06			0.1
15	Balgownie Seam	1.00E-02	1.0×10^{-6}	1.0×10^{-2}	6.29E-03			1
16	Interburden	2.32E-05	1.0×10^{-6}	1.0×10^{-2}	5.00E-06			1
17	Wongawilli Seam	1.00E-02	1.0×10^{-6}	1.0×10^{-2}	5.00E-03			10
18	Basement	5.32E-06	1.0×10^{-6}	1.0×10^{-2}	1.09E-06			

9.11 Water Balance

There are numerous opportunities for groundwater to discharge from and recharge to the groundwater system and into / out of the groundwater model. Those implemented in the model include:

- baseflow to major streams (represented by the river cells in MODFLOW);
- outflow / inflow to the eastern margin boundary representing the coastline, the northern margins representing the Appin mining area within the Bulli Seam and southern margin representing the Dendrobium mining area in the Wongawilli Seam (general heads in MODFLOW); and
- mine inflows to active mining areas and the sinks caused by historical mining areas.

The average water balance across the calibration period for the transient calibration model across the entire model area is summarised in **Table 11**.

The total inflow (recharge) to the aquifer system into the model domain is approximately 28ML/day, comprising rainfall recharge (approximately 52%), inflow from the head dependent boundaries on the margins (approximately 0.5%), and leakage from streams into the aquifer (approximately 42%). The remaining 5.5% is accounted for with changes in storage.

It is assumed that any water carried by the limited extent and duration of flow in ephemeral streams would have a negligible contribution to groundwater recharge via leakage from the stream bed.

Table 11 Simulated Water Balance at End of Transient Calibration

	Inflow (ML/d)	Outflow (ML/d)
Storage	2.82	2.26
Constant Head	0.09	0.03
Drains (Outflow = Groundwater Entering Mine Workings)	0.00	5.01
Recharge (Direct Rainfall)	27.46	6.04
Et (Evapotranspiration)	0.00	33.48
River (Leakage/Baseflow)	22.57	6.22
Head Dependent Boundary (GHB)	0.19	0.09
Total	53.13	53.12
% Discrepancy	-0.01%	

9.12 Effect of Structures

Due to the limitations and constraints inherent with the model set up and model code, as well as uncertainty in the location, stratigraphic persistence and hydraulic properties of geological structures in the Study Area, they are not simulated in the model.

It has been observed that faults encountered within the three levels of extraction have not encountered water make with any faults or dykes in the workings (Gujarat NRE Coking Coal, 2014).

10. POTENTIAL SUBSIDENCE EFFECTS, IMPACTS AND CONSEQUENCES

10.1 Stream Bed Alluvium and Plateau Colluvium

There are no anticipated subsidence effects on stream bed alluvium or plateau colluvium as there is no significant accumulation of Quaternary sediments within the Study Area.

The presence of alluvial sediments is limited to the upland swamps, which have been measured up to 1.6m deep.

Where the swamps are absent in the lower catchment, the stream beds are dominated by either exposed sandstone or boulder reaches without significant alluvial deposits.

10.2 Upland Swamps

Due to limitations of the MODFLOW SURFACT code and the regional scale model set up, the effect of subsidence on the small thickness (<2m) of perched groundwater in the upland swamps, with limited and variable spatial extent, was not assessed in the simulation.

Further discussion of the potential effects on swamps is contained in Biosis (2014).

10.3 Basement Groundwater Levels

Figures 37 to **42** show north - south and east – west cross sections of the overall modelled hydraulic head (m) for modelled initial conditions at the end of the calibration period (i.e. the end of LW5 extraction) and at the end of proposed mining at Wonga East.

Figure 37 and **Figure 38** show initial conditions and de-saturated areas underlying the escarpment in the south eastern area of the model. Zero pressures also extend into the Bulli Seam and overburden due to pre-existing mining voids from the lengthy period of mining in the region prior to the model simulation period.

Figure 39 and **Figure 40** show the same cross sections following the end of the calibration period after completion of LW5. Here early fracture zone implementation over LW4 and LW5 has caused a vertical propagation of the zero pressure contour. This does not propagate through to surface but positive pressures are maintained in the Upper Bulgo Sandstone. The fracture zone developed within the model is pushed into the Lower Hawkesbury Sandstone and a decline in head within the Hawkesbury sand stone is also evident.

Figure 41 and **Figure 42** show these cross sections following completion of mining in the Wongawilli seam. Here, the fracture zone has fully developed and this has led to a zero head contour breaking through to surface.

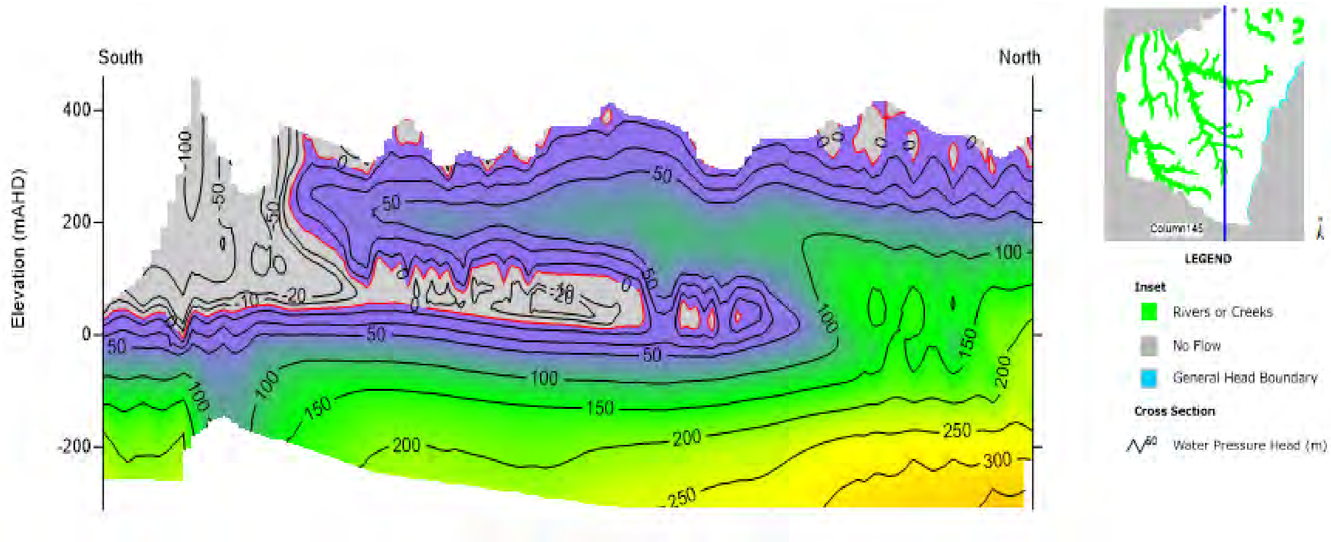


Figure 37 Predicted Pressure Head Initial Conditions at Wonga East (North – South Cross Section on Easting 303000)

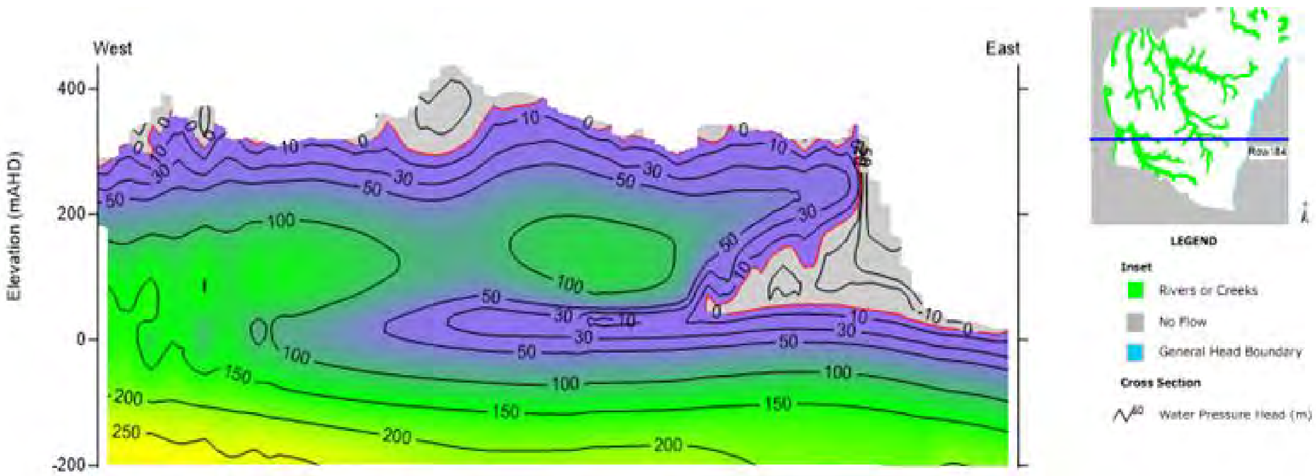


Figure 38 Predicted Pressure Head Initial Conditions at Wonga East (East – West Cross Section on Northing 6196895)

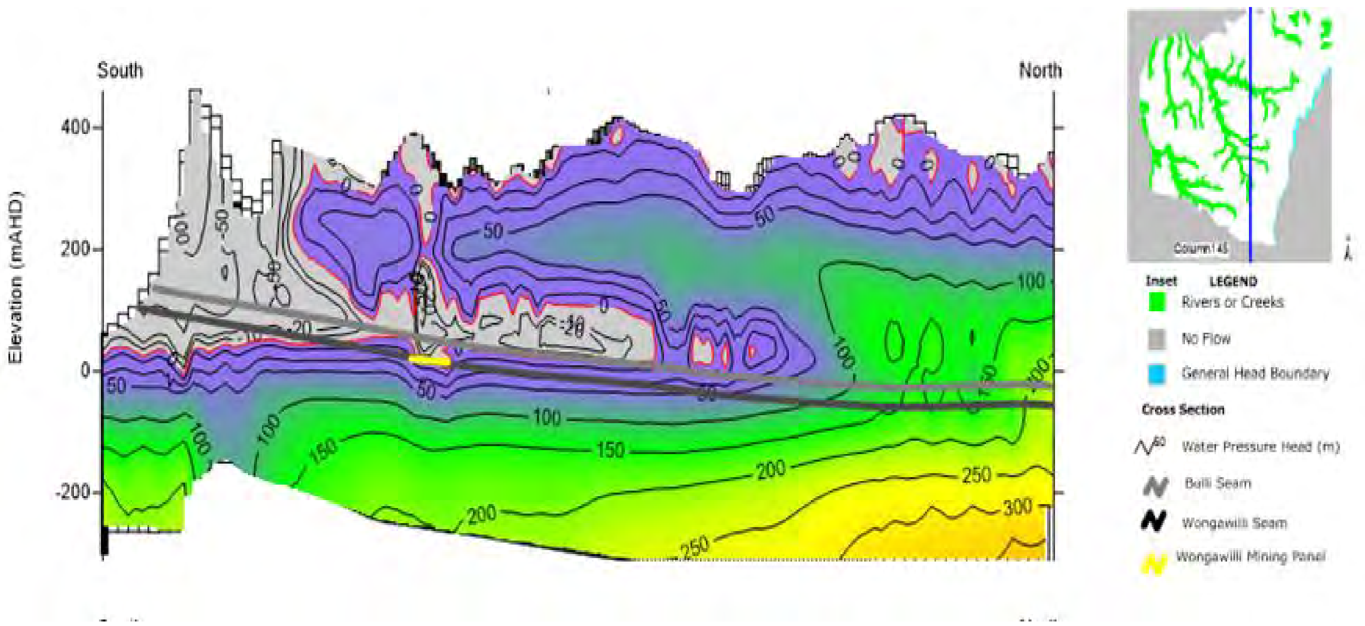


Figure 39 **Predicted Pressure Head at Wonga East at the End of LW5 (North – South Cross Section on Easting 303000)**

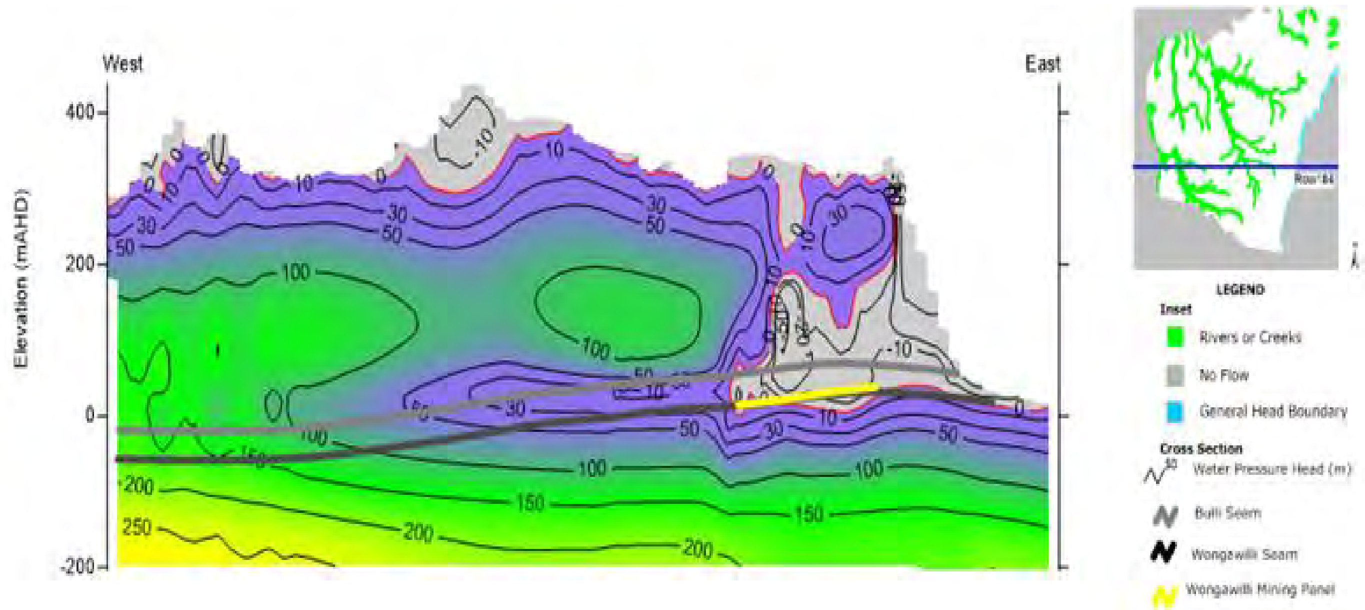


Figure 40 **Predicted Depressurisation at Wonga at the End of LW5 (East – West Cross Section on Northing 6196895)**

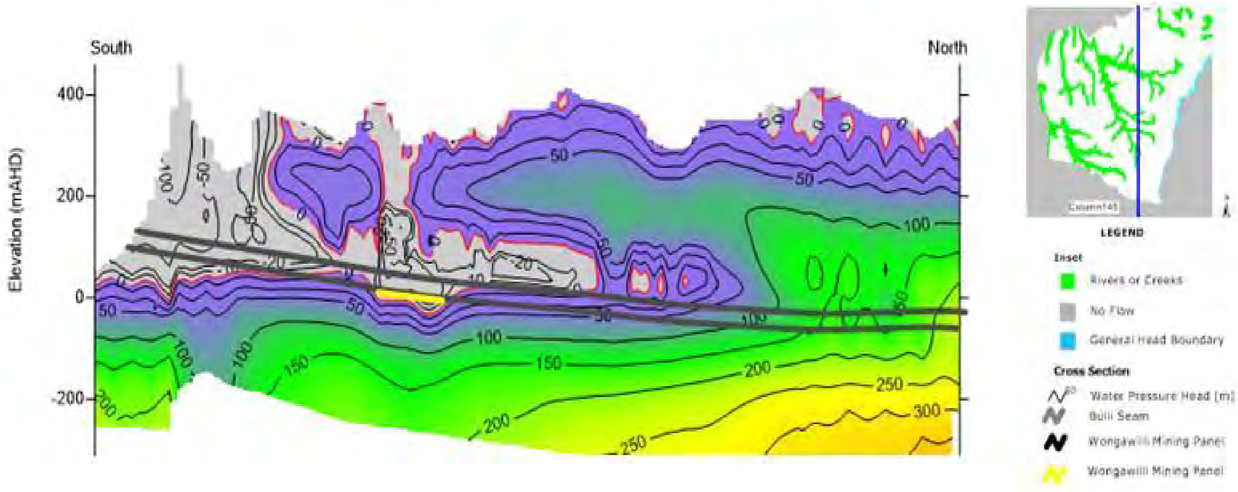


Figure 41 Predicted Depressurisation at Wonga East at the End of Mining (North – South Cross Section on Easting 303000)

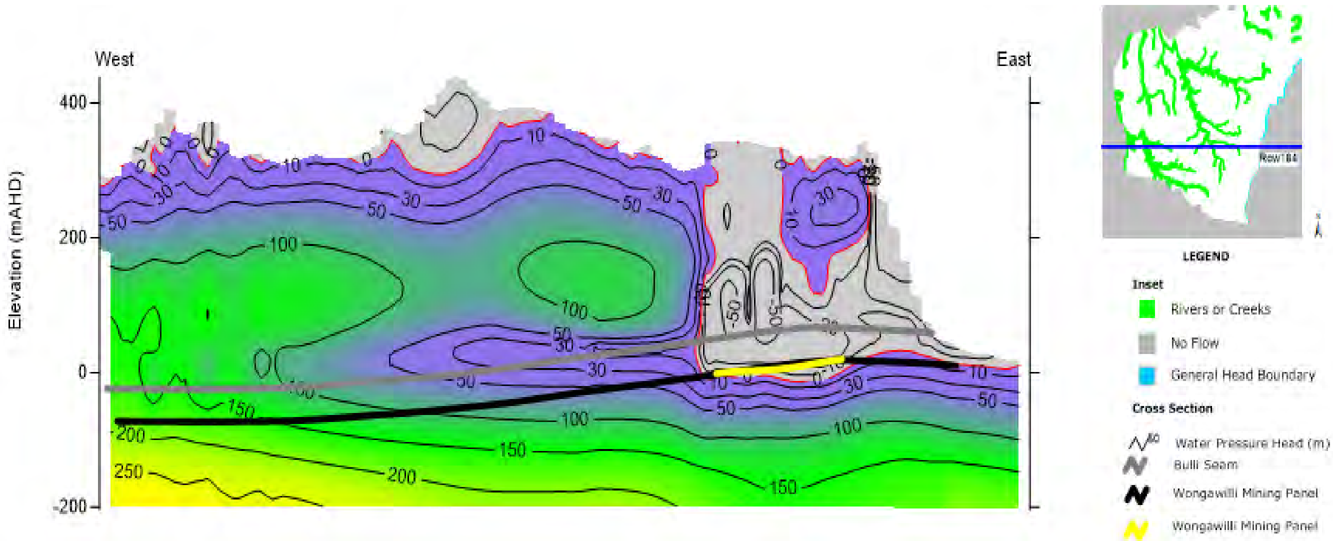


Figure 42 Predicted Depressurisation at Wonga East at the End of Mining (East – West Cross section on Northing 6196895)

10.3.1 Shallow, Perched, Ephemeral, Hawkesbury Sandstone

Perched, ephemeral, shallow groundwater within the upper Hawkesbury Sandstone (Layer 1) could undergo a water level reduction over the proposed workings after subsidence.

However, as the "ephemeral" shallow Hawkesbury Sandstone aquifers dissipate after extended dry periods, the effect on the mostly disconnected, perched aquifers with limited extent was not modelled. However, it is logical to conclude that fracturing of the upper, shallow strata would enhance the leakage rate from the perched aquifers into underlying strata over subsided areas, as well as enhancing the rainfall recharge and subsequent seepage rate from these perched aquifers into local streams or the underlying aquifers.

Subsidence of Layer 1 is not anticipated to have a significant overall effect on stream baseflow or stream water quality where the temporary aquifers seep into local catchments. However, temporary, localised effects may be observed.

10.3.2 Upper Hawkesbury Sandstone

The upper Hawkesbury Sandstone aquifer extends across the Study Area, with piezometer data indicating phreatic water levels ranging from 1 – 20m below surface in Wonga East.

It should be noted that the monitored water level is affected by semi-confined head pressures, whereas the first drilling water intercept, which indicates the upper bound of the aquifer varied from 17 – 48m below surface in Wonga East.

Once the piezometer is completed, subsequent water level measurements indicate a combination of head pressure in the aquifer, variability of recharge or other factors.

Based on past experience in the Southern Coalfields, the upper regional Hawkesbury Sandstone water levels can rise by up to 2m ahead of a piezometer being undermined, then reduce by up to 15m after development of cracking and additional secondary void space (porosity) in the aquifer. Apart from GW1, all of the piezometers installed by Wollongong Coal have monitored the post mining period in the Bulli and / or Balgownie mining phases. GW1 was installed after Longwall 4 in the Wongawilli Seam was extracted and observed water level reduction of up to 25m, with subsequent recovery of up to 31m due to extraction of Longwall 5.

The reduced water level generally recovers over a few months, depending on rainfall recharge in the catchment and the post subsidence outflow seepage rate, if it occurs, to local streams. Re-establishment of the pre-mining water level generally occurs, although the water levels may not necessarily fully recover.

Modelling of Layer 1 (which can include the Hawkesbury Sandstone as well as the Newport / Garie Formation, Bald Hill Claystone or Upper Bulgo Sandstone in eroded creek bed locations) after the end of mining in Wonga East indicates up to 1m of drawdown as shown in **Figure 43** in comparison to pre Wongawilli Seam development.

Figure 44 shows drawdown after mining is completed in comparison to post LW5 (currently approved) groundwater levels.

As shown in **Figure 45** and **Figure 46,** 50 and 100 years respectively after mining has been completed in Wonga East, water level reduction is generally less than 1m in comparison to pre-mining levels. These show that at 100 years, no further extension of a drawdown cone occurs and there is a slight reduction in impacted area in comparison to 50 years following completion of mining.

A drawdown of up to 3m is predicted for a small area overlying LW3.

10.3.3 Lower Hawkesbury Sandstone

Modelling of Layer 3 (Lower Hawkesbury Sandstone, as well as the Newport / Garie Formation, Bald Hill Claystone or Upper Bulgo Sandstone in eroded creek bed locations after the end of mining at Wonga East indicates up to 30m of drawdown as shown in **Figure 47** in comparison to pre Wongawilli Seam development. **Figure 48** shows drawdown after mining is completed in comparison to post LW5 (currently approved) groundwater levels. The main difference between these two drawdown periods is the drawdown over LW4 and LW5.

Figure 49 and **Figure 50** indicate that 50 years after mining, a further 5m reduction in groundwater pressures in comparison to initial conditions occurs, and at 100 years after completion of mining, water pressures remain static in comparison to the previous 50 years. This suggests that the peak impact is achieved prior to 50 years although no effective recovery is seen until after 100 years.

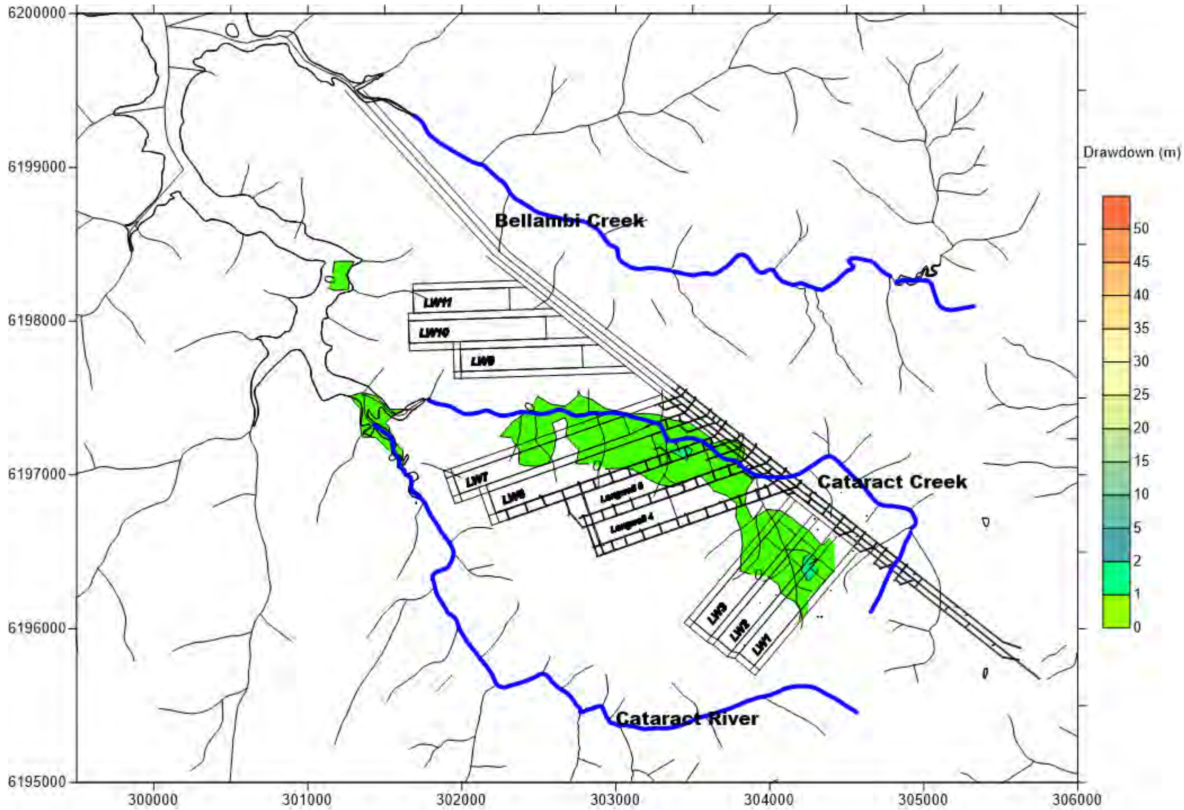


Figure 43 **Layer 1 Drawdown after Mining at Wonga East Relative to Start of Mining in Wongawilli Seam.**

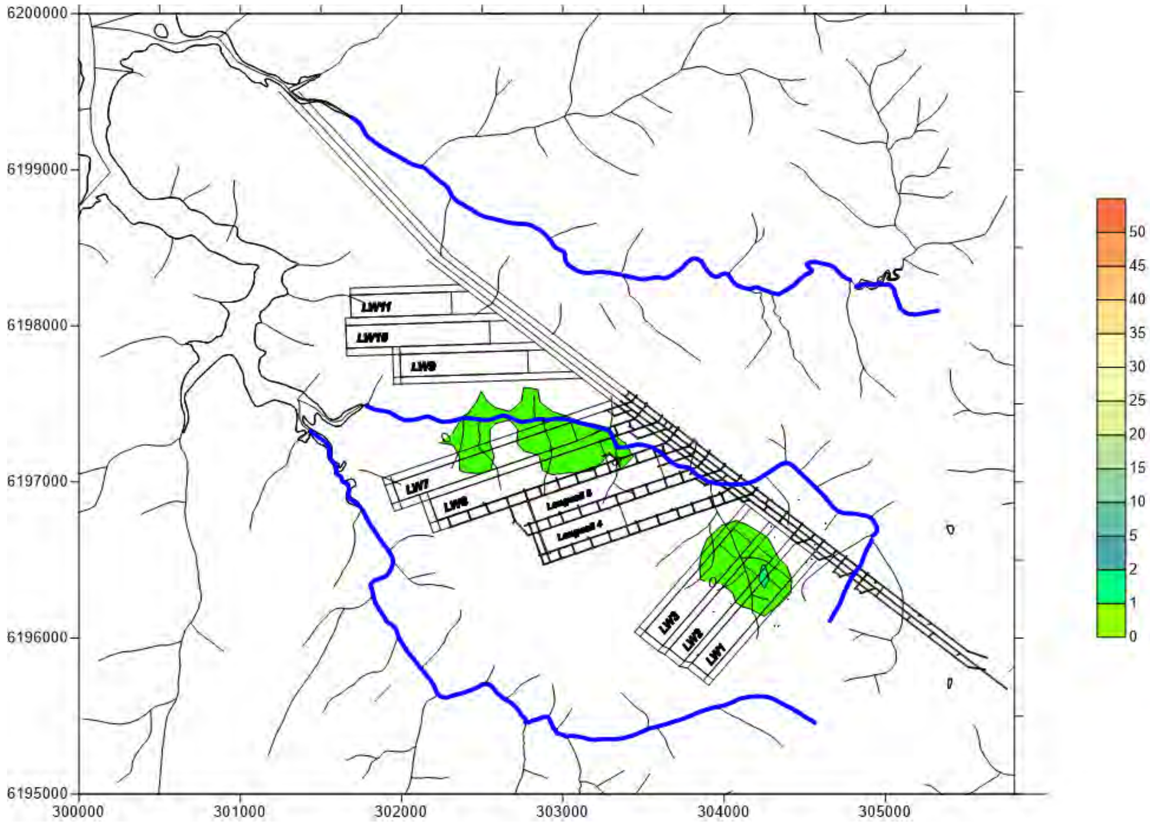


Figure 44 Layer 1 Drawdown after Mining Longwalls 4 and 5 at Wonga East Relative to End of LW5

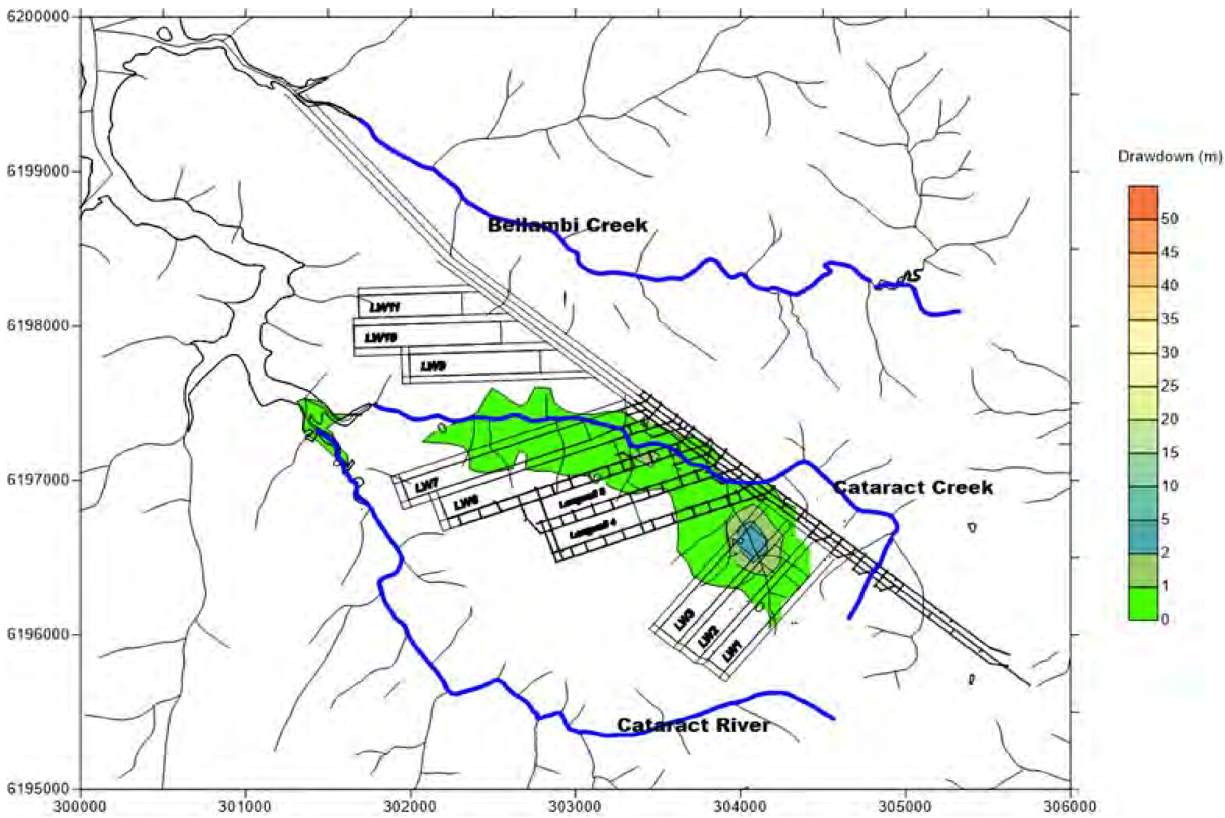


Figure 45 Layer 1 Recovery 50 Years After Mining at Wonga East

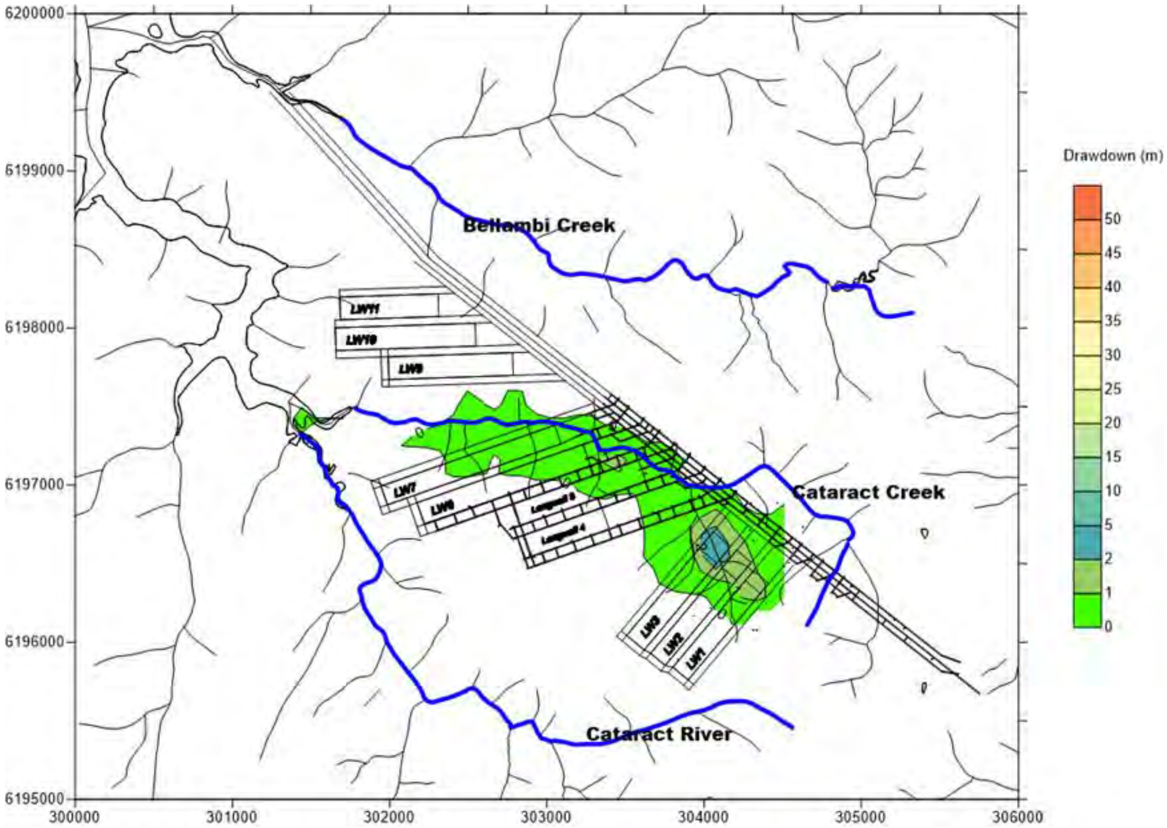


Figure 46 Layer 1 Recovery 100 Years After Mining at Wonga East

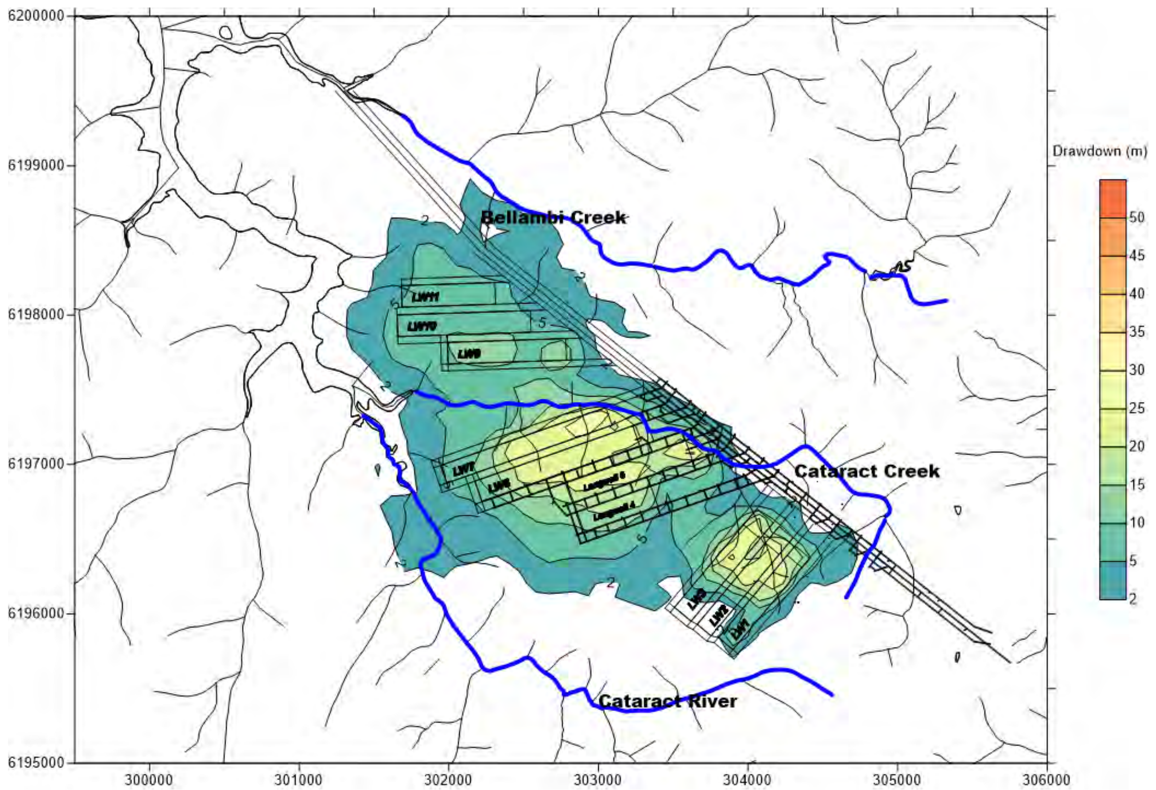


Figure 47 Layer 3 Drawdown After Mining at Wonga East in Comparison to Pre Wongawilli Seam Development

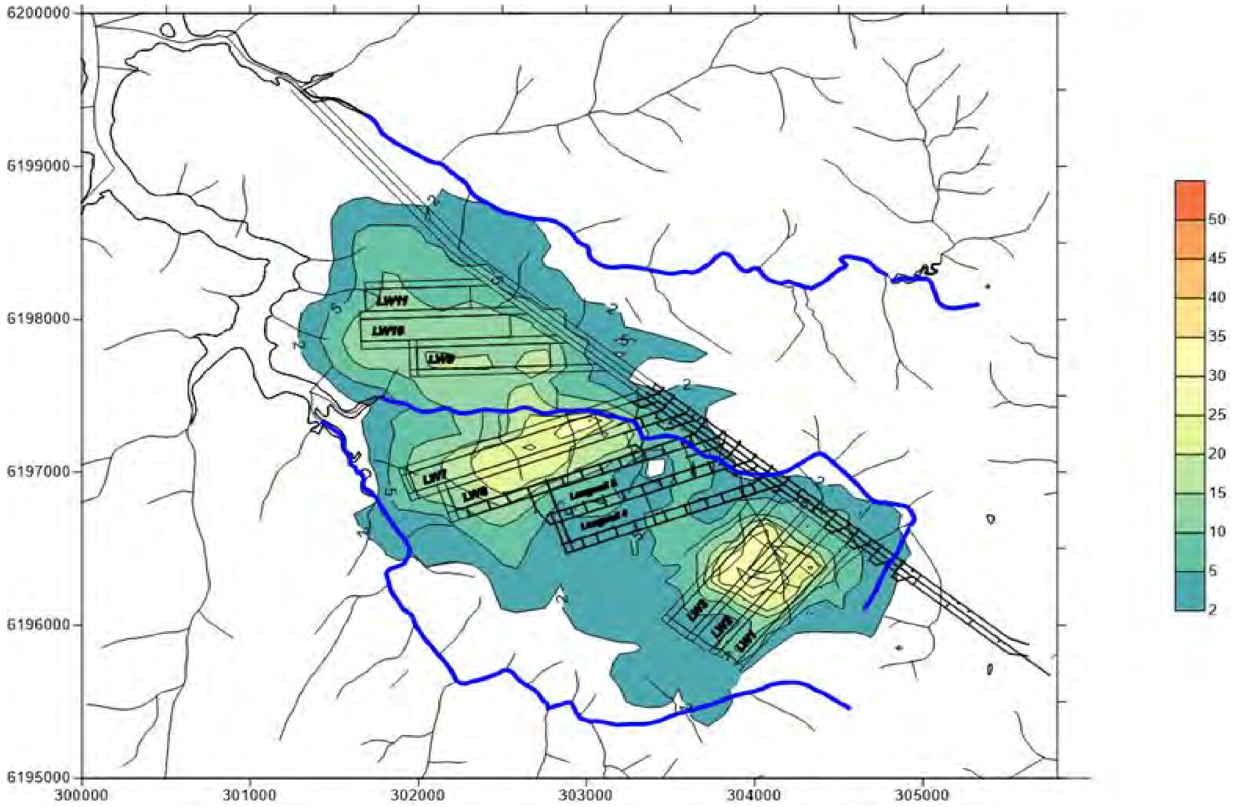


Figure 48 Layer 3 Drawdown After Mining at Wonga East in Comparison to Post LW5 Development

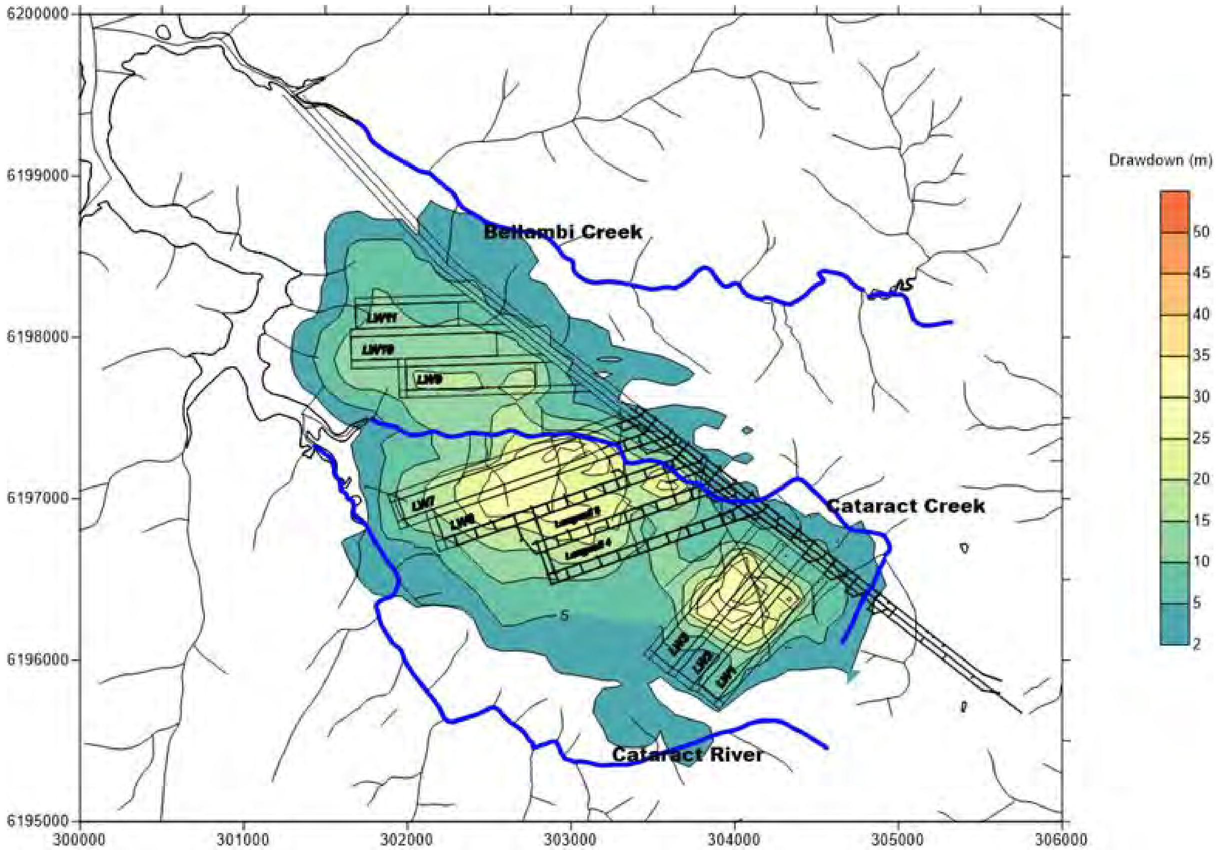


Figure 49 Layer 3 Recovery 50 Years After Mining at Wonga East

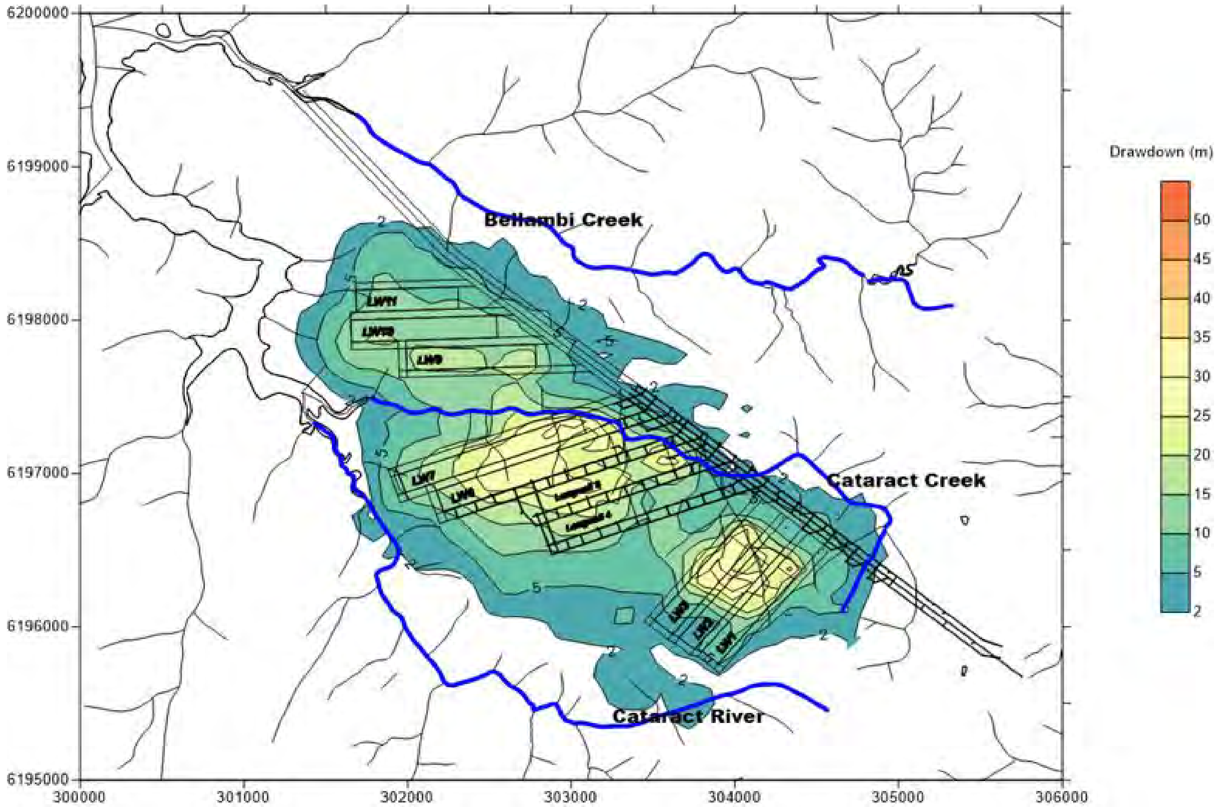


Figure 50 Layer 3 Recovery 100 Years After Mining at Wonga East

10.3.4 Upper Bulgo Sandstone

Modelling of Layer 5 (Bulgo Sandstone) after the end of mining, indicates up to 45m of drawdown over Wonga East, which occurs within the footprint of LW6, LW7 and part of LW9 in comparison to pre Wongawilli Seam development. **Figure 51** shows drawdown after mining is completed in comparison to post LW5 groundwater levels. As in overlying layers, the main difference between these two drawdown periods is the drawdown over LW4 and LW5. No significant increase in the areal extent of the drawdown cone is observed between the two scenarios.

Elsewhere over LW1 to LW3, drawdown of up to 25m occurs after the completion of mining as shown in **Figure 52.**

Modelling indicates that drawdown of up to 2m extends a maximum of 1km to the west of LW7 following completion of mining.

Figures 53 and **54** indicate that 50 and 100 years respectively after mining has been completed, the drawdown footprint in comparison to initial conditions remains relatively static to that predicted at the end of mining in Wonga East. Within the 50 years following mining, an additional 5m drawdown is predicted with signs of recovery in the following 50 year period.

The degree of drawdown increases with increasing depth towards the workings in the upper, mid to lower Bulgo Sandstone in association with an upward migration of zero pore pressures over subsided Wongawilli longwalls.

10.3.5 Scarborough Sandstone

Modelling of Scarborough Sandstone (Layer 10) after the end of mining Wonga East indicates drawdown below the base of the layer as shown in **Figure 55**, with the depressurisation after extraction of Longwall 5 shown in **Figure 56.** The predicted areal extent of drawdown at the end of mining shows 2m extending a maximum of 2km to the west of LW10

Figure 57 indicates that 50 years after mining has been completed, water levels over the longwall footprint are still depressed in comparison to pre-mining levels.

However, the drawdown cone has recovered significantly with the 2m drawdown contour extending a maximum of 1km to the northwest of the mains. After 100 years, drawdown continues to contract such that the 2m contour is less than 500m from the longwall and mains headings as shown in **Figure 58**.

10.3.6 Bulli Seam

No Bulli Seam drawdown figures are presented in this section as the seam is generally dry in the vicinity of the Wonga East workings.

10.3.7 Wongawilli Seam

Drawdown in the Wongawilli Seam at the end of mining in comparison to pre Wongawilli Seam development in Wonga East is modelled to reach up to 46m over LW10. Less drawdown occurs up dip with up to 30m overlying LW4 – LW7 and up to 12m overlying LW1 – LW3. The areal extent of the 2m drawdown contour at the end of mining at Wonga East extends a maximum of 1100m to the north of Longwall 11 as shown in **Figure 59**.

Figure 60 shows drawdown after mining is completed in comparison to post LW5 (currently approved) groundwater levels. As in overlying layers, the main difference between these two drawdown periods is the drawdown over LW4 and LW5. There is a significant difference in the areal extent of the drawdown cones observed between the two scenarios due to the drawdown associated with the currently approved mining of LW5 and development headings for LW6.

Fifty years after mining is completed, the Wongawilli Seam is modelled to recover by up to 90m in comparison to initial conditions over Wonga East as shown in **Figure 61**.

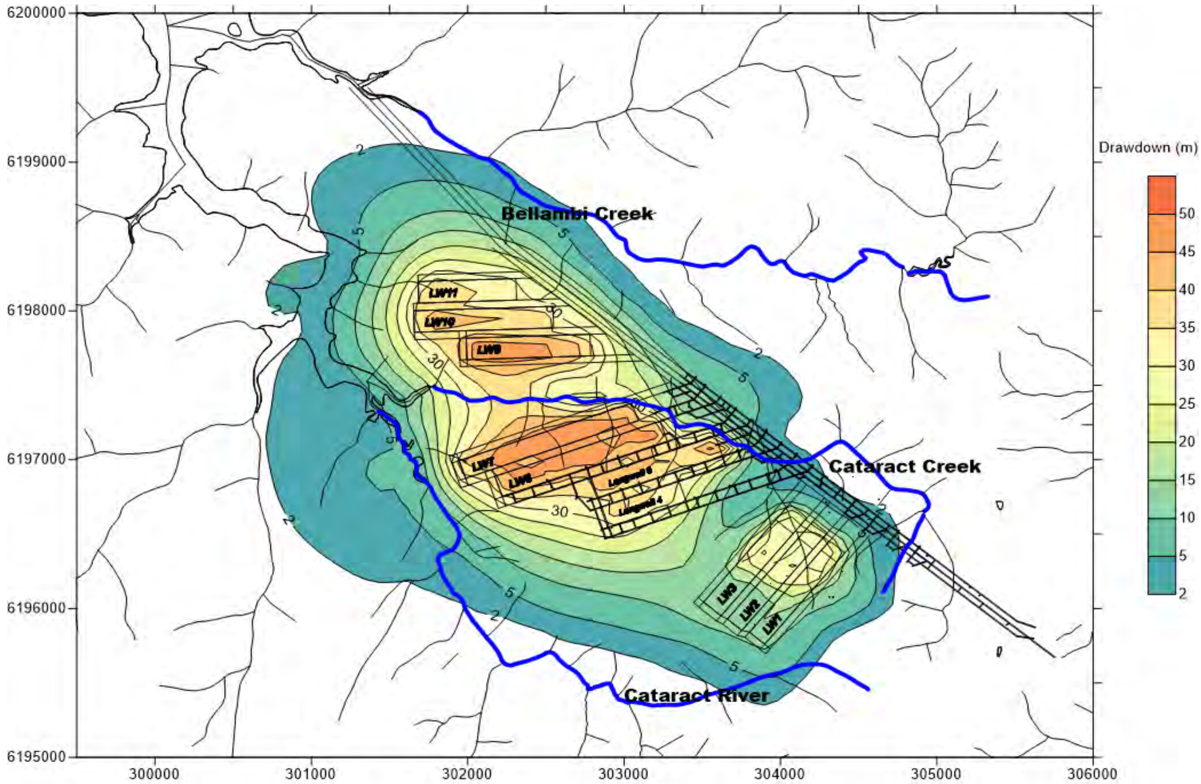


Figure 51 Upper Bulgo Sandstone Drawdown After Mining Wonga East in Comparison to Pre Wongawilli Seam Development

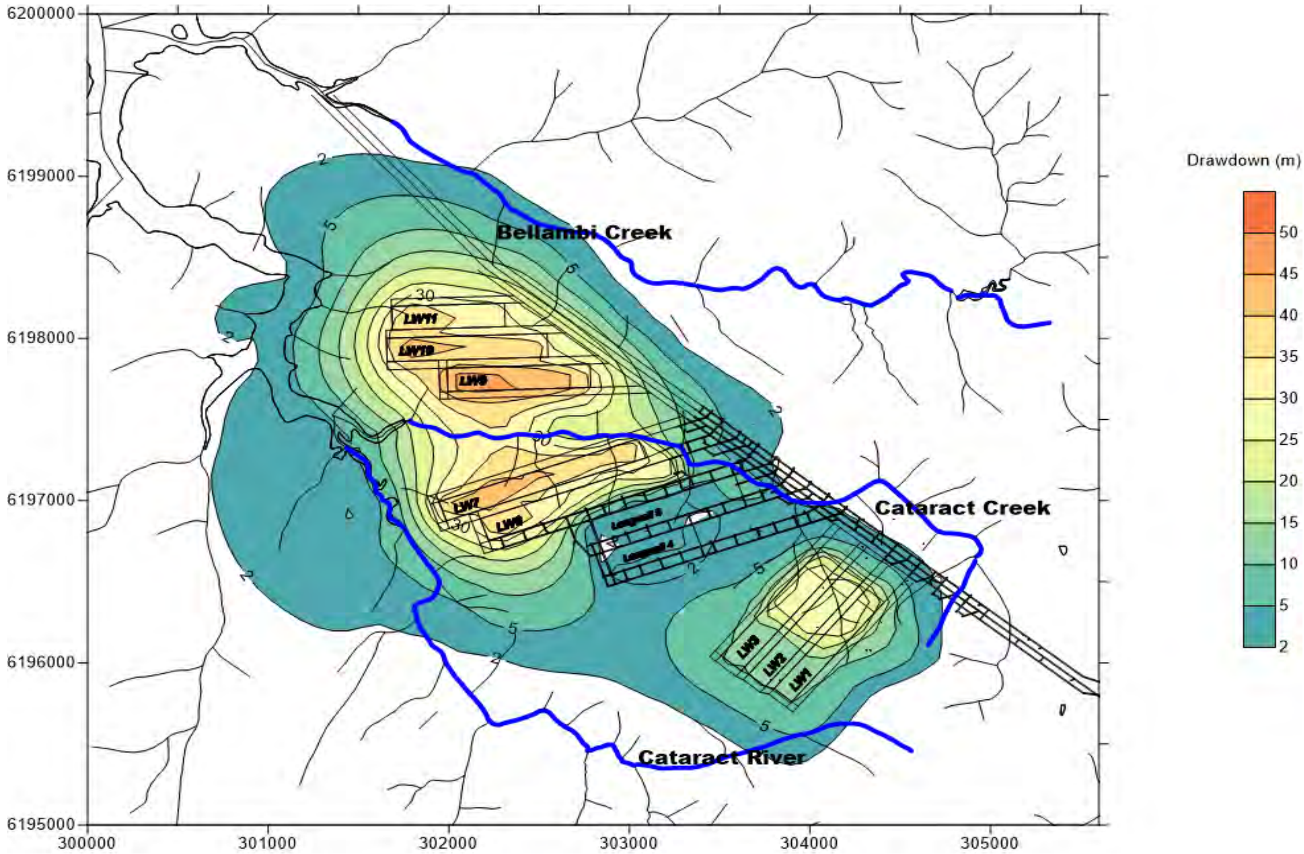


Figure 52 Upper Bulgo Sandstone Drawdown After Mining at Wonga East in Comparison to Post LW5 Development

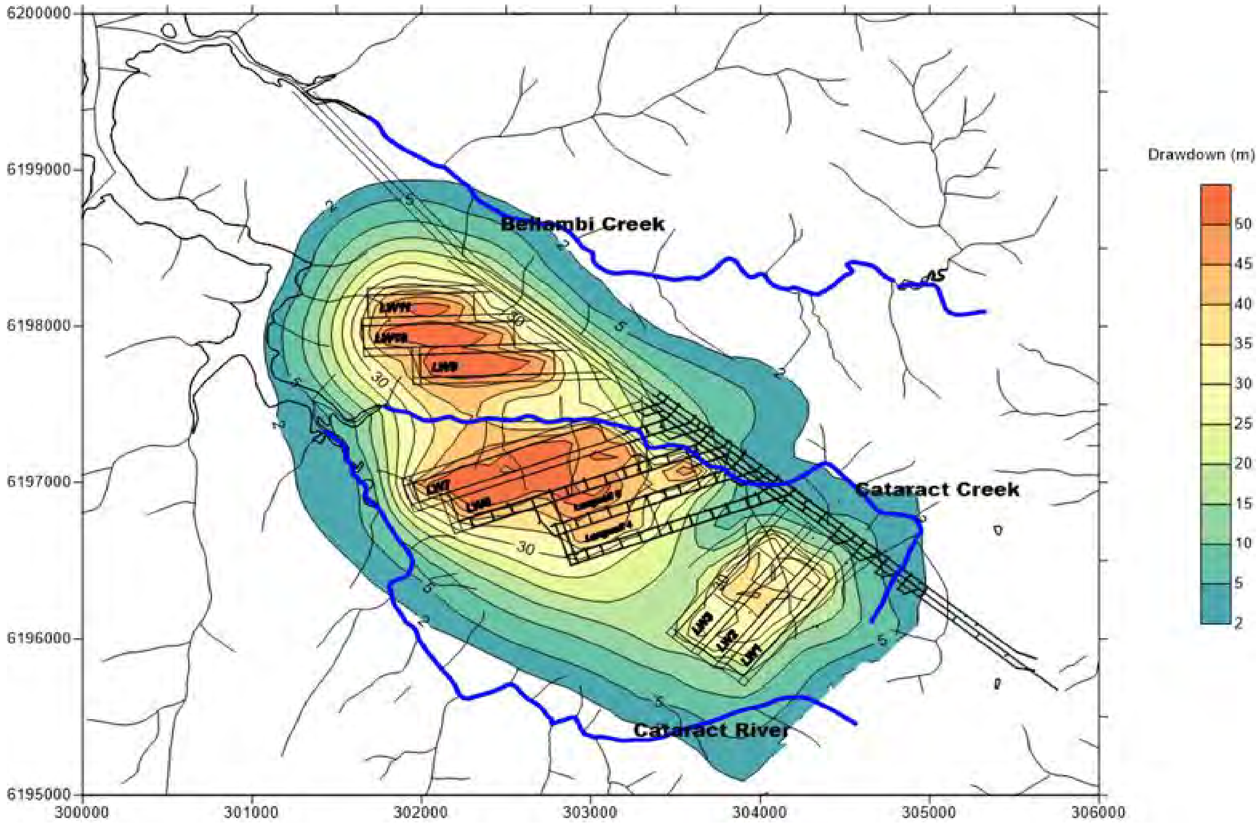


Figure 53 Upper Bulgo Sandstone Recovery 50 Years After Mining at Wonga East

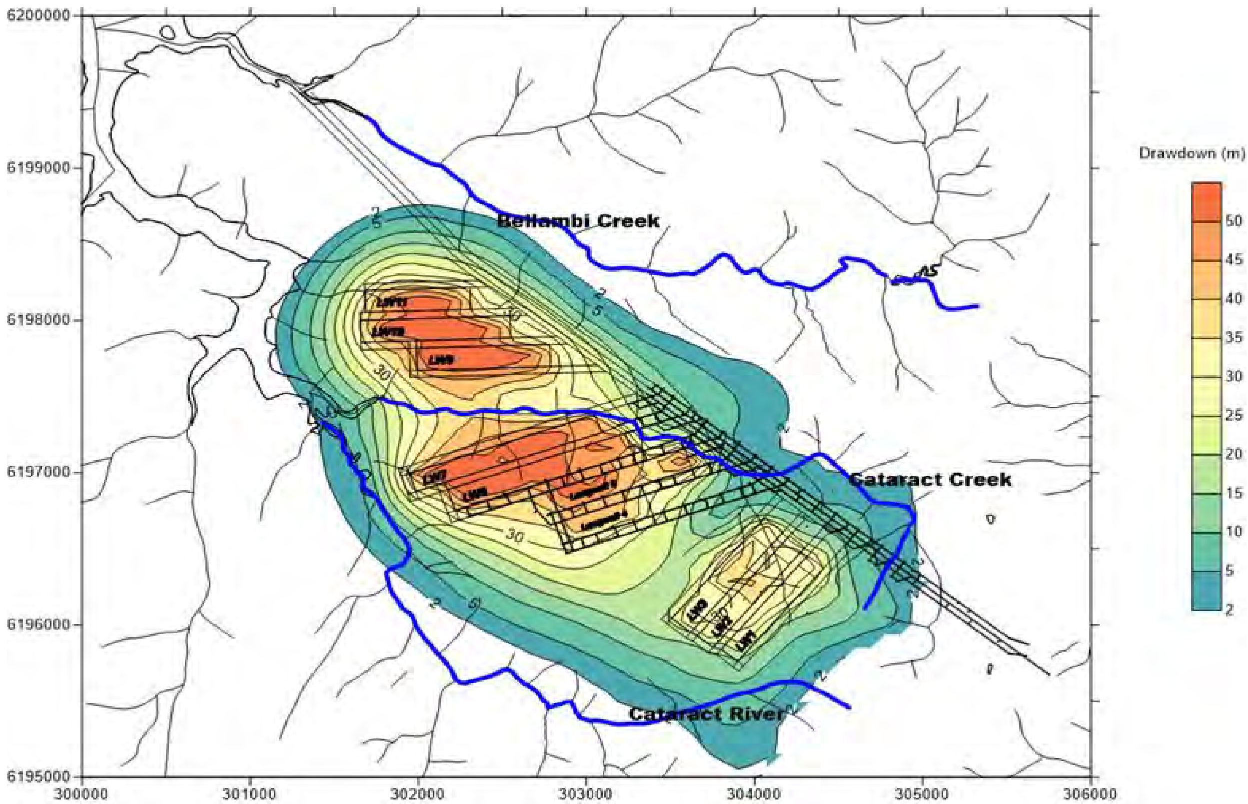


Figure 54 Upper Bulgo Sandstone Recovery 100 Years After Mining at Wonga East

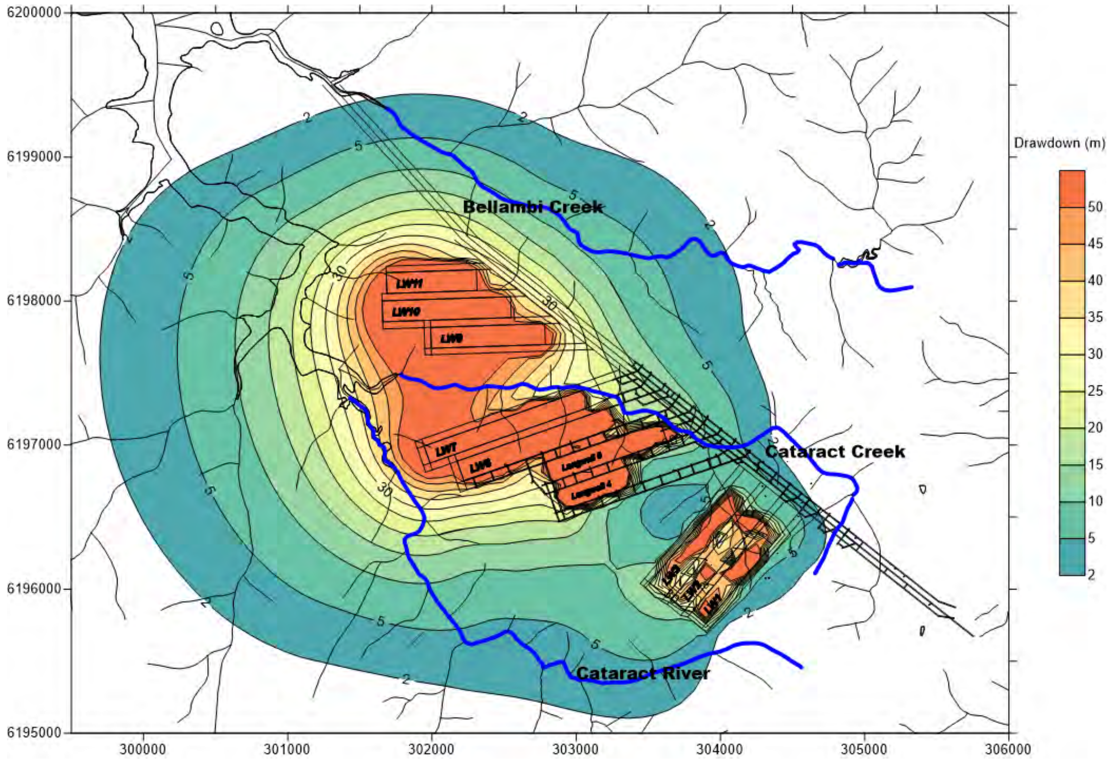


Figure 55 Scarborough Sandstone Drawdown After Mining Wonga East in Comparison to Pre Wongawilli Seam Development

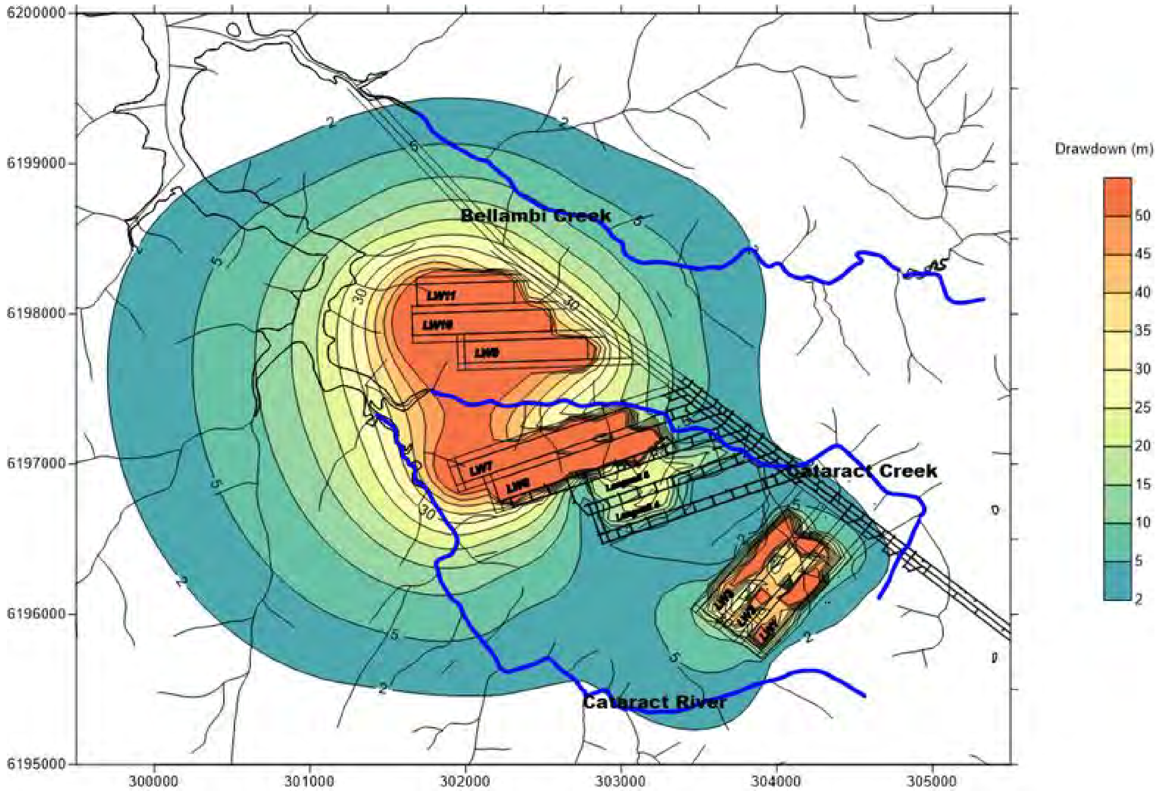


Figure 56 Scarborough Sandstone Drawdown After Mining at Wonga East in Comparison to Post LW5 Development

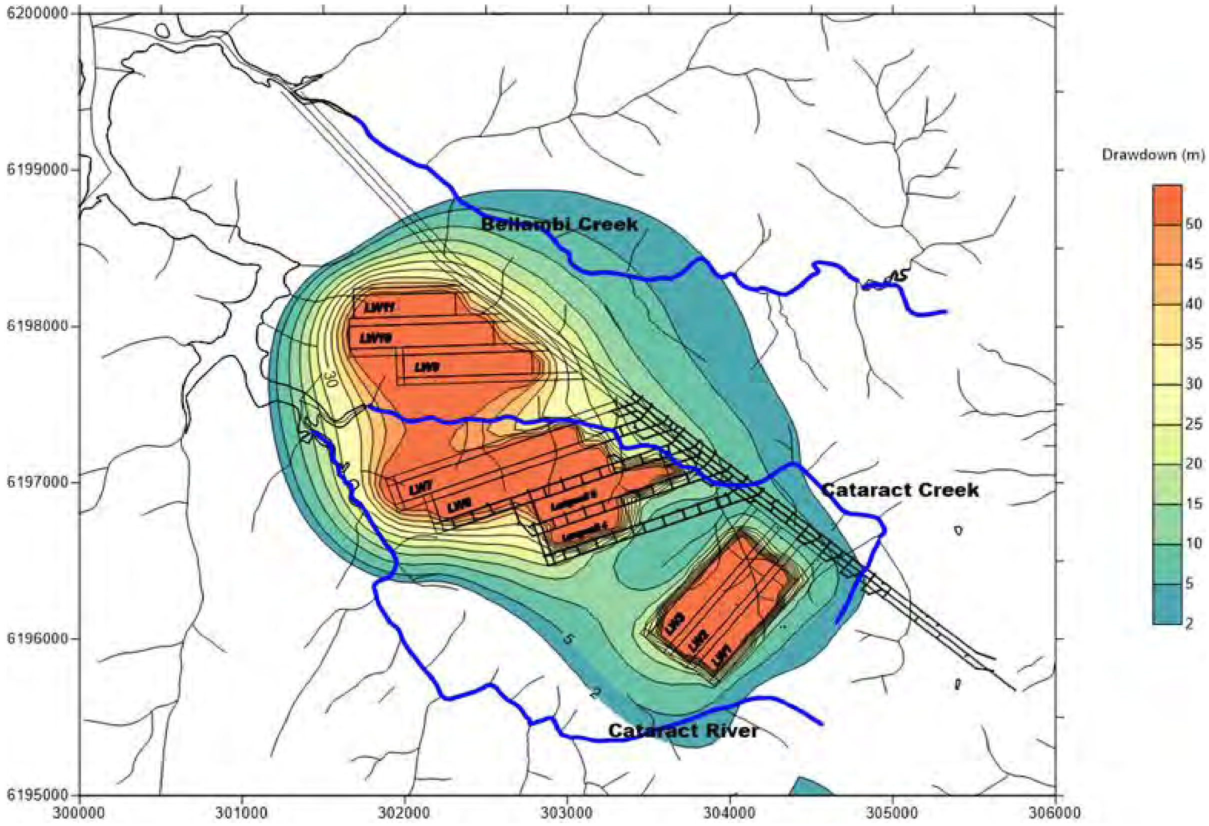


Figure 57 Scarborough Sandstone Recovery 50 Years After Mining

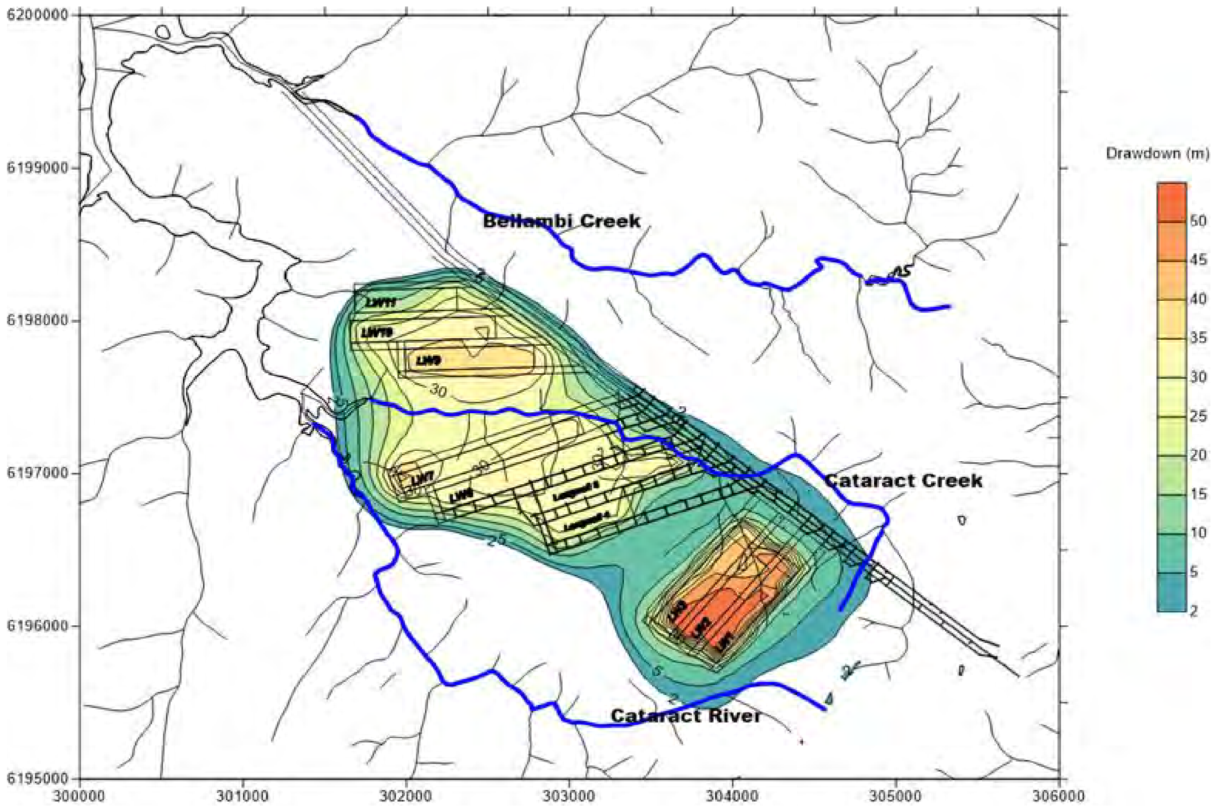


Figure 58 Scarborough Sandstone Recovery 100 Years After Mining

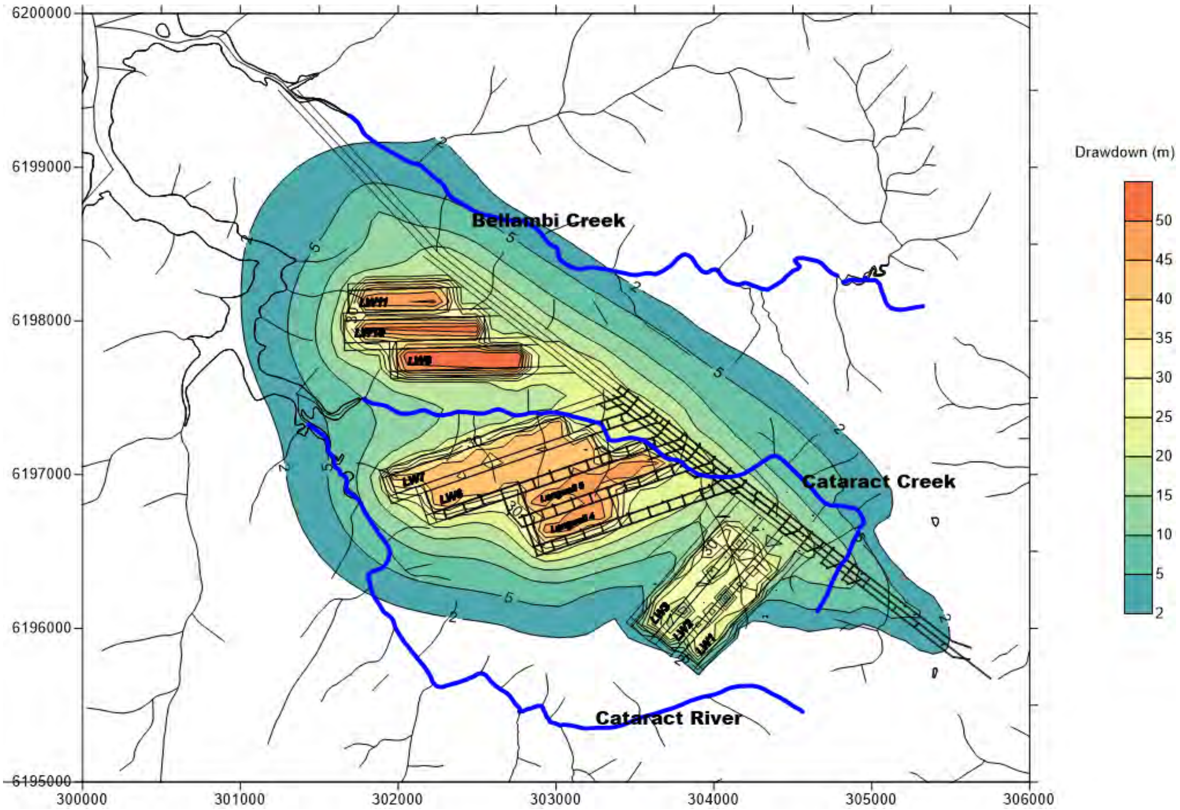


Figure 59 Wongawilli Seam Drawdown After Mining Wonga East in Comparison to Pre Wongawilli Seam Development

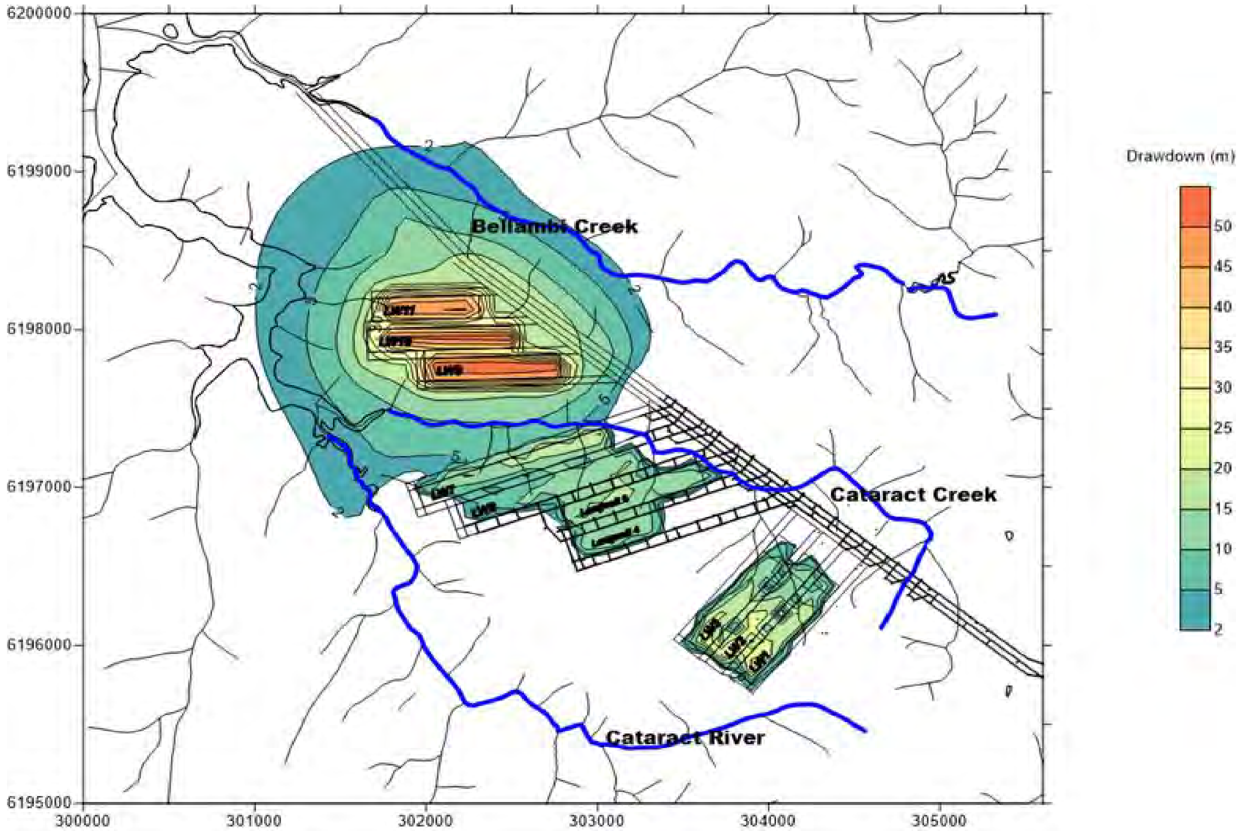


Figure 60 Wongawilli Seam Drawdown After Mining at Wonga East in Comparison to Post LW5 Development

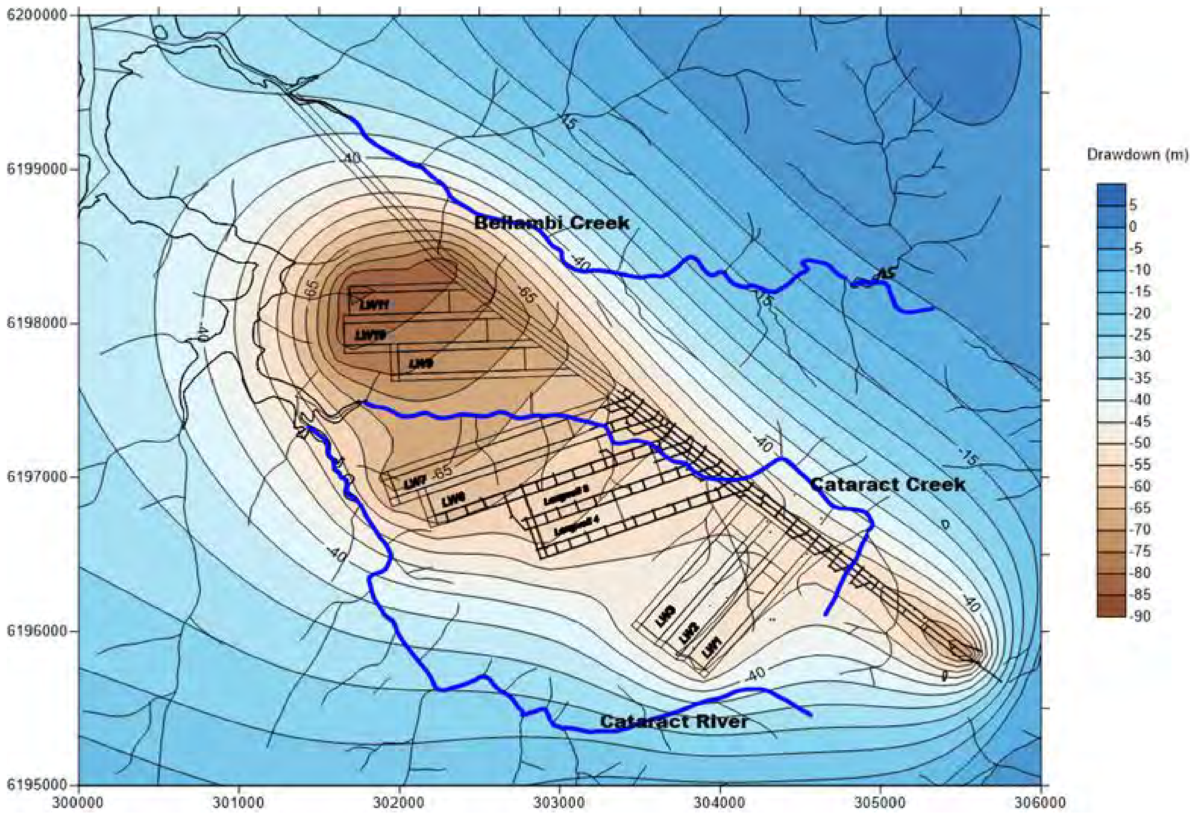


Figure 61 Wongawilli Seam Recovery 50 Years After Mining

10.4 Stream and Groundwater System Connectivity

A number of mechanisms can potentially occur within shallow groundwater systems associated with streams:

- direct flow of surface water into mining induced fracture systems with vertical drainage into the shallow basement groundwater system;
- inter-connection of the depressurised strata and horizontal to sub-horizontal or "stepped" shear plane/s located beneath a stream bed and associated subsided hill slopes;
- flow of surface water from "gaining" streams into the shallow groundwater system which then migrates along the local hydraulic gradient and re-emerges further down stream, with no hydraulic connection to the workings if there is no continuous, vertically connected fracturing;
- reversal of water transfer from the shallow groundwater system to the "losing" streams during periods of high recharge; or
- flow of stream water into the shallow groundwater system migrating along the hydraulic gradient to emerge further downstream within other groundwater catchment regimes.

10.4.1 Cataract Creek

The geotechnical subsidence assessment (SCT Operations 2013) concluded the multi-seam mined Bulli and Balgownie Seam workings at Wonga East diminished the spanning capacity remaining in the Bulgo Sandstone directly above the proposed Wongawilli Seam longwalls.

Observations over Longwall 4 in the Wongawilli Seam indicate that due to the previously fractured nature of the overburden above the Bulli and Balgownie Seam workings the subsidence "bowl" did not effectively extend outside of the longwall footprint (SCT Operations, 2013);and Seedsman Geotechnics, 2012A).

In the multi-seam mined area, even though horizontal bedding displacement may have extended up into the upper Bulgo Sandstone, this does not mean a direct, free vertical drainage hydraulic connection is present from the surface to the workings.

Monitoring of mine water balance (SCT Operations 2014) has not detected any associated short term increase in mine water make from the current Wonga East workings following significant rain in the catchments over the Wonga East workings.

Monitoring of water level trends in piezometer NRE-A over the multi-seam mined area indicates the upper Hawkesbury Sandstone down to the Upper Bulgo Sandstone lithologies have an enhanced response to rainfall recharge. However, no adverse effect on stream flow has been observed as the headwater tributaries and main channel of Cataract Creek have had continuous flow throughout the monitoring period.

The bord and pillar mined areas represented by the open standpipe and vibrating wire piezometers at NRE-B, C and D have a limited to minor response to rainfall recharge.

Where only Bulli seam first workings have been extracted, the proposed workings are not predicted to destabilise the Bulli seam pillars sufficiently to cause fracturing or displacement that will extend into the upper Bulgo Sandstone (Seedsman Geotechnics, 2012). This means there will be no predicted free drainage connection from surface to seam in these areas.

Beneath the plateau over the Bulli and Balgownie workings in the vicinity of Cataract Creek, extraction of the proposed longwalls is modelled to generate up to 3m of depressurisation in Layer 1 at the end of mining Wonga East.

The modelled, localised reduction is anticipated to reduce the regional phreatic surface gradient from the plateau to Cataract Creek, as well as toward Cataract reservoir, thereby potentially reducing baseline seepage flow volumes to the creek and dam.

It is also possible that, where they exist, or have been generated as a result of dilational movement of the hillslope after subsidence, perched and / or phreatic hillslope seepage outflow points may be relocated to lower elevations in the catchment due to the dilational fracturing of the hillslopes and associated hillslope basal shear zone movement as a result of valley closure.

Although the effect could not be addressed in the groundwater model due to the very thin zones of up to 10cm thickness (Mills, K.W, pers comm), the potential generation of a horizontal to sub - horizontal shear plane (or planes) in accordance with the theory of Mills (2007) in the perched hillslope aquifers and between 6 – 10m below the valley floor may lower the hillslope seepage outflow elevations. This could mean that the post Wongawilli Seam extraction baseflow seepage to the valley could occur lower down in the catchment, and could generate a re-location in the transition point in the creek from ephemeral to intermittent / perennial flow.

It is also likely that three stages of dilational, horizontal to sub-horizontal hillslope shear zones have previously been generated following extraction of the secondary workings in the Bulli Seam, the longwalls in the Balgownie Seam, and Longwalls 4 and 5 in the Wongawilli Seam, and that the incremental effect due to extraction of the proposed Longwalls 6 to 11 (and Longwalls 1 to 3) will not cause an observable change in overall stream discharge into Cataract Reservoir.

Mapping of the stream bed and tributaries indicates that baseflow seepage changes have probably already occurred in Cataract Creek, prior to extraction of Longwalls 4 and 5 in the Wongawilli Seam, based on the high degree of iron hydroxide seepage and precipitation present in the upper reaches all the way down to the Cataract Reservoir.

Due to the lack of stream bed, flow and chemistry monitoring prior to July 2008, quantification of the changes in water flow and chemistry in Cataract Creek due to mining the Bulli Seam and Balgownie Seam is not possible.

However, no observable change has been noted in the flow and chemistry of Cataract Creek due to extraction of Longwalls 4 and 5 in the Wongawilli Seam (Geoterra, 2014A).

Stream flow modelling indicates the average daily stream flow from Cataract Creek to Cataract Reservoir is 11.2ML/d of which 3.5ML/d is baseflow, with a median baseflow of 2.2ML/d (WRM Water & Environment, 2014).

The groundwater modelling predicts a 0.013ML/day (4.74ML/year) loss of stream baseflow in the Cataract Creek catchment at the end of the proposed mining as shown in **Table 12** and **Figure 62**.

The modelled (0.12%) annual change in the Cataract Creek catchment flows are therefore relatively minor compared to the average annual stream flow into Cataract Reservoir.

10.4.2 Cataract River (Upstream of Cataract Reservoir) and Bellambi Creek

Although groundwater level reductions are predicted over the Wonga East workings, the majority of the changes are contained within the Cataract Creek catchment.

As such, there is anticipated to be no observable change in stream flow or groundwater seepage in the Cataract River (upstream of Cataract Reservoir) and Bellambi Creek catchments due to the very low proportion of the two catchments that may be partially depressurised as shown in **Table 12** and **Figure 62**.

The modelling predicts a reduction in baseflow of 1.20ML/yr in the Cataract River (upstream of Cataract Reservoir) and a reduction of 0.88ML/yr in Bellambi Creek. The modelled annual changes for the Cataract River (0.03%) and Bellambi Creek (0.02%) flows are therefore relatively minor compared to the average annual stream flow into Cataract Reservoir.

Table 12 Modelled Cataract Creek, Cataract River and Bellambi Creek Stream Flow Changes

	Baseflow Loss (ML/day) / (ML/year)	Change Due to Proposed Mining Compared to Current Flows (ML/day) / (ML/year)
Cataract Creek (Upstream of Cataract Reservoir)		
Current	0.005 / 1.83	-
End of Mining	0.018 / 6.57	0.013 / 4.74
Cataract River (Upstream of Cataract Reservoir)		
Current	0.0007 / 0.26	-
End of Mining	0.004 / 1.46	0.0033 / 1.20
Bellambi Creek		
Current	0.0006 / 0.22	-
End of Mining	0.003 / 1.10	0.0024 / 0.88
TOTAL		**0.0187 / 6.83**

10.5 Cataract Reservoir

Cataract Reservoir has a full operating storage of 97,190ML. The lowest level of the storage as advised by the SCA is 27,620ML or 29.3% capacity on 20 July 2006.

10.5.1 Stream Inflow

Due to the setback of the proposed workings from the Cataract reservoir, no adverse impacts on stored water quantity or quality are predicted to occur on, or in, Cataract Reservoir, based on the factors discussed in previous sections.

It is anticipated, however, that the water will flow via subsurface fractures and discharge down gradient into the lower section of the streams, and / or into Cataract Reservoir. As such, the change is anticipated to be a sub-surface diversion, not an overall loss, to the surface water balance.

The modelled sub-surface total transfer of 6.83 ML/year from the Cataract Creek, Cataract River and Bellambi Creek catchments at the end of the proposed mining at Wonga East is less than 0.03% of the low level storage, or 0.007% of its full storage capacity.

10.5.2 Strata Depressurisation

The modelled transfer of stored water within Cataract Reservoir to the underlying groundwater system due to depressurisation of the regional groundwater system in the vicinity of the lake is 0.005ML/day (1.83ML/year) at the end of mining.

The modelled sub-surface transfer of 1.83ML /year from the stored waters at the end of the proposed mining is less than 0.007% of the low level, or 0.002% of its full storage capacity.

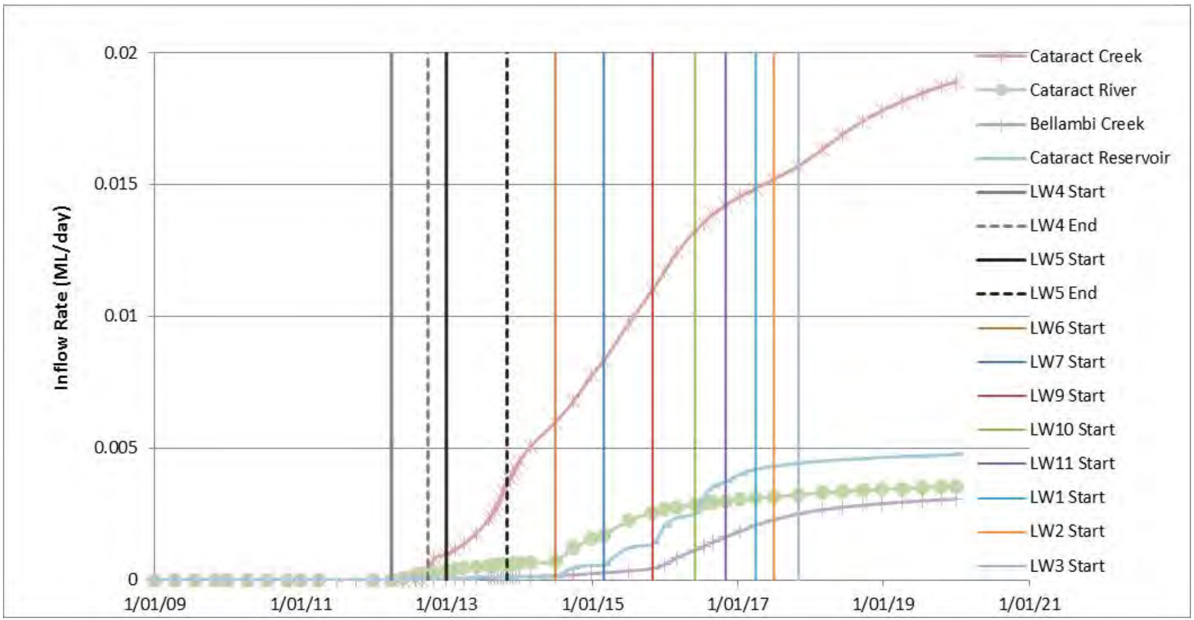


Figure 62 Wonga East Stream and Cataract Reservoir Related Depressurisation Losses

10.6 Subsidence Interaction with Faults and Dykes

The Corrimal Fault is mapped as crossing over the proposed Wonga East workings in Longwalls 6 to 9, however it is not anticipated to generate a hydraulic connection to the surface water system or Cataract Reservoir through extraction of LW6. The fault has been identified as a "hinge fault" with a varying throw of approximately 25m in the east, reducing to 1.8m at Maingate 5, and predicted to reduce to no displacement around Longwalls 7 and 8.

Recent intersection of the Corrimal Fault during development of the Longwall 6 gate-road indicates the fault zones contains three "normal" faults with up to 0.93m displacement, and associated smaller faults, with no associated groundwater inflow (Wollongong Coal, 2014). This indicates that the Corrimal Fault "zone" is diminishing to the north and is anticipated to fade out before it intersects with the reservoir. This observation indicates the potential re-activation or displacement of the Corrimal Fault due to subsidence and, therefore, its potential to cause a significant hydraulic connection between the workings and the mine, and to cause a significant drainage potential from the reservoir to the mine is not considered likely.

A thin (<1m wide) highly weathered dyke is located over the Wonga East workings, however, due to its highly weathered clay state and associated low intrinsic permeability, undermining this structure is not anticipated to enhance its permeability or potential hydraulic connection to the surface water systems (including Cataract Reservoir).

If inflow monitoring in the mine and observation of the piezometers installed over the Wonga East mining domain indicate there may be a potential for increased permeability along the Corrimal Fault due to mining induced changes, then the mining of subsequent panels can be adjusted through adaptive management of the mine workings.

To date, mining in the Bulli seam on both sides of the Corrimal Fault (both first and second workings), has not resulted in observable increased flows to the mine workings (Gujarat

NRE Coking Coal, 2013).

Based on past mining experience and interpretation of the mine water balance monitoring (SCT Operations, 2014), the faults in the Bulli / Balgownie workings are essentially dry and are not anticipated to provide enhanced permeability fluid pathways in the proposed mining area.

No water inrush has been observed with mining through faults or dykes in the Bulli, Balgownie or Wongawilli Seam workings (S Wilson, pers comm).

10.7 Groundwater Inflow to the Workings

The predicted modelled inflow to the proposed workings for each stage is shown in **Table 13** and **Figure 63**.

It should be noted that the proposed extraction will start with Longwall 6, progress to Longwall 11 and then re-locate and extract Longwalls 1 to 3, which are higher up in the catchment.

Table 13 Predicted Groundwater Mine Inflows

Stage	Measured Inflow (ML/day)	Predicted Inflow (ML/day)	Predicted Inflow (ML/year)
Pre Longwall 4	n/a	0.63	230
Post Longwall 5	1.05	1.06	370
Post Longwalls 6 and 7	-	1.27	464
Post Longwalls 8 to 11	-	1.7	620
Post Longwalls 1 to 3	-	1.2	438

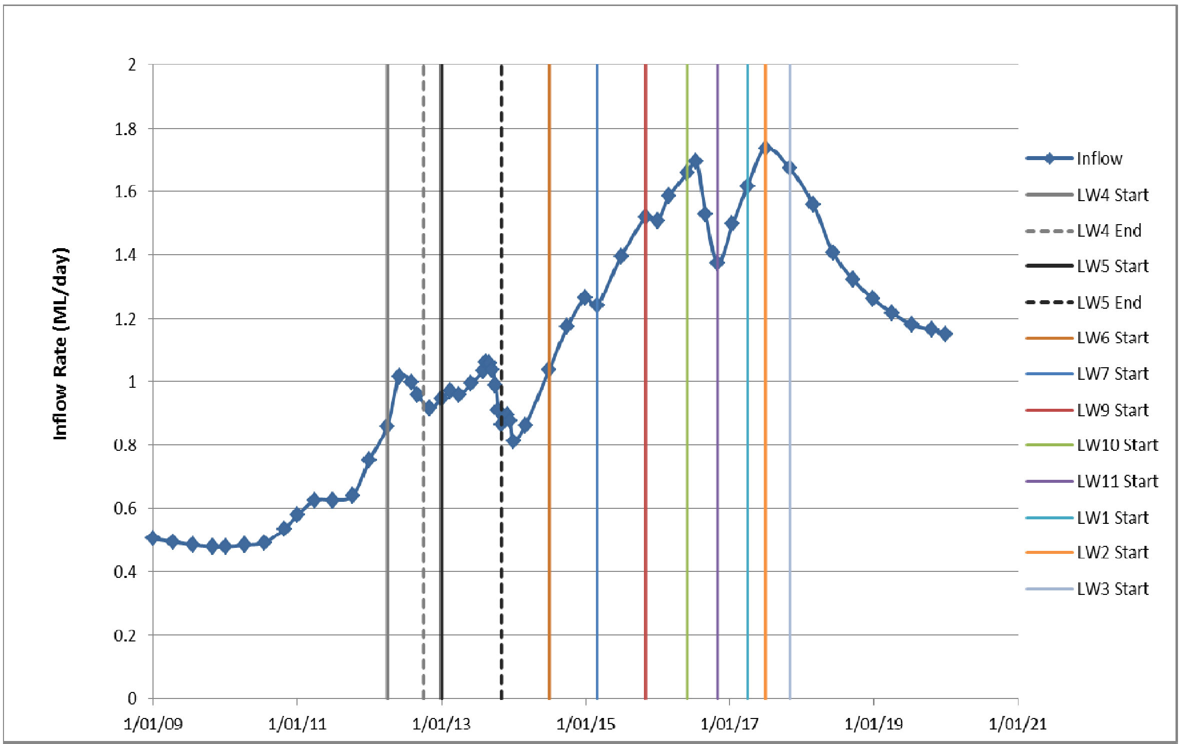


Figure 63 Predicted Groundwater Inflows

The modelled seepage rates into the workings may be enhanced if unidentified fracture related storages are intercepted, which may lead to short term increases of potentially up to 0.1 - 0.5ML/day which should dissipate over a period of weeks to months.

10.8 Groundwater Quality

Previous observations at Russell Vale indicate that groundwater quality within the regional groundwater system has not been adversely affected, however there may be some localised increased iron hydroxide precipitation and limited lowering of pH if the groundwater is exposed to "fresh" surfaces in the strata through dissolution of unweathered iron sulfide or carbonate minerals.

The degree of iron hydroxide and pH change is difficult to predict, and can range from no observable effect to a distinct discolouration of the formation water. The discolouration does not pose a health hazard, however it can cause iron hydroxide precipitation at seepage points in local streams which can also be associated with algal matting and / or lowering of dissolved oxygen levels in the creek at the seepage point.

It should be noted that many Hawkesbury Sandstone aquifers in the Southern Coalfield already have significant iron hydroxide levels, and that ferruginous seeps can also be observed in previously un-subsided catchment areas.

As a result of the proposed workings, pH acidification of up to 1 unit may occur, however the change may be reduced if the aquifer has sufficient bicarbonate levels.

Outside of isolated iron hydroxide seepages, no adverse groundwater quality is anticipated to discharge from the proposed Wongawilli Seam workings subsidence areas.

10.9 Loss of Bore Yield

There will be no loss of bore yield as there are no registered private bores or wells located within the Study Area.

11. CUMULATIVE GROUNDWATER RELATED IMPACTS

11.1 Upland Swamps

As outlined in Biosis (2014), no other adjoining mining operations provide a cumulative impact on swamps in the Study Area.

No swamps are present downstream of the Wollongong Coal lease area.

11.2 Basement Groundwater

The cumulative impact of the existing and proposed Russell Vale workings along with the surrounding mines has been assessed in the model runs by including the effects of:

- hydraulic permeability distribution over non-mining areas;
- subsidence, fracture propagation and associated hydraulic permeability distribution over bord and pillar, pillar extraction or longwalls on the regional groundwater pressure distribution;
- known or estimated degree of flooding in the adjoining workings, and;
- the separation distance from adjoining workings, where Appin / Westcliff / Northcliff / Metropolitan / Tahmoor mining areas were interpreted to be sufficiently distant from the existing and proposed Russell Vale Colliery workings to be discounted.

Groundwater modelling indicates that the influence of the Project within the Wongawilli Seam can be broken down into the depressurisation of two separate regimes:

- saturated coal measures above the Wongawilli Seam; and the
- shallower stratigraphy.

Deeper coal measure strata of the Wongawilli Seam and overburden immediately overhead would be depressurised to mining levels in the immediate footprint of the mine plan with up to 2m of drawdown in the Wongawilli Seam out to 1km beyond the mine plan at the end of the mining period.

The overlying Balgownie and Bulli seams have previously been mined and therefore significant depressurisation has occurred historically.

The shallower strata have the potential to be depressurised, most notably in the Bulgo Sandstone and the Hawkesbury Sandstone (where it is present) from Wongawilli subsidence related fracturing, as well as reworking the existing overburden fracture systems due to historical mining in the Bulli, Balgownie and Wongawilli Seams.

Modelling indicates significant depressurisation within these sandstone units overlying the proposed Russell Vale Wongawilli workings with the 2m depressurisation cone in the Upper Bulgo Sandstone extending to a distance or 1km beyond the proposed workings.

Regionally, the closest mining operations include those utilised for the model boundaries. The Appin Mine is located 13 km to the north-west operates within the Bulli Seam. Twelve kilometres to the south-west, Dendrobium Colliery is mining the Wongawilli Seam.

A review of the groundwater related studies undertaken for these projects indicates that regional drawdown at Appin extends approximately 2-3 km from the southern margins of the current operation (Heritage Computing 2009) and similarly at Dendrobium (Coffey

Geotechnics, 2012).

Modelling conducted for this study and previous studies in the Southern Coalfield indicates there will not be any superposition of drawdown cones between the Russell Vale and Appin / Dendrobium mining areas. Therefore, there is no cumulative depressurisation resulting from the Project and other mines.

Cumulative losses are therefore as shown in the model, which includes all of the adjoining historical, decommissioned mining areas and depressurisation due to the proposed Wongawilli Seam extraction does not expand into, or interact with, the current or proposed mining operations at Appin Mine and Dendrobium Colliery.

12. MODELLING UNCERTAINTY

The Australian groundwater modelling guidelines provide a guiding principle in relation to model uncertainty as shown below:

"Models should be constructed to address specific objectives, often well-defined predictions of interest. Uncertainty associated with a model is directly related to these objectives" (SKM 2012).

All models contain uncertainty and a groundwater model's predictive capacity is limited by the ability to simulate the study area at a sufficiently detailed scale.

The model predicts a negligible reduction in baseflow derived from the regional water table. Due to the observed isolation between perched and regional water tables, there is an expectation that there would be little effect on baseflow derived from aquifer sources due to regional depressurisation.

As the discrete features are too thin, not regionally pervasive, whilst their distribution in the strata and their associated hydraulic parameters are not known, the model can not predict the effect of water flow through horizontal to sub-horizontal shear zones associated with hillslope strata fracturing and valley closure.

The groundwater regime is heavily impacted within the overburden and regional stratigraphy due to past mining which has been ongoing since the end of the 19th century. However, no historical groundwater calibration data in terms of mine inflows and / or water levels is available prior to the installation of P501, P502 and P514 in 1992 within the Russell vale lease area.

The current proposal would mine beneath previously mined strata and has the potential to reactivate earlier subsidence impacted zones. It has been the intent of the model setup to adopt a conservative approach whereby fracturing is extended into the lower sections of the Hawkesbury Sandstone, with the modelling indicating there is a potential for depressurisation to shallow levels in the Hawkesbury Sandstone (or Bulgo Sandstone where it is exposed in the bed of Cataract Creek).

Setup of the fracturing and associated depressurisation distribution in the overburden utilised an adapted version of a theoretical depressurisation model, which is based on single seam longwall extraction (Tammetta, 2012). The applicability of the empirical model, and its adaptation to multiple seam extraction has not yet been sufficiently tested in the Russell Vale lease area as there is only one multiple intake vibrating wire piezometer within the Wonga East area (GW1) and it is not ideally located over the centre of the triple seam mined area near Longwalls 4 and 5. Further drilling and VWP / open standpipe piezometer installation is planned, and will commence after approval from the

SCA is attained.

In addition, other theoretical fracturing and strata depressurisation models are available that may be equally applicable to set up the fracturing and associated depressurisation distribution, such as the model developed by Ditton Geotechnical Services Pty Ltd (DGS).

The DGS based approach has been used and accepted by the Department of Planning and Environment for the modelling of the following mining proposals:

- Chain Valley - Mining Extension 1
- Whitehaven Coal - Narrabri North
- Donaldson Coal - Abel Underground Mine
- Donaldson Coal – Tasman Extension Underground Mine
- West Wallsend Underground Mine
- Wambo Underground Mine
- Angus Place
- Springvale

The possible connection of surface water features to a potential subsidence generated depressurisation field and subsequent depletion of stream flow in overlying drainage pathways is a significant potential environmental impact that may result from subsidence within a multi seam mining environment. To address this issue, a probabilistic or stochastic approach has been undertaken where hydraulic conductivity has been randomly generated using “fieldgen”, which is part of the PEST (Watermark Numerical Computing, 2014) suite of programs. The stochastic approach has been used to explore the uncertainty in the model predictions arising from hydraulic property heterogeneity and in this case specifically lateral or horizontal hydraulic conductivity.

The stochastic field arrays are generated using a statistical function for a chosen property. In this case, only horizontal hydraulic conductivity is varied. This includes the calibrated value within the model and using the standard deviation to vary the field array based on the observed population of measured conductivities. Standard deviation defines an acceptable range in Kx values.

Variation of the conductivity field was limited to the horizontal plane only because the base case predictions indicated that depressurisation to surface is likely. Therefore any interaction with surface water entities, (i.e. Cataract Creek) are likely to be more sensitive to lateral variability. Host vertical hydraulic conductivity was maintained from the base case predictive model.

The realisations have been used to generate 30 models with the randomised arrays from layers 1 to 10 (Hawkesbury Sandstone to Scarborough Sandstone), with each conductivity array in the upper 12 layers being different from corresponding arrays in the other models, whilst having the random values centred around the calibrated value for each model layer.

Each model is then run two times (complete model run from 1993) for the case with and without mining of the proposal. In this way, the changes to base flows from the drainage pathways which potentially interact with the mining proposal were compared and the potential variability of responses was assessed.

Statistics were derived from the packer database as shown in **Table 14**, which provides a summary of the stratigraphic test interval and sample number as well as the standard deviation for each interval.

Table 14 Stratigraphic Test Interval, sample Number and Standard Deviation

Stratigraphic Unit	Sample Number	SD of Log Kh
Hawkesbury Sandstone	52	1.04
Bald Hill Claystone	9	1.36
Bulgo Sandstone	55	1.15
Stanwell Park Claystone	15	1.28
Scarborough Sandstone	14	1.13
Wombarra Claystone	13	1.01
Coal Cliff Sandstone	21	0.77

Losses from Cataract Creek, Cataract River upstream of the reservoir, Bellambi Creek and Cataract Reservoir were extracted from each model along with predicted mine inflow rates for the Wonga East Workings.

Figure 64 shows mine inflow rates (ML/d) for the 30 stochastic model runs as well as the predicted base case predictive inflow for the calibrated model. It shows a peak inflow (R20) of 2.0ML/d which is a 10% increase on the base case predicted inflow peak. Early model time inflows which represent predominantly Bulli Seam inflows show that the Base Case model is in the higher end of the inflow estimates. **Figures 65** and **66** show losses from Cataract Creek and the combined loss curve for Cataract Creek, Cataract River, Bellambi Creek and Cataract Reservoir combined for the 30 model runs and the base case model results.

Figure 67 shows a probability distribution for mine inflow rates. Mean values (based on the period from start of mining in the Wongawilli Seam to End of Mining) are influenced by the long period of model time where inflows are predominantly from the unmined areas of the Bulli Seam. Average inflow for the Base Case model of 0.75 ML/d is in the upper quartile of the 30 model runs, whilst peak inflow rates show that the Base Case model peak inflows are approximately in the 50 to 60 percentile range.

The probability distribution for base flow losses from Cataract Creek is shown in **Figure 68** where the Base Case model results are within the upper quartile of the mean and maximum rates found from the multiple stochastic model runs. Similarly, base flow losses from the combined surface water features including Cataract Creek, Cataract River upstream of the reservoir, Bellambi Creek and Cataract Reservoir for the base case model are in the higher range of results which were found in the multiple model runs.

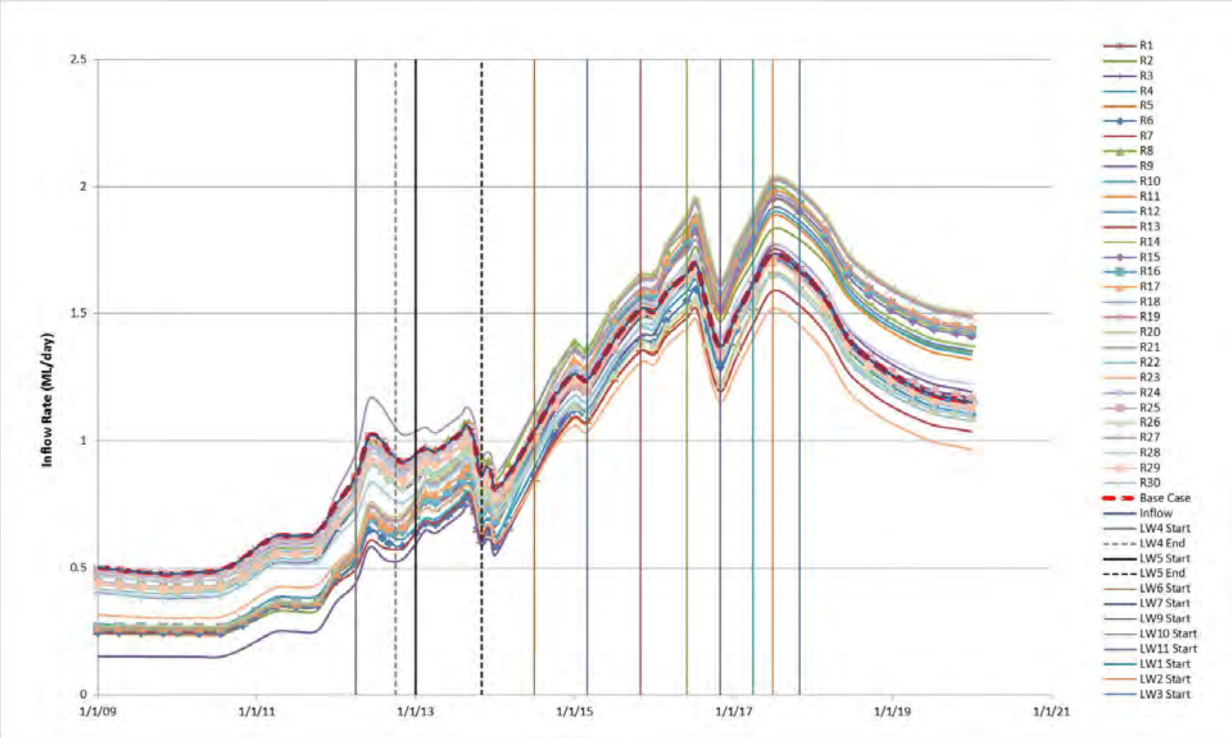


Figure 64 Mine Inflow

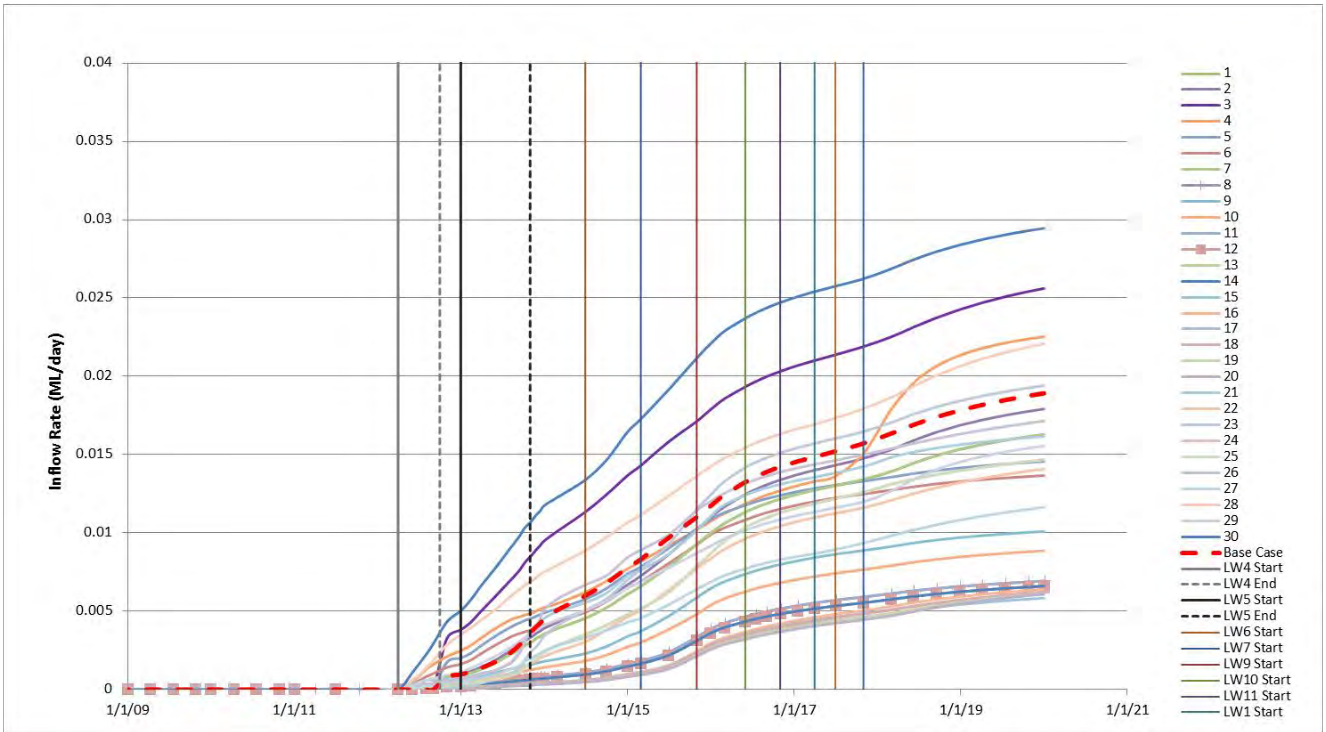


Figure 65 Base Flow Loss From Cataract Creek

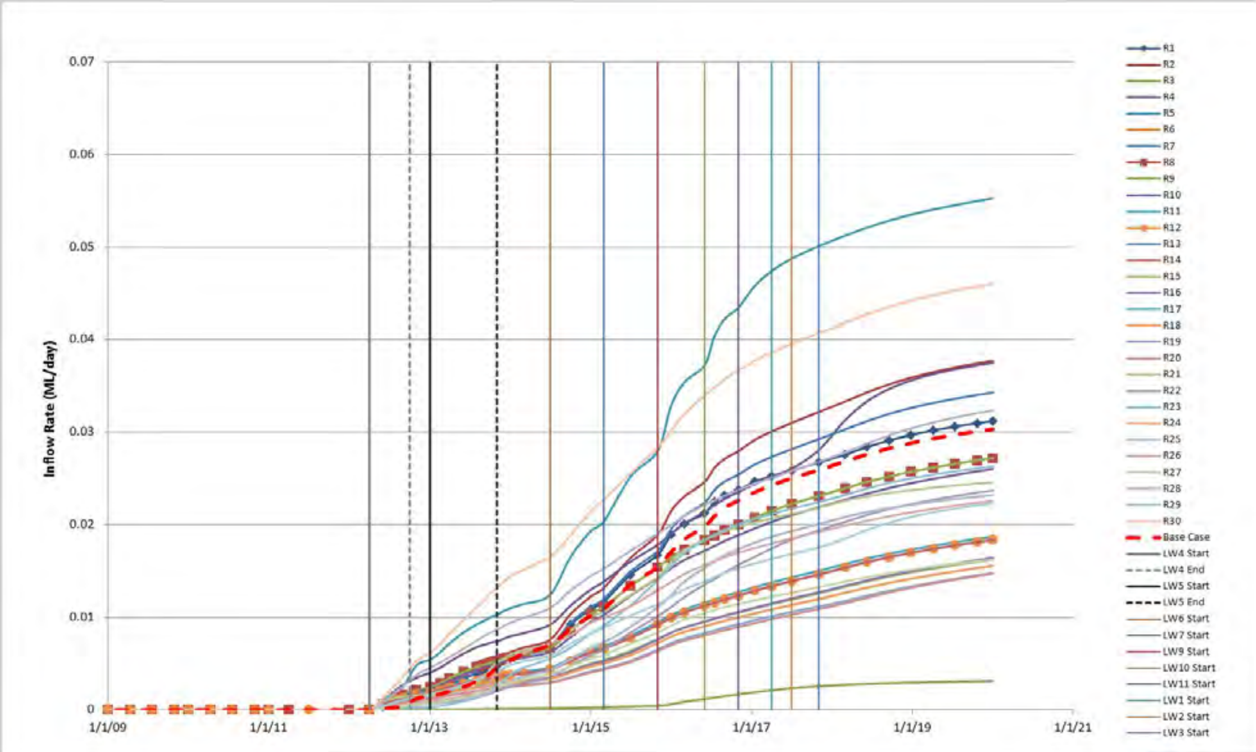


Figure 66 Combined Base Flow Losses from Cataract Creek, Cataract River, Bellambi Creek and Cataract Reservoir

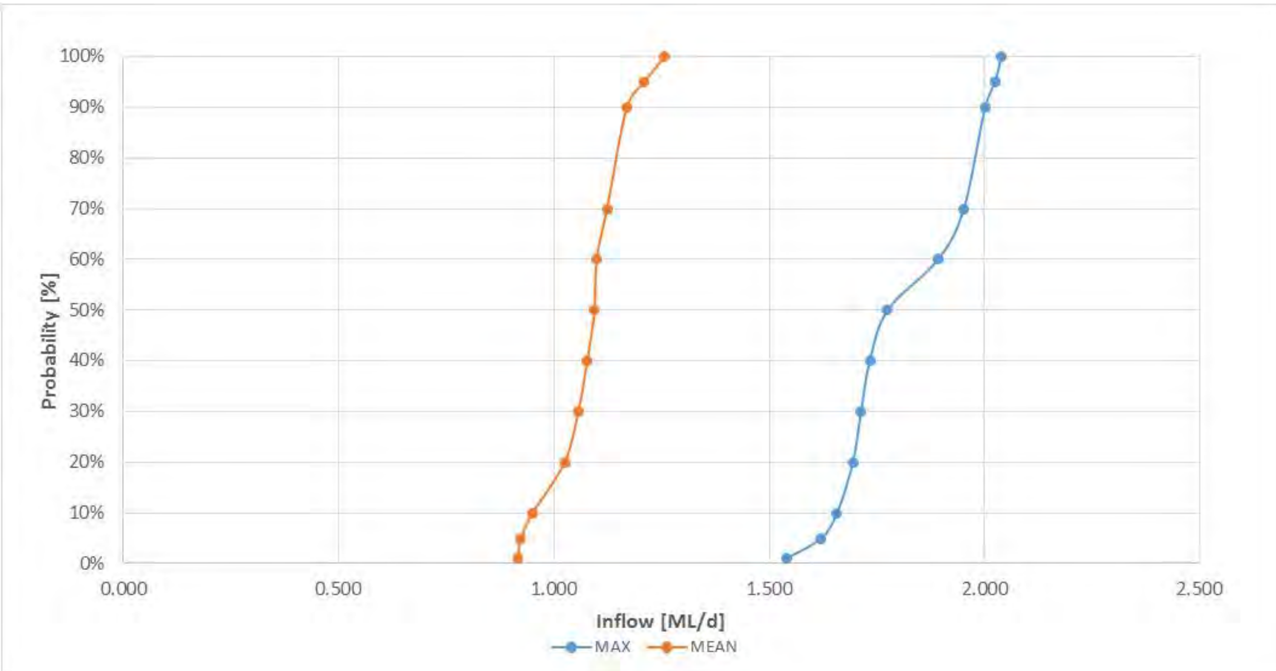


Figure 67 Mine Inflow Probability Frequency Distribution

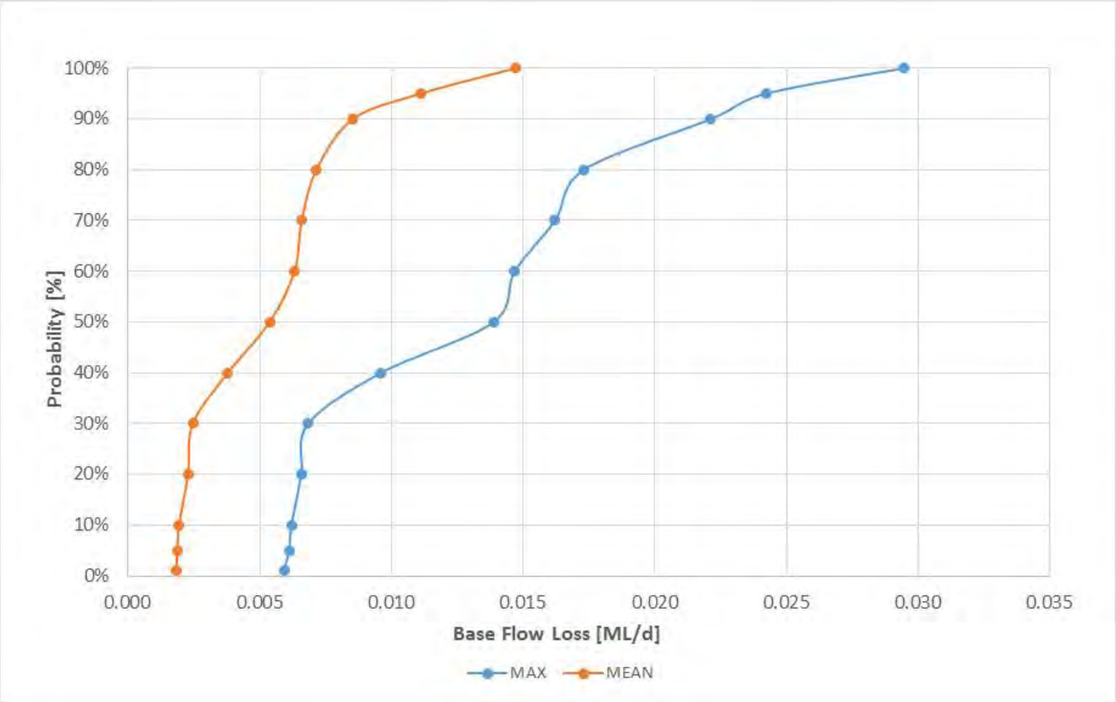


Figure 68 Cataract Creek Base Flow Loss Probability Frequency Distribution

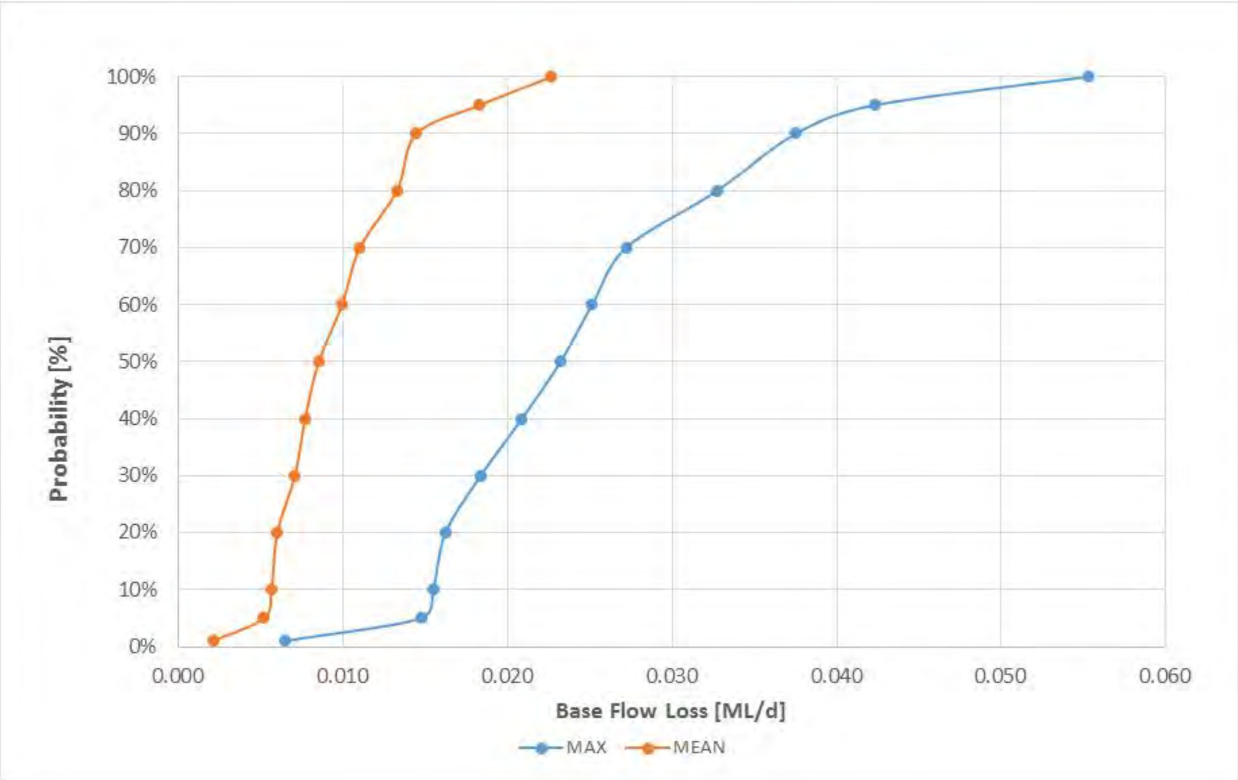


Figure 69 Combined Base Flow Loss Probability Frequency Distribution

12.1 Recharge Sensitivity

An analysis has also been carried out to assess the sensitivity of the model calibration to the assumed input parameters for recharge. The sensitivity analysis was carried out by first decreasing and then increasing recharge and evaluating the impacts of the changes on the calibration statistics. A range of multipliers was used with an upper and lower bound of 10 and 0.1 respectively. That is the range being an order of magnitude above and below the assumed calibrated value for recharge.

Figure 70 shows the results of the sensitivity analysis whereby calibration performance is measured in terms of the sum of residuals of calibration targets. It shows that increasing and decreasing recharge over the model domain does not improve calibration performance.

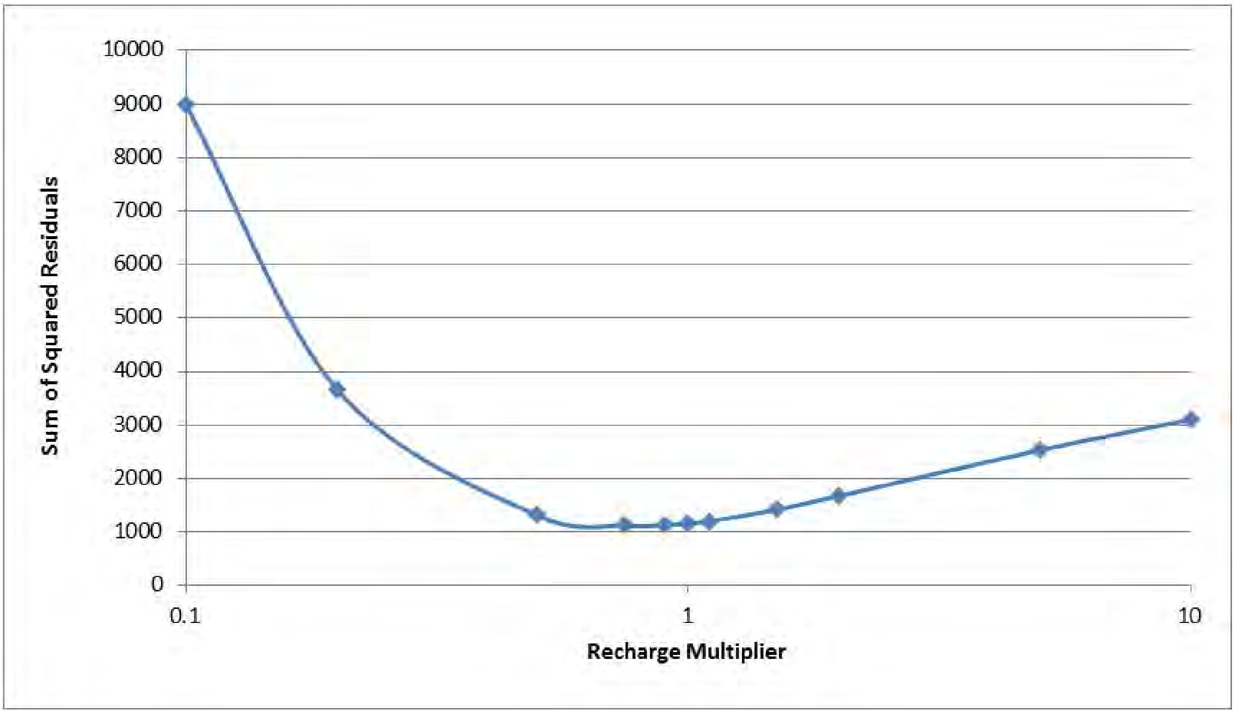


Figure 70 Recharge Sensitivity Analysis Results

13. MODEL LIMITATIONS

The adopted model has been designed to simulate the propagation of both near-field and far-field depressurisation effects throughout the regional aquifer system.

The model has not been designed to simulate the effects of near-surface tensile cracking or discrete structural features, such as the presence of faults or dykes or their displacement due to subsidence resulting from underground extractive mining.

The model does not include structural features such as faults and dykes which have the potential to compartmentalise or connect facets of sub-regional aquifers and also potentially surface water features to sub-surface strata. The current model has not assessed geological faults and structures due to the uncertainty in their location, vertical persistence, and their resultant attributes as barriers or transmissive conduits.

14. WATER LICENSING

14.1 Groundwater

The Project is covered by the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011* (Groundwater WSP), which applies to 13 groundwater sources.

The current groundwater licence under Part 5 of the *Water Act 1912* that is held by Russell Vale Colliery for 365ML/year (Licence No. 10BL602992) is located within Management Zone 2 of the Sydney Basin Nepean Groundwater Source. This includes all aquifers below the surface of the ground (clause 4), and covers alluvium, weathered and basement rocks.

As the current licence is held under part 5 of the *Water Act 1912*, Wollongong Coal will need to convert its existing licence to a WAL.

For the purposes of the WM Act, an 'aquifer' is defined as *"a geological structure or formation, or an artificial landfill that is permeated with water or is capable of being permeated with water"*. Abandoned workings are not geological structures or formations and as such, do not constitute aquifers. Therefore, water make sourced from abandoned workings does not constitute the taking of water from the water source, whereas the Wongawilli coal seam and overburden satisfy the definition of 'aquifer" and the mining effects on them are deemed to be a water "take".

Since the Groundwater WSP applies to all aquifers, Wollongong Coal will require WALs for all groundwater taken in the course of mining. The total licensing entitlement required will be the maximum mine water make, which will include the water taken from each formation.

Based on the predicted maximum inflow of 620ML/year, which includes approximately 0.2ML/day (73ML/year) of seepage inflow from adjoining, upgradient decommissioned workings which is not required to be licensed, Wollongong Coalwill require a WAL for at least 182 ML/year in addition to their current licence. This is the maximum predicted inflow (620ML/year) minus the existing licensing entitlement (365ML/yr) and the water taken from former mine workings (73 ML/year).

The Sydney Basin Nepean Groundwater Source WSP limits the total share component for aquifer licences in this water source to 16,283 unit shares.

14.2 Surface Water

The Project is located within the area covered by the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011* (Unregulated River WSP). The Unregulated River WSP includes six water sources, with the Project situated entirely within the 'Upper Nepean and Upstream Warragamba Water Source".

Clause 4 of the Unregulated River WSP states that these water sources include all water:

- *Occurring naturally on the surface of the ground shown on the Registered Map; and*
- *In rivers, lakes, estuaries and wetlands in these water sources.*

Wollongong Coal currently does not hold any licences for surface water use for the region covering the proposed mining area and will need to obtain WALs for the total volume of surface water taken from the Upper Nepean and Upstream Warragamba Water Source.

The WSP limits the total share component for unregulated river licences in this water source to 15,540.2 unit shares.

Impacts that would give rise to licensing requirements include:

- Reduction in base flows to streams due to drawdown;
- Additional runoff that infiltrates into the groundwater system via subsidence induced shallow cracking;
- Leakage from swamps; and
- Loss of water from Cataract Reservoir due to depressurisation.

Cracking of streams may result in a reduction of stream flow through re-directing water into the bedrock. Although this water may re-emerge downstream, the water is deemed to have been "taken" as it is diverted from above to below the ground surface. Section 60I of the WM Act indicates that the water is deemed to be taken even if it is returned to the water source. Section 60I states:

"a person takes water in the course of carrying out a mining activity if, as a result of or in connection with, the activity or a past mining activity carried out by the person, water is removed or diverted from a water source (whether or not water is returned to that water source) or water is re-located from one part of an aquifer to another part of an aquifer".

The maximum predicted loss of stream baseflow due to basement depressurisation under the Cataract Creek, Cataract River and Bellambi Creek catchments within Management Zone 2 of the Sydney Basin Nepean Groundwater Source, as a result of the proposed mining, is 6.83 ML/yr at the end of mining as shown in **Table 15**.

Table 15 Surface Water Licensing Requirements

Surface Water Source	**Predicted Surface Water "Take" (ML/year)**
Wonga East Stream Baseflow	6.83
Cataract Reservoir Leakage	1.83
(TOTAL)	**8.66**

Volumetric assessment of potential annual stream flow changes due to valley closure related cracking and transfer to sub-surface flow can not be assessed by the groundwater model, nor can it be predicted by any other method as the response of a stream bed to valley closure and compressional / tensional cracking is highly site specific and highly variable within a stream bed due to up to 36 factors (Kay, D.R, Waddington, A.A, 2014) and (Barbato, J et al, 2014).

Under the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources, which encompasses the Study Area and is contained within the Sydney Basin Nepean Groundwater Source Area, Wollongong Coal will require a WAL for the annual take of up to 8.66 ML/yr of stream baseflow resulting from depressurisation of deeper aquifers.

15. NSW AQUIFER INTERFERENCE POLICY MINIMAL IMPACT CONSIDERATIONS

The Aquifer Interference policy (AIP) prescribes minimal impact considerations which must be satisfied.

The minimal impact considerations for a water source vary depending on the nature of the water source (i.e. alluvial, coastal, fractured rock etc) and whether it is "highly productive groundwater" or "less productive groundwater".

The minimal impact considerations for less productive porous rock water sources are presented in **Table 16** and for the perched, ephemeral aquifers in **Table 17**.

The aquifers are not considered to be "highly" productive as although they contain total dissolved solids of less than 1500mg/L in the Hawkesbury Sandstone, there are no water supply works that yield water at a rate greater than 5L/sec in the Wonga East area.

Table 16 NSW Minimal Impact Considerations for Less Productive Porous Rock Water Sources

Minimal Impact Consideration	Proponent Response
Water Table – Level 1 Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan variations, 40m from any: a) high priority groundwater dependent ecosystem, or b) high priority culturally significant site listed in the schedule of the relevant water sharing plan, or A maximum of a 2 m decline cumulatively at any water supply work unless make good provisions should apply.	There are no: • high priority groundwater dependent ecosystems, or; • high priority culturally significant sites listed under Schedule 4 of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011. The swamps above the mine plan are not classified as Temperate Highland Peat Swamps on Sandstone (which is high priority GDE). There are no water supply works (i.e. groundwater bores) in the Wonga East proposal area that will undergo more than a 2m decline.
Water Table – Level 2 If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: a) high priority groundwater dependent ecosystem; or b) high priority culturally significant site listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than 2m decline cumulatively at any water supply work then make good provisions should apply.	Level 2 does not apply as Level 1 criteria is not exceeded
Water Pressure – Level 1 A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head	There are no water supply works (i.e. groundwater bores) in the Wonga East proposal area that will undergo a greater than 40% post water sharing plan pressure head decline

above the base of the water source to a maximum of a 2m decline, at any water supply work.	above the base of the water source, and no water supply work will undergo greater than 2m decline
<u>Water Pressure – Level 2</u> If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	Level 2 does not apply as Level 1 criteria is not exceeded
<u>Water Quality – Level 1</u> a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity, and b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a "reliable water supply" is not an appropriate mitigation measure to meet considerations 1(a) and 1(b) above. c) No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply".	The beneficial use category of the groundwater source will not be changed beyond 40m from the Wonga East proposal area. There are no highly connected surface water sources (alluvial aquifers) in the Wonga East proposal area There are no highly connected alluvial surface water sources defined as a reliable water supply within the Wonga East proposal area
<u>Water Quality – Level 2</u> If condition 1(a) is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works. If condition 1(b) is not met then appropriate studies are required to demonstrate to the Minister's satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity. Condition 1(c) does not apply as there are no river bank or high wall instability risks and no need for low permeability barriers between the site and highly connected surface waters	Level 2 does not apply as Level 1 is not exceeded

Table 17 NSW Minimal Impact Considerations for Perched Ephemeral Aquifer Water Sources

Minimal Impact Consideration	Proponent Response
Water Table – Level 1 Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan variations, 40m from any: c) high priority groundwater dependent ecosystem, or d) high priority culturally significant site listed in the schedule of the relevant water sharing plan, or A maximum of a 2 m decline cumulatively at any water supply work unless make good provisions should apply.	There are no: • high priority groundwater dependent ecosystems, or; • high priority culturally significant sites listed under Schedule 4 of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011. The swamps above the mine plan are not classified as Temperate Highland Peat Swamps on Sandstone (which is high priority GDE). There are no water supply works (i.e. groundwater bores) in the Wonga East proposal area that will undergo more than a 2m decline.
Water Table – Level 2 If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: c) high priority groundwater dependent ecosystem, or d) high priority culturally significant site listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than 2m decline cumulatively at any water supply work then make good provisions should apply.	Level 2 does not apply as Level 1 criteria is not exceeded
Water Pressure – Level 1 A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2m decline, at any water supply work.	There are no water supply works (i.e. groundwater bores) in the Wonga East proposal area that will undergo a greater than 40% post water sharing plan pressure head decline above the base of the water source, and no water supply work will undergo greater than 2m decline
Water Pressure – Level 2 If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	Level 2 does not apply as Level 1 criteria is not exceeded
Water Quality – Level 1 d) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity;	The beneficial use category of the groundwater source will not be changed beyond 40m from the Wonga East proposal

and e) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a “reliable water supply” is not an appropriate mitigation measure to meet considerations 1(a) and 1(b) above. f) No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a “reliable water supply”.	area. There are no highly connected surface water sources (alluvial aquifers) in the Wonga East proposal area There are no highly connected alluvial surface water sources defined as a reliable water supply within the Wonga East proposal area
Water Quality – Level 2 If condition 1(a) is not met then appropriate studies will need to demonstrate to the Minister’s satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works. If condition 1(b) is not met then appropriate studies are required to demonstrate to the Minister’s satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity. Condition 1(c) does not apply as there are no river bank or high wall instability risks and no need for low permeability barriers between the site and highly connected surface waters	Level 2 does not apply as Level 1 is not exceeded

16. MONITORING, CONTINGENCY MEASURES & REPORTING

Wollongong Coal will prepare a Water Management Plan in accordance with conditions of Project Approval.

The Water Management Plan will include a groundwater monitoring program, which will include monitoring of groundwater levels, water quality, pumping volumes and stream flows.

The ongoing collection and interpretation of the data will be used to update the TARP trigger levels and the groundwater model, as required.

16.1 Groundwater Levels

Piezometers to be included in the monitoring suite are shown in **Table 18**.

The suite is divided into standpipe and vibrating wire piezometers, with water level transducers and vibrating wire piezometers used to monitor standing water levels or pressure heads twice daily to assess variations in the colluvial and basement formations.

Table 18 Groundwater Level Monitoring Suite

	Piezometer Type
Basement	
NREA, C, D, E, G, NRE3, GW1A	Open Standpipe
NREA, B, D, NRE3, GW1	VWP

NOTE: VWP = vibrating wire piezometer

Inclusion of additional groundwater monitoring locations and depths will be incorporated, if required, following discussions with the SCA and NOW.

Monitoring will also involve bi-monthly manual standing water level measurement in all open standpipe piezometers, at which time the loggers will be downloaded and re-initiated as shown in **Table 19**.

Table 19 Standing Water Level Monitoring Method and Frequency

Monitoring Site	Sampling Method	Frequency / Download	Units
NREA, C, D, E, G, NRE3, GW1A	Water level logger / dip meter	twice daily / bi-monthly	mbgl
NREA, B, D, NRE3, GW1A	Vibrating wire piezometer	twice daily / quarterly	m head pressure
SP1, SP2	Water level logger / dip meter	twice daily / bi-monthly	mbgl
PL1A, B PL18, PL25A, B, C, D	Water level logger / dip meter	twice daily / bi-monthly	mbgl
PW1, 4, 11	Water level logger / dip meter	twice daily / bi-monthly	mbgl
PCc2, 3, 4, 5A, 5B, 6	Water level logger / dip meter	twice daily / bi-monthly	mbgl
PCr1	Water level logger / dip meter	twice daily / bi-monthly	mbgl
PB4	Water level logger / dip meter	twice daily / bi-monthly	mbgl

NOTE: mbgl = meters below ground level

16.2 Groundwater Quality

Tables 20 and **21** present the parameters to be measured, frequency of monitoring and sampling method for groundwater quality monitoring, with monitoring to continue for 12 months after mining has ceased.

Table 20 Groundwater Quality Monitoring Parameters

ANALYTES	Units	FREQUENCY
EC, pH	µS/cm, pH units	Bi - monthly
(EC, pH) + TDS, Na, K, Ca, Mg, F, Cl, SO4, HCO3, NO3, Total N, Total P, hardness, Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd (metals filtered)	mg/L	Start / finish of panel for piezometers adjacent to a panel, or in an active mining area, otherwise 1 sample per year

The frequency of monitoring will be reassessed after mining is complete as it may be possible, depending on results, to lengthen the intervals. The frequency of monitoring and the parameters to be monitored may be varied by NOW once the variability of the groundwater quality is established.

Groundwater samples should be collected at the start and finish of each panel from piezometers either adjacent to an active panel, or within an active mining area and analysed at a NATA registered laboratory for major ions and selected metals. Piezometers not within an active mining area should be sampled and analysed once per year.

It is anticipated that the groundwater monitoring program will be maintained in its current status, with possible modification of the program at the end of each panel after a review of all monitoring data has been conducted.

Additional piezometers may be added to the existing suite if required.

The groundwater monitoring program is anticipated to be extended beyond the active mining period in order to assess the potential long term change in groundwater level recovery and quality changes for 12 months after completion of mining.

Table 21 Groundwater Quality Monitoring Method and Frequency

Monitoring Site	Sampling Method	Frequency
Open Standpipe Piezometers	Pumped field meter readings	Bi-monthly
Open Standpipe Piezometers	Pumped sample for laboratory analysis	Start / finish of each panel for piezometers adjacent to a panel or in an active mining area, otherwise 1 sample per year

16.3 Surface Water and Groundwater Connectivity

The potential for surface water and groundwater system hydraulic connectivity will be assessed through monitoring of stream flows in and near actively mined areas, as outlined in Geoterra (2012) as well as through monitoring and interpretation of the basement groundwater open standpipe and vibrating wire piezometers water levels / pressures and mine inflow changes.

16.4 Mine Water Pumping

The volume of water pumped into and out of the Russell Vale Colliery workings will be monitored daily to enable the differential groundwater seepage into the workings to be assessed.

In addition, completion of the pump calibration tests, ongoing QA / QC and regular assessment of the pumping data will be required to enable reliable assessment of mine groundwater make due to extraction of the proposed workings.

16.5 Ground Survey

The ground surface over the proposed underground workings will be surveyed in accordance with the Extraction Plan (to be prepared in accordance with the conditions of Project Approval).

16.6 Rainfall

Daily rainfall data will be obtained from a local weather station for the duration of mining in the proposal catchment area.

16.7 Ongoing Monitoring

All results will be reviewed after each panel is completed and an updated monitoring and remediation program will be developed, if required, in consultation with NOW and DRE.

16.8 Quality Assurance and Control

QA/QC should be attained by calibrating all measuring equipment, ensuring that sampling equipment is suitable for the intended purpose, using NATA registered laboratories for chemical analyses and ensuring that site inspections and reporting follow procedures outlined in the ANZECC 2000 Guidelines for Water Quality Monitoring and Reporting.

16.9 Impact Assessment Criteria

16.9.1 Groundwater Levels

Impact assessment criteria investigation trigger levels should be initially set where a groundwater level reduction exceeds more than 10% of the saturated aquifer thickness over a 12 month period, compared to the minimum height within the last 12 months of data, excluding any short term recharge peaks. Should the trigger be exceeded, the actual rate of change of water levels should be investigated to determine whether the change is solely subsidence induced or due to a range of other potential factors.

If a significant increase in the rate of water level decline is noted, based on interpretation by a qualified hydrogeologist, then an assessment should be conducted to determine the cause of the change (such as variation in climate or effects from adjacent mining operations) and to consider potential contingency measures that may be adopted.

16.9.2 Groundwater Quality

Groundwater quality impact assessment criteria are sourced from the Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC, 2000) for Aquatic Ecosystems as shown in **Table 22.**

Table 22 Groundwater Quality Impact Assessment Criteria

Indicator	Irrigation Criteria
pH	<6.5 or >7.5 or >10% variation over 4 months compared to previous 12 months data
Conductivity	>10% variation over 4 months compared to previous 12 months data
TDS	>350mg/L or >10% variation compared to previous 12 months data
Total Nitrogen	>250µg/L or >10% variation compared to previous 12 months data
Total Phosphorus	>20µg/L or >10% variation compared to previous 12 months data

A trigger to assess the cause and effects of adverse groundwater quality changes should be implemented when there is a prolonged and extended non-conformance of the outlined criteria at a particular piezometer. If a field parameter (pH, conductivity) is outside the designated criteria for at least six months in a sequence, or alternatively, exceeds its previous range of results by greater than a 10% variation for at least 4 months, then the cause should be investigated, and a remediation strategy should be proposed, if warranted.

The criteria and triggers should be reviewed after each 12 month block of data is interpreted and may be modified as appropriate, depending on the results.

If the impacts on the groundwater system resulting from future underground operations are demonstrated to be greater than anticipated, the proponent should:

- assess the significance of these impacts;
- investigate measures to minimise these impacts; and
- describe what measures would be implemented to reduce, minimise, mitigate or remediate these impacts in the future to the satisfaction of the Director-General, NOW and the Sydney Catchment Authority.

16.10 Contingency Procedures

Contingency procedures should be developed as required, with the measures to be developed being dependent on the issue that requires addressing.

The procedures should be used to manage any impacts identified by monitoring that demonstrate the groundwater management strategies may not have adequately predicted or managed the groundwater system's anticipated response to mining.

Activation of contingency procedures should be linked to the assessment of monitoring results, including water quality, aquifer hydrostatic pressure levels and the rate of water level changes.

Performance indicators should be identified prior to extraction of the proposed underground workings and a statistical assessment should be undertaken to detect when, or if, a significant change has occurred in the groundwater system which should benchmark the natural variation in groundwater quality and standing water levels.

A monitoring and management strategy along with an outline of a Trigger Action Response Plan (TARP) should be prepared to provide guidance on the procedures and actions required in regard to the surface water and groundwater systems in the proposed mining area.

16.11 Piezometer Maintenance and Installation

The current network should be maintained by protecting the wellhead from damage by animals and scrub fires by maintaining their steel sealed wellheads.

If required, the piezometers may be cleaned out by air sparging if they become clogged.

In the event that any new piezometers are required, they should be installed by suitably licensed drillers after obtaining the approvals from the SCA and NOW.

16.12 Reporting

Following completion of extraction of each panel, a report should be prepared for all prior panels that summarises all relevant monitoring to date. The report should outline any changes in the groundwater system over the relevant mining area.

The report should contain an interpretation of the data along with:

- a basic statistical analysis (mean, range, variance, standard deviation) of the results for the parameters measured;
- an interpretation of water quality and standing water level changes supported with graphs or contour plots; and

- an interpretation and review of the results in relation to the impact assessment criteria.

Relevant monitoring and management activities for each year should also be reported in the AEMR.

16.13 Adaptive Management

The proponent has committed to developing a valley closure based trigger system for managing impacts on the creek with the exact values to be determined based on the best available predictive models and assessment of existing closure data from LW 4 & 5. This will be undertaken in liaison with regulators as part of the development of management plans for Cataract Creek.

An adaptive management plan should be developed to use the monitoring program to detect the need for adjustment to the mining operation so that the subsidence predictions are not exceeded and so that subsidence impacts creating a risk of negative environmental consequences do not occur.

The adaptive management procedures should be implemented to provide a systematic process for continually detecting impacts, validating predictions and improving mining operations to prevent further adverse impacts on the swamp and basement groundwater systems overlying the proposed mining domains.

Monitoring, evaluation, and reporting on management performance and ecological impact should be integrated into the site's core management systems to progress the technical understanding and predictive capability of subsidence effects, impacts and consequences on surface water systems.

An evidence-based approach should be used to validate the extent to which outcomes are being achieved, with the monitoring results being related to, and demonstrating how management strategies have been achieved or where improvements can be made.

As Longwalls 6 to 11 are planned to be mined first, and as they do not overlie the main channel or significant tributaries of Cataract Creek, they would provide a "baseline" monitoring opportunity to assess the effect of subsidence on fracture propogation and development through the overburden, height of fracturing, development of cracking at surface, changes to an upland swamp perched water system (Crus1) as well as flow and water quality in Cataract Creek and any changes in mine inflows.

Data gained from monitoring a suite of extensometers, vibrating wire piezometer arrays and open standpipe piezometers as well as geochemical monitoring of groundwater and surface water and stream flow regimes over the panels would then be able to be used to update the current geotechnical, hydrogeological and hydrological assessments for the proposed mining and to incorporate, if required, adaptive management measures for future panels.

Additional groundwater related monitoring that could be used to enhance the adaptive management process may include:

- continuation of the existing mine water pump monitoring and updating the mine water balance;
- additional drilling, with a range of vibrating wire piezometers and core testing to establish the mechanical and hydraulic properties of the overburden in proximity to

water dependent systems in the catchments (including swamps);

- installation of additional deep vibrating wire piezometers and extensiometers to assess/quantify the impacts of fracturing within the subsidence zone;
- installation of paired shallow piezometers (where appropriate) targeting swamps and the underlying shallow Hawkesbury Sandstone aquifer to assess their hydraulic connection and climatic implications;
- sediment profiling in swamps to characterise type, thickness and sensitivity to differential subsidence; and
- updating of the numerical modelling when sufficient additional data becomes available to enhance the prediction of subsidence zone fracture distributions, connectivity and groundwater transmissivity capacities.

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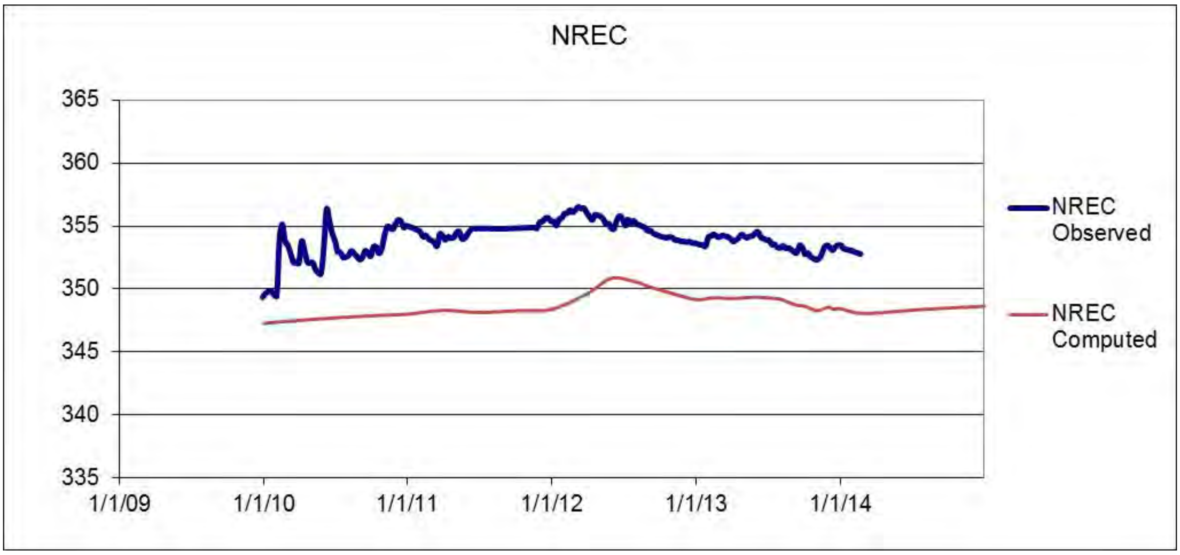
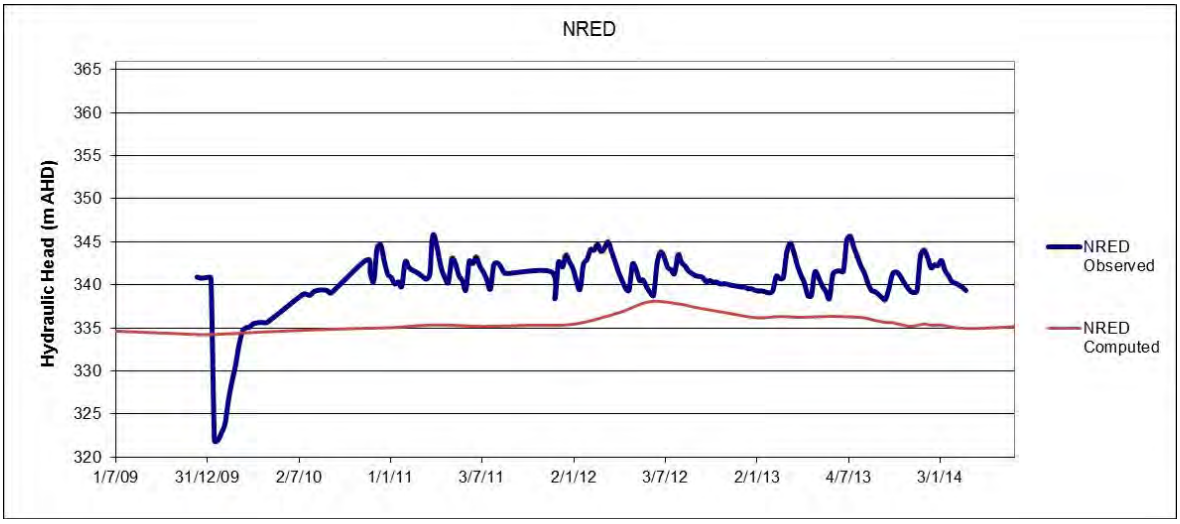
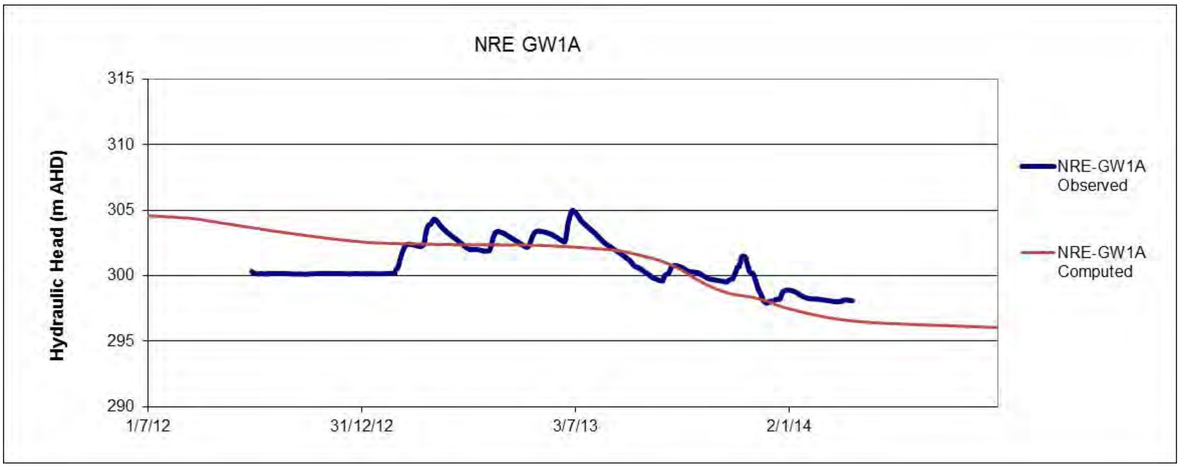
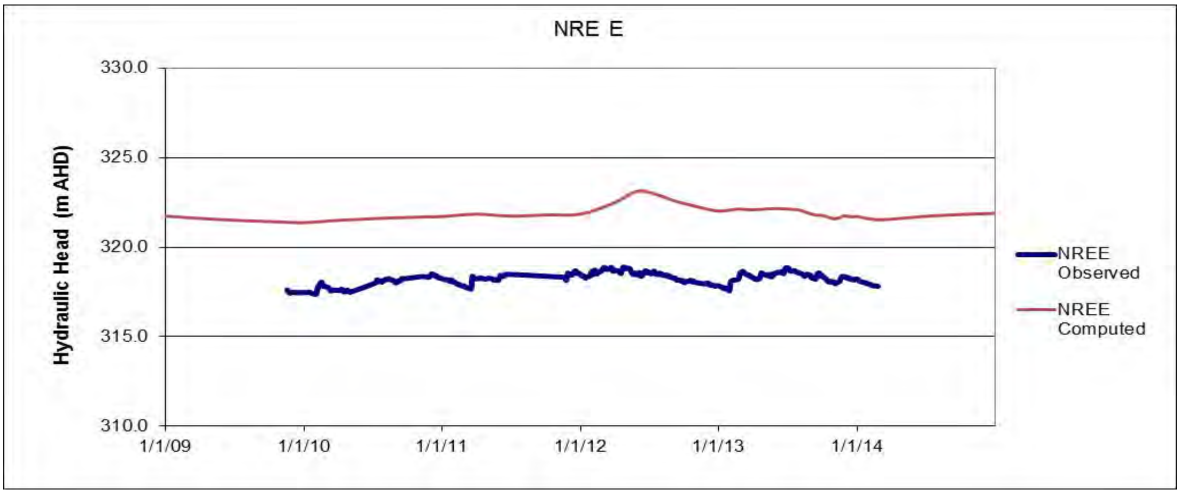
Appendix A
Piezometer Water Level Calibration Graphs

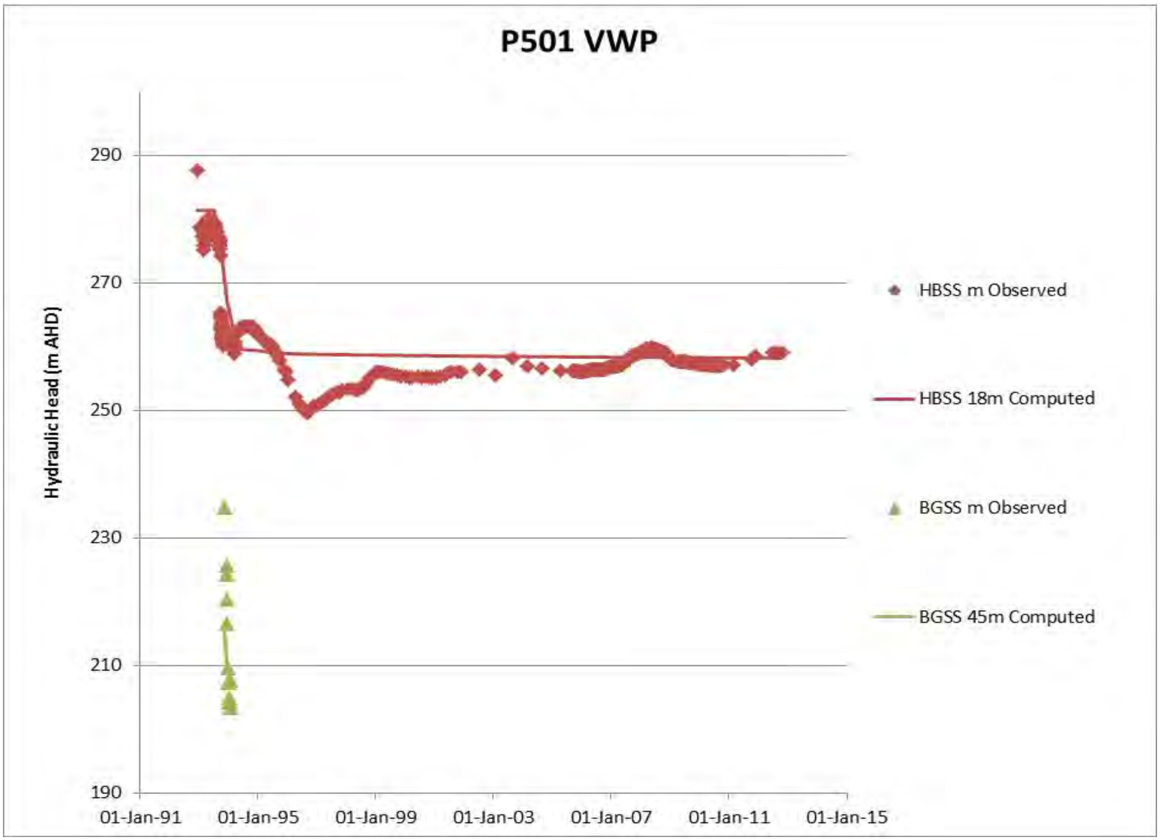

NREA
Hydraulic Head m AHD)
380
375
370
365
360
355
350
345
340
14/10/2009
14/10/2010
14/10/2011
13/10/2012
14/10/2013
14/10/2014
14/10/2015
NREA Observed
NREA Computed

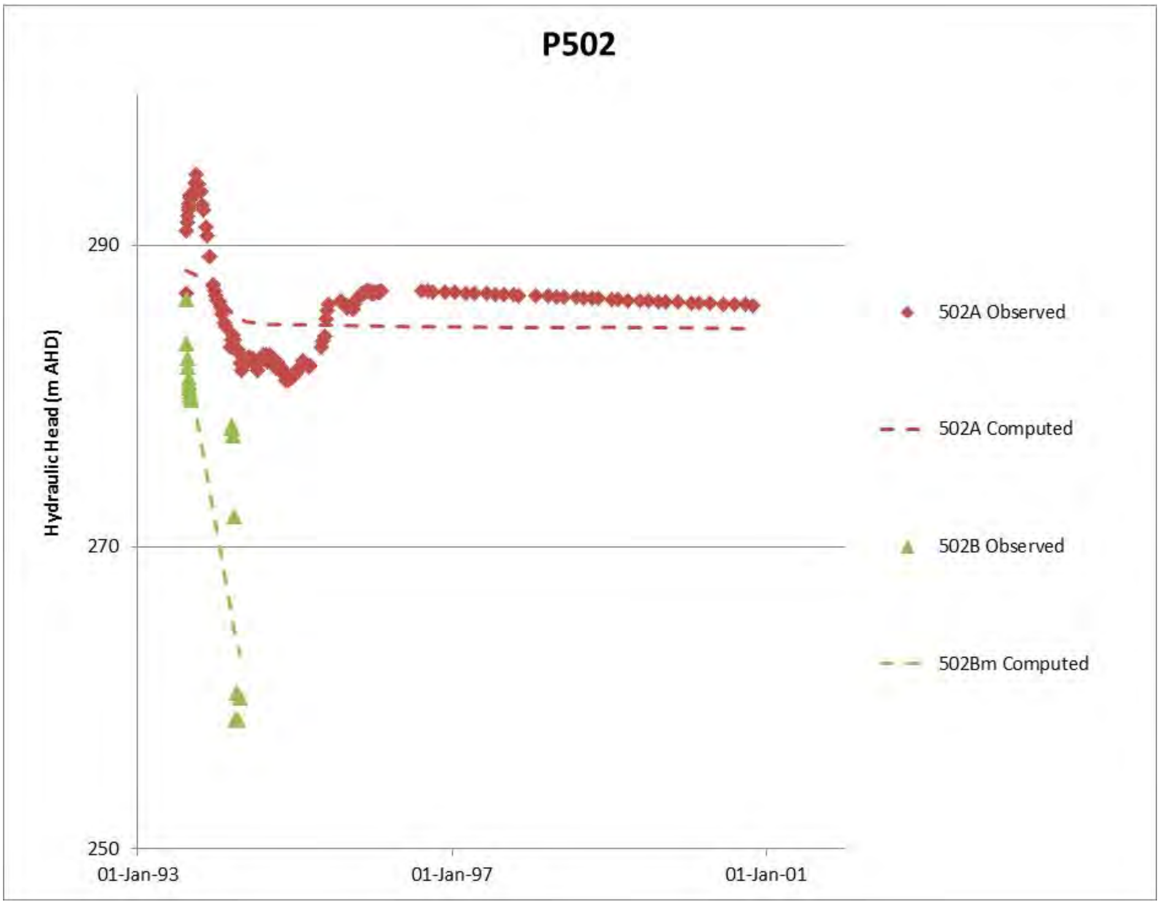

NREC
365
360
355
350
345
340
335
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
1/1/14
NREC Observed
NREC Computed

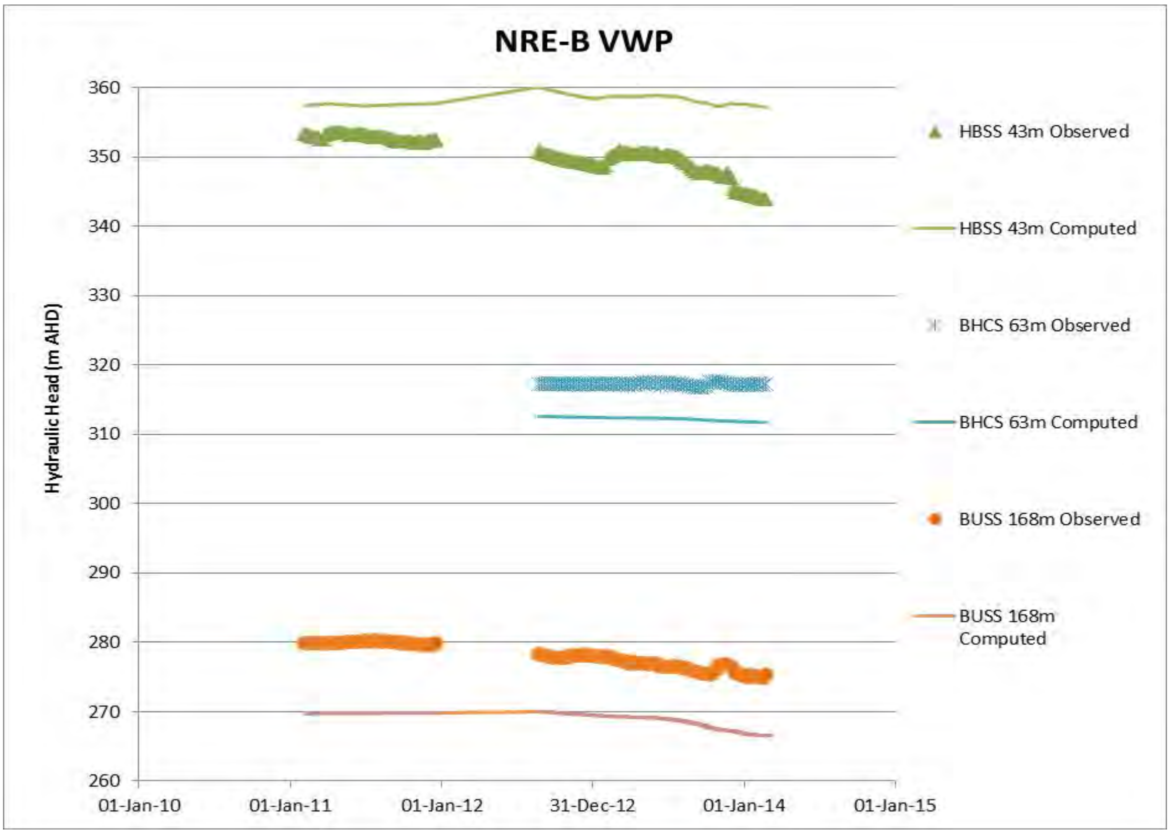

NRED
Hydraulic Head (m AHD)
365
360
355
350
345
340
335
330
325
320
1/7/09
31/12/09
2/7/10
1/1/11
3/7/11
2/1/12
3/7/12
2/1/13
4/7/13
3/1/14
NRED Observed
NRED Computed

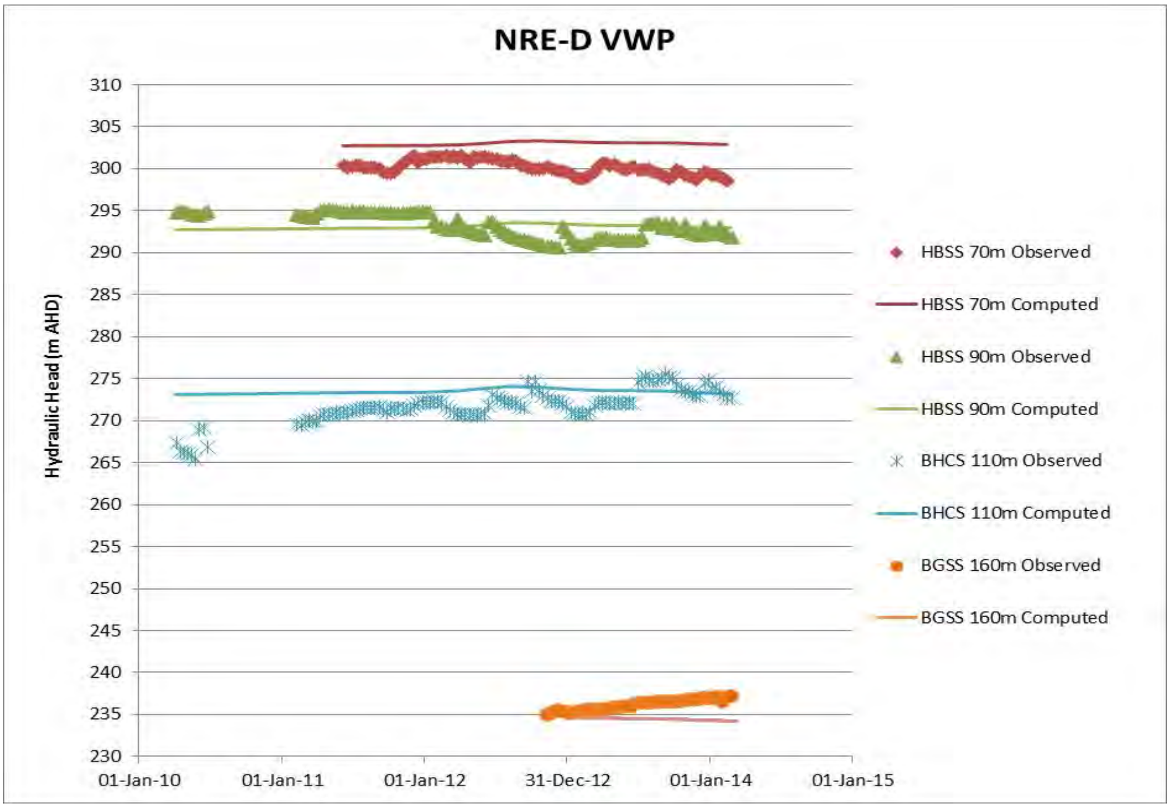

NRE GW1A
Hydraulic Head (m AHD)
315
310
305
300
295
290
1/7/12
31/12/12
3/7/13
2/1/14
NRE-GW1A Observed
NRE-GW1A Computed

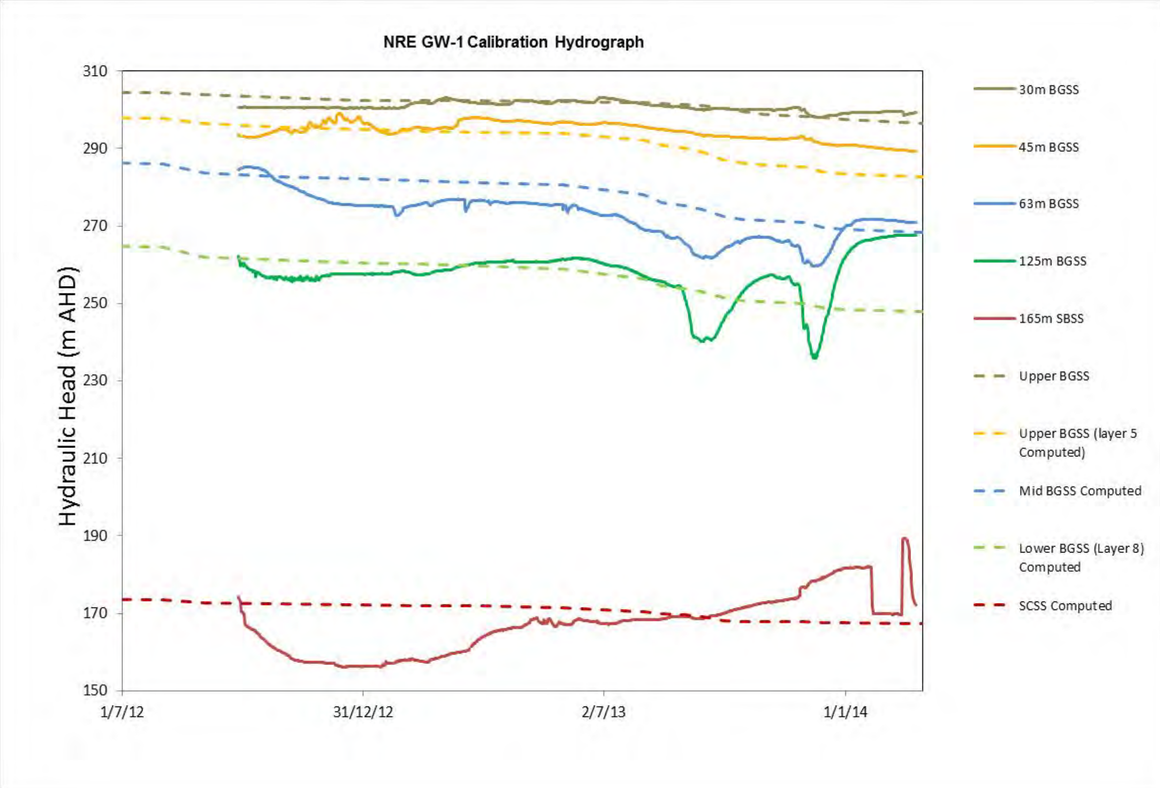

NRE E
Hydraulic Head (m AHD)
330.0
325.0
320.0
315.0
310.0
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
1/1/14
NREE Observed
NREE Computed


P501 VWP
Hydraulic Head (m AHD)
290
270
250
230
210
190
01-Jan-91
01-Jan-95
01-Jan-99
01-Jan-03
01-Jan-07
01-Jan-11
01-Jan-15
HBSS m Observed
HBSS 18m Computed
BGSS m Observed
BGSS 45m Computed


P502
Hydraulic Head (m AHD)
290
270
250
01-Jan-93
01-Jan-97
01-Jan-01
502A Observed
502A Computed
502B Observed
502Bm Computed


NRE-B VWP
Hydraulic Head (m AHD)
360
350
340
330
320
310
300
290
280
270
260
01-Jan-10
01-Jan-11
01-Jan-12
31-Dec-12
01-Jan-14
01-Jan-15
HBSS 43m Observed
HBSS 43m Computed
BHCS 63m Observed
BHCS 63m Computed
BUSS 168m Observed
BUSS 168m Computed


NRE-D VWP
Hydraulic Head (m AHD)
310
305
300
295
290
285
280
275
270
265
260
255
250
245
240
235
230
01-Jan-10
01-Jan-11
01-Jan-12
31-Dec-12
01-Jan-14
01-Jan-15
HBSS 70m Observed
HBSS 70m Computed
HBSS 90m Observed
HBSS 90m Computed
BHCS 110m Observed
BHCS 110m Computed
BGSS 160m Observed
BGSS 160m Computed


NRE GW-1 Calibration Hydrograph
Hydraulic Head (m AHD)
310
290
270
250
230
210
190
170
150
1/7/12
31/12/12
2/7/13
1/1/14
30m BGSS
45m BGSS
63m BGSS
125m BGSS
165m SBSS
Upper BGSS
Upper BGSS (layer 5 Computed)
Mid BGSS Computed
Lower BGSS (Layer 8) Computed
SCSS Computed

Appendix B
IESC Significance Guidelines Response

EPBC Significant Impact Criteria Response

Criteria	Proponent's Response
Hydrological Characteristics	
Will the proposal change the water quantity, including the timing of variations in water quantity	A maximum "take" of 620 ML/year is predicted from the combined surface water system associated with the proposed Wonga East extraction
Will the proposal change the integrity of hydrological or hydrogeological connections, including substantial structural damage (e.g. large scale subsidence)	Yes
Will the proposal change the area or extent of a water resource	No
Water Quality	
Is there a risk that the ability to achieve relevant local or regional water quality objectives will be materially compromised	No
Will the proposal create risks to human or animal health or to the condition of the natural environment as a result of the change in water quality	No risks to human or animal health, or adverse effects on upland swamps due to change in water quality
Will the proposal substantially reduce the amount of water available for human consumptive uses or for other uses, including environmental uses, which are dependent on water of the appropriate quality	No observable reduction in water quality available for human consumption, other uses, or environmental use is predicted
Will the proposal cause persistent organic chemicals, heavy metals, salt or other potentially harmful substances to accumulate in the environment	No
Will the proposal seriously affect the habitat or lifecycle of a native species dependent on a water resource	No serious effect on the habitat or lifecycle of a native species dependent on a water resource is predicted in the streams. Vegetation in upland swamp CCUS4 may be affected directly overlying the subsided workings
Is there predicted significant worsening of local water quality (where current local water quality is superior to local or regional water quality objectives	No
Will high quality water be released into an ecosystem which is adapted to a lower quality of water	No

Appendix D

PEER REVIEW OF GROUNDWATER ASSESSMENT

Heritage Computing Pty Ltd ● ABN 75 392 967 126 ● T/A **HydroSimulations**
PO Box 241, Gerringong NSW 2534. Phone: (+61 2) 4234 3802

noel.merrick@heritagecomputing.com

DATE: 22 June 2014

TO: Dianne Munro
Principal
Hansen Bailey
John Street
Singleton NSW 2330
Tel: (02) 6575 2001

FROM: Dr Noel Merrick

RE: **Peer Review – Russell Vale Colliery Groundwater Impact Assessment**

OUR REF: HS2014/12

1. Introduction

GeoTerra Pty Ltd and Groundwater Exploration Services (GES) Pty Ltd have jointly undertaken the groundwater impact assessment for Russell Vale Colliery, which is located about 13 km to the north-west of Wollongong on the New South Wales South Coast. The subject of the assessment is the Russell Vale Colliery Underground Expansion Project. This is proposed to consist of Wongawilli Seam Longwalls 1, 2, 3, 6, 7, 9, 10 and 11. Longwalls 4 and 5 have already been mined. If approval is received, the next panel to be mined would be Longwall 6.

At the request of Hansen Bailey, acting on behalf of Wollongong Coal Ltd, Heritage Computing Pty Ltd (now trading as HydroSimulations) has undertaken a peer review of the supplied document that forms the assessment.

2. Documentation

The following report comprises the current documentation for the groundwater assessment:

1. GeoTerra and GES, 2014, Russell Vale Colliery Underground Expansion Project Preferred Project Report Wonga East Groundwater Assessment, Bellambi, NSW. Report NRE1 - R1C GW for Wollongong Coal Ltd., 19 June 2014.

Initial reviews were conducted on draft reports dated 20 May 2014 and 5 June 2014. No other documentation was relied upon as a basis for this review, and electronic model files were not examined. However, the reviewer met with the modeller (Andrew Fulton, GES) on a number of occasions during development of the model.

Document #1 has 17 sections:

1. Introduction

2. Relevant Legislation and Guidelines
3. Previous Groundwater Related Studies
4. Previous and Proposed Mining
5. Study Area Description
6. Previous Groundwater System Subsidence Effects
7. Potential Strata Deformation and Associated Groundwater Effects
8. Hydrogeological Investigations
9. Groundwater Modelling
10. Potential Subsidence Effects, Impacts and Consequences
11. Cumulative Groundwater Related Impacts
12. Modelling Uncertainty
13. Model Limitations
14. Water Licensing
15. NSW Aquifer Interference Policy Minimal Impact Considerations
16. Monitoring, Contingency Measures and Reporting
17. References.

The initial reviews advised restructuring the contents of the report without sacrificing content. This has been done.

The Appendices to Document #1 contain:

A. Piezometer Water Level Calibration Graphs
B. IESC Significance Guidelines Response

3. Review Methodology

There are two accepted guides to the review of groundwater models: (A) the Murray-Darling Basin Commission (MDBC) Groundwater Flow Modelling Guideline[1], issued in 2001,and (B) newer guidelines issued by the National Water Commission at the end of June 2012 (Barnett et al., 2012[2]). Both guides also offer techniques for reviewing the non-modelling components of a groundwater impact assessment. The 2012 national guidelines build on the 2001 MDBC guide, with substantial consistency in the model conceptualisation, design, construction and calibration principles, and the performance and review criteria, although there are differences in details. The new guide is almost silent on coal mine modelling and offers no direction on best practice methodology for such applications. There is, however, an expectation of more effort in uncertainty analysis, although the guide is not prescriptive as to which methodology should be adopted.

The Russell Vale model type is Moderate Complexity (under the MDBC guidelines) and Class 2 Confidence Level (under the NWC guidelines). This is the appropriate level for a groundwater impact assessment for a mining development.

The review was conducted solely on several versions of a single submitted report and discussions with Mr Andrew Fulton. Electronic model files were not examined.

The groundwater guides include useful checklists for peer review. For the initial reviews, the Model Appraisal checklist[3] in MDBC (2001) was used for groundwater model review. This checklist has questions on (1) The Report; (2) Data Analysis; (3) Conceptualisation; (4) Model Design; (5) Calibration; (6) Verification; (7) Prediction; (8) Sensitivity Analysis; and (9) Uncertainty Analysis. Non-modelling components of the impact assessments are addressed by the first three sections of the checklist. The NWC checklist (which essentially has Yes/No rather than graded assessment) has been completed only for the final review.

The detailed assessment of the groundwater modelling, according to the MDBC checklist, is recorded in the model appraisal checklist in **Table 1**. The corresponding review according to the

1 MDBC (2001). Groundwater flow modelling guideline. Murray-Darling Basin Commission. URL: www.mdbc.gov.au/nrm/water_management/groundwater/groundwater_guides
2 Barnett, B, Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A. (2012). *Australian Groundwater Modelling Guidelines*. Waterlines report 82, National Water Commission, Canberra.
3 The new guidelines include a more detailed checklist but they do not offer the graded assessments of the 2001 checklist, which this reviewer regards as more informative for readers.

NWC checklist is included as **Table 2**, with a compliance checklist at **Table 3**. These tables contain the primary commentary for the peer review. Summary and supplementary commentary is offered in the following sections of this review.

4. Report Matters

Document #1 is a good quality document of 145 pages length plus two appendices that contain a comparison of observed and simulated hydrographs and a checklist that addresses Independent Expert Scientific Committee (IESC) requirements. Another Appendix could have been included that would show the calibrated hydraulic conductivity field for each model layer and the spatial rainfall recharge distribution. The report is well structured and the graphics are mostly of high quality.

The objective of the study is " to address any potential groundwater impacts relating to the proposed extraction and associated subsidence of the Wongawilli Seam in the Wonga East mining area". This objective has been met.

A full water balance summary is given only for the transient calibration period, and then only at the end date instead of an average over the period. No water balance is offered for steady-state conditions, and only selected water balance components (mine inflow, baseflows) are reported during prediction.

There had been modelling conducted previously in 2012 but only a cursory reference is made to it in Section 9. It is not clear how the previous and current models differ, other than the use of different software (FEFLOW and MODFLOW-SURFACT) and investigation of a different mine plan.

The report includes discussion on alternative representations of the fractured zone. The use of the Tammetta formula (adapted conservatively for multiple worked seams) implies fracturing to ground surface over already-mined Longwalls 4 and 5. A comment would be in order as to whether this assumption has field support. If not, the impact predictions are conservative. Monitoring of water level trends in piezometer NRE-A over the multi-seam mined area seems to lend support to fracturing reaching to the upper Hawkesbury Sandstone.

The report is missing a Summary or Conclusion section. In the first draft there was a very good summary of the scope of the study and its findings in an Executive Summary. While the Executive Summary is properly housed in the companion main report, much of this could have been retained as a concluding statement.

Over six pages of references are cited. However, many have incomplete citations, and "et al." attributions are not always spelled out as they should be.

5. Data Matters

The coverage of geology and hydrogeology is particularly good, with a brief section on field-derived permeabilities. However, the remaining aspects of the groundwater system are treated only briefly. The water table pattern in Figure 21, based on measurements and inferred levels, is sensible as it suggests logical groundwater flow from ridges to drainage lines. The water table pattern generated by the model is not subsequently compared with this figure.

Initial cross-sections of pressure heads (presented in the modelling section of the report) show substantial prior depressurisation due to neighbouring mining.

The rainfall residual mass (cumulative deviation from the mean) curve has been used effectively to show often strong correlation with groundwater hydrographs. This is a vital tool for investigating cause-and-effect where climate plays a role in groundwater responses. Where mining effects are observed, the timing of longwall panels is compared with the hydrograph responses to confirm mining as the probable cause.

Although there is good field evidence and conceptual discussion on the gaining/losing characteristics of the various watercourses, there is no substantiation with statistics for flow rates and durations of flow.

The adopted evapotranspiration (ET) rate (0.005 m/day = 1,825 m/year) is considered too high as it reflects evaporation rather than actual ET. The Bureau of Meteorology provides estimates of actual ET (limited by water availability) across Australia. Allowance should always be made for MODFLOW's weak linear representation of the ET process, which means that evaporation rates will always be too high as a surrogate for ET. However, this is not considered a serious issue, as the ET process will be activated in the model only where the water table comes within 4 m of ground surface. A depth to water map could have illustrated the locations where that might occur (along drainage lines).

The mine water balance in Figure 28 has detailed partitioning of components.

The conceptualisation based on the field investigations and data analysis is justified and well illustrated graphically in Figure 31 for a mining situation. The adopted conceptual model is consistent with other studies in the Southern Coalfield.

An important aspect of the conceptualisation is that geological faults and other structures have no significant role in the groundwater regime. Document #1 states that "faults encountered within the three levels of extraction have not encountered water make with any faults or dykes in the workings". The absence of water flows associated with faults is an important finding, as the role of faults in groundwater systems and their incorporation in models, is often a matter of contention.

6. Model Matters

The modelling section should commence with a brief summary of previous groundwater modelling, with reasons for what is assumed to be a substantial overhaul, given the adoption of a different software platform (MODFLOW-SURFACT instead of FEFLOW). It should be stated whether the current model is an enhancement or a replacement.

There is confusion as to the commencement year for transient simulation. Table 9 in Section 9.6 suggests 1993 but the introductory Section 9 states that 2003 is year zero.

There is also confusion over the meaning of Figure 33, as the caption (predicted height of depressurisation zone) is inconsistent with the legend (top of depressurisation to surface). It is likely that the legend is correct and the caption is wrong.

The most illustrative figures for the effects of past and future mining on the groundwater system are presented as Figures 37 to 42. All figures display pressure head (in metres), which can be considered as the height of water remaining above a mined seam. Figures 37 and 38 reveal substantial initial (presumably 1993) depressurisation due to neighbouring mining. Figures 39 and 40 show incremental depressurisation for current conditions (end of Longwall 5), while Figures 41 and 42 show continued depressurisation at the end of mining. In places, the zero pressure head at the water table has coalesced with the zero pressure head generated by mining.

Although monitoring of water level trends in piezometer NRE-A over the multi-seam mined area indicates an enhanced response to rainfall recharge in the upper Hawkesbury Sandstone down to the Upper Bulgo Sandstone, higher rainfall recharge has not been assumed in the model. While it is reasonable to maintain uniform recharge for the base case model, enhanced recharge could have been investigated in a sensitivity analysis.

Figures 67 to 69 show effectively the uncertainty associated with estimates for mine inflow and baseflow reductions. They show the results of 31 alternative model parameterisations, selected from the packer test database of horizontal hydraulic conductivities. However, there is an error in the text associated with Figure 67, which shows a probability distribution for mine inflow rates. Mean values have been recalculated just for the duration of Wongawilli Seam mining, rather than from the start of the simulation in 1993, but the text still says the mean is "influenced by the long period of model time where inflows are predominantly from the unmined areas of the Bulli Seam".

Estimation of fractured zone height above multi-seams is an open question. Here, the combined seam thicknesses are treated as the effective mined height. This would certainly be valid when the seams are contiguous, but a lower "effective thickness" would be more appropriate when there is intervening interburden. The adopted approach would be conservative.

Refer to **Table 1** for more detailed commentary.

7. Conclusion

The objective of the Russell Vale Groundwater Model is stated in Document #1 as the simulation of "the current and proposed mining activities within the Wongawilli Seam in the Wonga East area and to understand the effects to groundwater and surface water environment in a local and regional context". More broadly, the groundwater assessment in Document #1 is required to fulfil aspects of the Director General's Requirements, especially "the potential impacts of the project on the quantity, quality and long-term integrity of the groundwater resources in the project area".

The impacts of importance are stipulated in the Aquifer Interference Policy, especially drawdown impacts on GDEs and private bores, and water quality departures from beneficial use. In addition, the volumetric takes of water are to be determined (and partitioned where necessary) for licensing purposes.

The groundwater assessment includes a table (Table 16) that addresses the minimal harm considerations for less productive porous rock water sources. Each *consideration* is addressed in full. This reviewer concurs with the finding that no Level 2 impacts have been identified.

It is the reviewer's opinion that all objectives have been met satisfactorily.

Furthermore, it is the reviewer's opinion that the Russell Vale Groundwater Model has been developed competently and is "fit for purpose" for addressing the potential environmental impacts from the proposed underground mining operations and for estimating indicative dewatering rates.

The uncertainty in modelling predictions is assessed thoroughly by analysing the outputs of 31 models with parameterisations based on the statistical distribution of packer test permeabilities.

Due to the substantial depressurisation that has been caused by earlier mining at the subject mine, and at neighbouring historical mines, the additional effects of mining the Wongawilli Seam with eight more longwall panels are considered marginal.

Yours sincerely,

NPMerrick

Dr Noel Merrick

Table 1. Model Appraisal: Russell Vale Colliery Groundwater Model

Q.	QUESTION	Not Applicable or Unknown	Score 0	Score 1	Score 3	Score 5	Score	Max Score (0, 3, 5)	COMMENT
1.0	THE REPORT								145p text. 2 App.
1.1	Is there a clear statement of project objectives in the modelling report?		Missing	Deficient	Adequate	Very Good			Section 1.1 - Scope of Work (DGRs, regulator submissions on PPR).
1.2	Is the level of model complexity clear or acknowledged?		Missing	No	Yes				Reference to new national guidelines. Class 2 confidence classification. Equivalent to Impact Assessment Model, medium complexity.
1.3	Is a water or mass balance reported?		Missing	Deficient	Adequate	Very Good			Not for Steady state. Transient calibration period - adequate (Table 11) - at end, not averaged. Prediction - missing summary (partial in Table 12, 13)
1.4	Has the modelling study satisfied project objectives?		Missing	Deficient	Adequate	Very Good			"...address any potential groundwater impacts relating to the proposed extraction and associated subsidence..."
1.5	Are the model results of any practical use?			No	Maybe	Yes			Quantitative impact assessment with uncertainty. Aquifer Interference Policy checked for minimal harm compliance.
2.0	DATA ANALYSIS								
2.1	Has hydrogeology data been collected and analysed?		Missing	Deficient	Adequate	Very Good			Sections 5, 8. Good overviews of geology and hydrogeology. Brief section on field-derived permeability.
2.2	Are groundwater contours or flow directions presented?		Missing	Deficient	Adequate	Very Good			Includes map of observed water level contours (Figure 21) - but excludes Wonga West. (Simulated pattern not checked against this.) Figures 37, 38 give initial pore pressures on S-N and W-E sections.
2.3	Have all potential recharge data been collected and analysed? (rainfall, streamflow, irrigation, floods, etc.)		Missing	Deficient	Adequate	Very Good			Rainfall in Section 5.2.1. Rainfall residual mass (CRD) in Figure 3. Stream flow in Section 5.8 - no statistics.

2.4	Have all potential discharge data been collected and analysed? (abstraction, evapotranspiration, drainage, springflow, etc.)		Missing	Deficient	Adequate	Very Good			Field assessment of gaining/losing. No abstraction by bores. Cataract Dam evaporation records. Could cite BoM actual ET estimate for region - model ET rate seems high. Expect a summary of stream baseflow or flow duration percentiles.
2.5	Have the recharge and discharge datasets been analysed for their groundwater response?		Missing	Deficient	Adequate	Very Good			Standpipe and VWP hydrographs are related to CRD (useful in discriminating climate effects - good correlation) and longwall dates. Mine water balance (Figure 28) has detailed partitioning of components - drop "rainfall" from caption.
2.6	Are groundwater hydrographs used for calibration?			No	Maybe	Yes			24 graphs. Standpipe and VWPs.
2.7	Have consistent data units and standard geometrical datums been used?			No	Yes				K in m/s and m/d.
3.0	CONCEPTUALISATION								
3.1	Is the conceptual model consistent with project objectives and the required model complexity?		Unknown	No	Maybe	Yes			
3.2	Is there a clear description of the conceptual model?		Missing	Deficient	Adequate	Very Good			Section 9.1.
3.3	Is there a graphical representation of the modeller's conceptualisation?		Missing	Deficient	Adequate	Very Good			Figure 31.
3.4	Is the conceptual model unnecessarily simple or unnecessarily complex?			Yes	No				Consistent with detail in other Southern Coalfield models. Fractured zone (goaf) handling via ramp function for K.
4.0	MODEL DESIGN								Minimal reference to previous 2012 model using FEFLOW.
4.1	Is the spatial extent of the model appropriate?			No	Maybe	Yes			Dimensions unstated: probably 23 km x 23 km. Finite differences. 18 layers. Includes many mines. 25m to 250m cell size.

4.2	Are the applied boundary conditions plausible and unrestrictive?		Missing	Deficient	Adequate	Very Good			Mostly controlled by seam heads in mines around the boundary. Topo divide along open western boundary - could defend this with expanded Figure 21 (water level map) or reference to Appin model report. Cross-sections of initial conditions are given as pressure heads. Streams use RIV algorithm - RIV MODFLOW. Mines use DRN. ET maximum rate is quite high for MODFLOW linear decay. Variable stress periods. Strong argument for excluding faults.
4.3	Is the software appropriate for the objectives of the study?			No	Maybe	Yes			MODFLOW-SURFACT. Unsaturated properties not stated. Time-varying properties (TMP) for fractured zone.
5.0	CALIBRATION								**Jan.1993-Feb.2014**
5.1	Is there sufficient evidence provided for model calibration?		Missing	Deficient	Adequate	Very Good			**Steady-state**: missing. Should give RMS statistics and show watertable contours to compare with Figure 21. No scattergram. Steady-state = 1991: CRD (Figure 3) justifies "average" conditions. **Transient**: adequate. Two attributes: heads and mine inflow - no check on baseflow. Evidence = scattergram; mRMS and %RMS; hydrograph comparisons. Historical mine inflow matched in transient calibration. No spatial residual map to see where calibration is poor.
5.2	Is the model sufficiently calibrated against spatial observations?		Missing	Deficient	Adequate	Very Good			Steady state: ??%RMS, ??mRMS. 32 sites, unknown number of points. Cannot compare pattern with observed/inferred contours. Vertical head separation very good at VWPs. Transient scattergram centred on 45 degree line.

5.3	Is the model sufficiently calibrated against temporal observations?		Missing	Deficient	Adequate	Very Good			Marginally adequate, based on hydrograph comparisons. Trends generally OK. Fluctuations not reproduced. VWP matches as good as can be expected. Statistical performance is good: 2.6%RMS, 6mRMS. 2328 data points. (4.9mRMS if GW1 is excluded - could state %RMS also - expect ~4%RMS). Mine inflow well matched. Scattergram (Figure 36) reinforces lack of amplitude matching (horizontal lines at some sites).
5.4	Are calibrated parameter distributions and ranges plausible?		Missing	No	Maybe	Yes			Table 10. Manual and PEST. Fractured Kz reasonable (consistent with other groundwater models).
5.5	Does the calibration statistic satisfy agreed performance criteria?		Missing	Deficient	Adequate	Very Good			<10 %RMS. Reasonable replication of hydrograph trends but not amplitudes.
5.6	Are there good reasons for not meeting agreed performance criteria?		Missing	Deficient	Adequate	Very Good			Difficulties acknowledged and discussed briefly.
6.0	VERIFICATION								**No need**
6.1	Is there sufficient evidence provided for model verification?	N/A	Missing	Deficient	Adequate	Very Good			
6.2	Does the reserved dataset include stresses consistent with the prediction scenarios?	N/A	Unknown	No	Maybe	Yes			
6.3	Are there good reasons for an unsatisfactory verification?	N/A	Missing	Deficient	Adequate	Very Good			
7.0	PREDICTION								**Feb.2014-Feb.2018. Recovery for >200years.**
7.1	Have multiple scenarios been run for climate variability?		Missing	Deficient	Adequate	Very Good			Average rain - normal practice. No climate change scenario.
7.2	Have multiple scenarios been run for operational /management alternatives?		Missing	Deficient	Adequate	Very Good			One mine plan - normal practice. Impacts presented for Project (LW6 onwards) and for all Wongawilli longwalls (LW4 onwards).

7.3	Is the time horizon for prediction comparable with the length of the calibration / verification period?		Missing	No	Maybe	Yes			21 years calibration. 4 years prediction.
7.4	Are the model predictions plausible?			No	Maybe	Yes			Drawdown magnitudes and mine inflows seem reasonable. Maximum baseflow effect 7 ML/a (3 streams total). Maximum reservoir effect <0.01% of full storage. No third party bores of concern. Good pressure head sections. Zero pressure breaks through to surface above panels. Fracturing to surface not substantiated by observed water losses.
8.0	SENSITIVITY ANALYSIS								Replaced by uncertainty analysis.
8.1	Is the sensitivity analysis sufficiently intensive for key parameters?		Missing	Deficient	Adequate	Very Good			31 Kx realisations. Although %rain is examined for its effect on calibration statistics, it is not clear whether hydrograph amplitudes improve. S not tested for improved hydrograph amplitudes.
8.2	Are sensitivity results used to qualify the reliability of model calibration?		Missing	Deficient	Adequate	Very Good			Only for %rain.
8.3	Are sensitivity results used to qualify the accuracy of model prediction?		Missing	Deficient	Adequate	Very Good			Monte Carlo realisations (30 + base model).
9.0	UNCERTAINTY ANALYSIS								
9.1	If required by the project brief, is uncertainty quantified in any way?		Missing	No	Maybe	Yes			31 Monte Carlo Kx realisations using packer test statistics. Tight mine inflow range. Broader baseflow range but still small. Good probability distributions - mean calculated from start of LW4.
	TOTAL SCORE								PERFORMANCE:

Table 2: Review checklist (2012 National Guidelines)

Review questions	*Yes/No*	*Comment*
1. Planning		
1.1 Are the project objectives stated?	Y	Section 1.1
1.2 Are the model objectives stated?	Y	P74
1.3 Is it clear how the model will contribute to meeting the project objectives?	Y	
1.4 Is a groundwater model the best option to address the project and model objectives?	Y	
1.5 Is the target model confidence-level classification stated and justified?	Y	Class 2
1.6 Are the planned limitations and exclusions of the model stated?	Y	Section 13
2. Conceptualisation		
2.1 Has a literature review been completed, including examination of prior investigations?	Y	Southern Coalfield
2.2 Is the aquifer system adequately described?	Y	
2.2.1 hydrostratigraphy including aquifer type (porous, fractured rock ...)	Y	
2.2.2 lateral extent, boundaries and significant internal features such as faults and regional folds	Y	
2.2.3 aquifer geometry including layer elevations and thicknesses	Y	Isopachs not in Appendix
2.2.4 confined or unconfined flow and the variation of these conditions in space and time?	Y	
2.3 Have data on groundwater stresses been collected and analysed?	Y	Climate & prior mining
2.3.1 recharge from rainfall, irrigation, floods, lakes	Y	Rain
2.3.2 river or lake stage heights	N	
2.3.3 groundwater usage (pumping, returns etc)	NA	No private bores nearby
2.3.4 evapotranspiration	N	Only evaporation
2.3.5 other?	-	
2.4 Have groundwater level observations been collected and analysed?	Y	
2.4.1 selection of representative bore hydrographs	Y	All
2.4.2 comparison of hydrographs	Y	
2.4.3 effect of stresses on hydrographs	Y	Compared CRD and LW periods
2.4.4 watertable maps/piezometric surfaces?	Y	Local watertable
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of groundwater head and flow data?	NA	
2.5 Have flow observations been collected and analysed?	Y	Mine inflow
2.5.1 baseflow in rivers	N	Not shown
2.5.2 discharge in springs	NA	
2.5.3 location of diffuse discharge areas?	NA	
2.6 Is the measurement error or data uncertainty reported?	N	

Review questions	*Yes/No*	*Comment*
2.6.1 measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	N	
2.6.2 spatial variability/heterogeneity of parameters	NA	Uniform
2.6.3 interpolation algorithm(s) and uncertainty of gridded data?	N	
2.7 Have consistent data units and geometric datum been used?	Y	
2.8 Is there a clear description of the conceptual model?	Y	
2.8.1 Is there a graphical representation of the conceptual model?	Y	
2.8.2 Is the conceptual model based on all available, relevant data?	Y	
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?	Y	
2.9.1 Are the relevant processes identified?	Y	
2.9.2 Is justification provided for omission or simplification of processes?	Y	
2.10 Have alternative conceptual models been investigated?	N	
3. Design and construction		
3.1 Is the design consistent with the conceptual model?	Y	
3.2 Is the choice of numerical method and software appropriate?	Y	
3.2.1 Are the numerical and discretisation methods appropriate?	Y	
3.2.2 Is the software reputable?	Y	MODFLOW-SURFACT
3.2.3 Is the software included in the archive or are references to the software provided?	?	No archive submitted (nor should it be)
3.3 Are the spatial domain and discretisation appropriate?	Y	
3.3.1 1D/2D/3D	3D	
3.3.2 lateral extent	Y	23km x 23km
3.3.3 layer geometry?	Y	18 layers
3.3.4 Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?	Y	25-250m cell size
3.3.5 Is the vertical discretisation appropriate? Are aquitards divided in multiple layers to model time lags of propagation of responses in the vertical direction?	Y N	
3.4 Are the temporal domain and discretisation appropriate?	Y	
3.4.1 steady state or transient	T	
3.4.2 stress periods	Y	
3.4.3 time steps?	N	Missing (expect ATO)
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?	Y	
3.5.1 Is the implementation of boundary conditions consistent with the conceptual model?	Y	
3.5.2 Are the boundary conditions chosen to have a minimal impact on key model outcomes? How is this ascertained?	Y	Far away
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?	Y	Aligned with neighbouring findings

Review questions	*Yes/No*	*Comment*
3.5.4 Are lateral boundaries time-invariant?	Y	
3.6 Are the initial conditions appropriate?	Y	
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?		Steady-state modelling
3.6.2 Is the effect of initial conditions on key model outcomes assessed?	N	
3.6.3 How is the initial concentration of solutes obtained (when relevant)?	NA	
3.7 Is the numerical solution of the model adequate?		Not stated
3.7.1 Solution method/solver		Not stated
3.7.2 Convergence criteria		Not stated
3.7.3 Numerical precision		Not stated
4. Calibration and sensitivity		
4.1 Are all available types of observations used for calibration?	N	Not baseflow
4.1.1 Groundwater head data	Y	
4.1.2 Flux observations	Y	Mine inflow
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc.	-	
4.2 Does the calibration methodology conform to best practice?		Not stated - believed to be PEST
4.2.1 Parameterisation		
4.2.2 Objective function		
4.2.3 Identifiability of parameters		
4.2.4 Which methodology is used for model calibration?		Not stated - believed to be PEST
4.3 Is a sensitivity of key model outcomes assessed against?		
4.3.1 parameters	Y	Monte Carlo Kx
4.3.2 boundary conditions	Y	Recharge
4.3.3 initial conditions	N	
4.3.4 stresses	N	
4.4 Have the calibration results been adequately reported?	Y	
4.4.1 Are there graphs showing modelled and observed hydrographs at an appropriate scale?	Y	
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	Y	Multi-VWP hydrographs
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?	Y	
4.5 Are multiple methods of plotting calibration results used to highlight goodness of fit robustly? Is the model sufficiently calibrated?	Y Y	Scattergram; hydrographs. 2.5%RMS transient.
4.5.1 spatially	?	Missing simulated water table
4.5.2 temporally	Y	Hydrograph comparison
4.6 Are the calibrated parameters plausible?	Y	
4.7 Are the water volumes and fluxes in the water balance realistic?	Y	

Review questions	*Yes/No*	*Comment*
4.8 has the model been verified?	N	Transcient calibration 1993-2014
5. Prediction		
5.1 Are the model predictions designed in a manner that meets the model objectives?	Y	AIP impacts
5.2 Is predictive uncertainty acknowledged and addressed?	Y	
5.3 Are the assumed climatic stresses appropriate?	Y	Stable
5.4 Is a null scenario defined?		Not stated
5.5 Are the scenarios defined in accordance with the model objectives and confidence level classification?	Y	
5.5.1 Are the pumping stresses similar in magnitude to those of the calibrated model? If not, is there reference to the associated reduction in model confidence?	NA	
5.5.2 Are well losses accounted for when estimating maximum pumping rates per well?	NA	
5.5.3 Is the temporal scale of the predictions commensurate with the calibrated model? If not, is there reference to the associated reduction in model confidence?	Y	4 yrs prediction vs. 22 yrs calibration
5.5.4 Are the assumed stresses and timescale appropriate for the stated objectives?	Y	
5.6 Do the prediction results meet the stated objectives?	Y	
5.7 Are the components of the predicted mass balance realistic?	Y	
5.7.1 Are the pumping rates assigned in the input files equal to the modelled pumping rates?	NA	
5.7.2 Does predicted seepage to or from a river exceed measured or expected river flow?		Not stated
5.7.3 Are there any anomalous boundary fluxes due to superposition of head dependent sinks (e.g. evapotranspiration) on head-dependent boundary cells (Type 1 or 3 boundary conditions)?		Unlikely
5.7.4 Is diffuse recharge from rainfall smaller than rainfall?	Y	
5.7.5 Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?		Unlikely
5.8 Has particle tracking been considered as an alternative to solute transport modelling?	NA	
6. Uncertainty		
6.1 Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?	Y	
6.2 Is the model with minimum prediction-error variance chosen for each prediction?	N	
6.3 Are the sources of uncertainty discussed?	Y	
6.3.1 measurement of uncertainty of observations and parameters	N Y	
6.3.2 structural or model uncertainty	Y	Packer Kx statistics
6.4 Is the approach to estimation of uncertainty described and appropriate?	Y	Monte Carlo

Review questions	*Yes/No*	*Comment*
6.5 Are there useful depictions of uncertainty?	Y	Probability curves
7. Solute transport	NA	
7.1 Has all available data on the solute distributions, sources and transport processes been collected and analysed?		
7.2 Has the appropriate extent of the model domain been delineated and are the adopted solute concentration boundaries defensible?		
7.3 Is the choice of numerical method and software appropriate?		
7.4 Is the grid design and resolution adequate, and has the effect of the discretisation on the model outcomes been systematically evaluated?		
7.5 Is there sufficient basis for the description and parameterisation of the solute transport processes?		
7.6 Are the solver and its parameters appropriate for the problem under consideration?		
7.7 Has the relative importance of advection, dispersion and diffusion been assessed?		
7.8 Has an assessment been made of the need to consider variable density conditions?		
7.9 Is the initial solute concentration distribution sufficiently well-known for transient problems and consistent with the initial conditions for head/pressure?		
7.10 Is the initial solute concentration distribution stable and in equilibrium with the solute boundary conditions and stresses?		
7.11 Is the calibration based on meaningful metrics?		
7.12 Has the effect of spatial and temporal discretisation and solution method taken into account in the sensitivity analysis?		
7.13 Has the effect of flow parameters on solute concentration predictions been evaluated, or have solute concentrations been used to constrain flow parameters?		
7.14 Does the uncertainty analysis consider the effect of solute transport parameter uncertainty, grid design and solver selection/settings?		
7.15 Does the report address the role of geologic heterogeneity on solute concentration distributions?		
8. Surface water–groundwater interaction		
8.1 Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?	Y	
8.2 Is the implementation of surface water–groundwater interaction appropriate?	Y	RIV
8.3 Is the groundwater model coupled with a surface water model?	N	
8.3.1 Is the adopted approach appropriate?	-	
8.3.2 Have appropriate time steps and stress periods been adopted?	-	
8.3.3 Are the interface fluxes consistent between the	-	

Review questions	*Yes/No*	*Comment*
groundwater and surface water models?		

Table 3: Compliance checklist

Question	*Yes/No*
1. Are the model objectives and model confidence level classification clearly stated?	Y
2. Are the objectives satisfied?	Y
3. Is the conceptual model consistent with objectives and confidence level classification?	Y
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Y
5. Does the model design conform to best practice?	Y
6. Is the model calibration satisfactory?	Y
7. Are the calibrated parameter values and estimated fluxes plausible?	Y
8. Do the model predictions conform to best practice?	Y
9. Is the uncertainty associated with the predictions reported?	Y
10. Is the model fit for purpose?	Y

Appendix E

RUSSELL VALE COLLIERY UNDERGROUND EXPANSION PROJECT PREFERRED PROJECT REPORT GROUNDWATER & SURFACE WATER RESPONSE TO SUBMISSIONS RESIDUAL MATTERS ADDENDUM

GeoTerra

WOLLONGONG COAL LTD

RUSSELL VALE COLLIERY UNDERGROUND EXPANSION PROJECT PREFERRED PROJECT REPORT GROUNDWATER & SURFACE WATER RESPONSE TO SUBMISSIONS RESIDUAL MATTERS ADDENDUM

Bellambi, NSW

NRE8 - RTS - A

19 JUNE, 2014

GeoTerra PTY LTD **ABN 82 117 674 941**

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NRE8 – RTS - A (19 June, 2014)

GeoTerra

Wollongong Coal Ltd
PO Box 281
Fairy Meadow NSW 2519

Attention: D Clarkson

Dave,

RE: Wonga East Surface Water Residual Matters Addendum

Please find enclosed a copy of the above mentioned report.

Yours faithfully

GeoTerra Pty Ltd

Andrew Dawkins (AuSIMM CP-Env)

Principal Hydrogeologist

Distribution:	Original	GeoTerra Pty Ltd
	1 electronic copy	Wollongong Coal Ltd
	1 electronic copy	Hansen Bailey Pty Ltd

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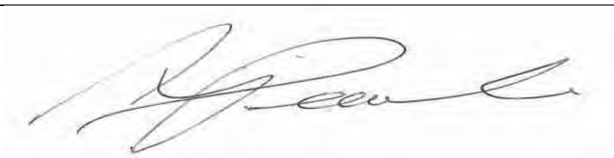
GeoTerra

Authorised on behalf of GeoTerra Pty Ltd:	
Name:	Andrew Dawkins
Signature:	
Position:	Principal Hydrogeologist

Date	Rev	Comments
05.06.2014		Draft
19.06.2014	A	Incorporate review comments

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1. INTRODUCTION

This addendum covers outstanding matters that have not been addressed in the Response to Submissions for the Wollongong Coal Ltd (WCL), Russell Vale Colliery, Underground Expansion Project – Preferred Project Report and prior assessments.

The accompanying reports are outlined in the references section.

The remaining issues are addressed in the following sections, based on a summarised compilation of all government agency responses to the Preferred Project Report.

2. STREAM WATER QUALITY MONITORING

2.1 Stream Monitoring Sites

The location of the Wonga East stream monitoring sites and the respective Bulli, Balgownie and Wongawilli (proposed and extracted) workings are shown in **Figures 1** to **3.**

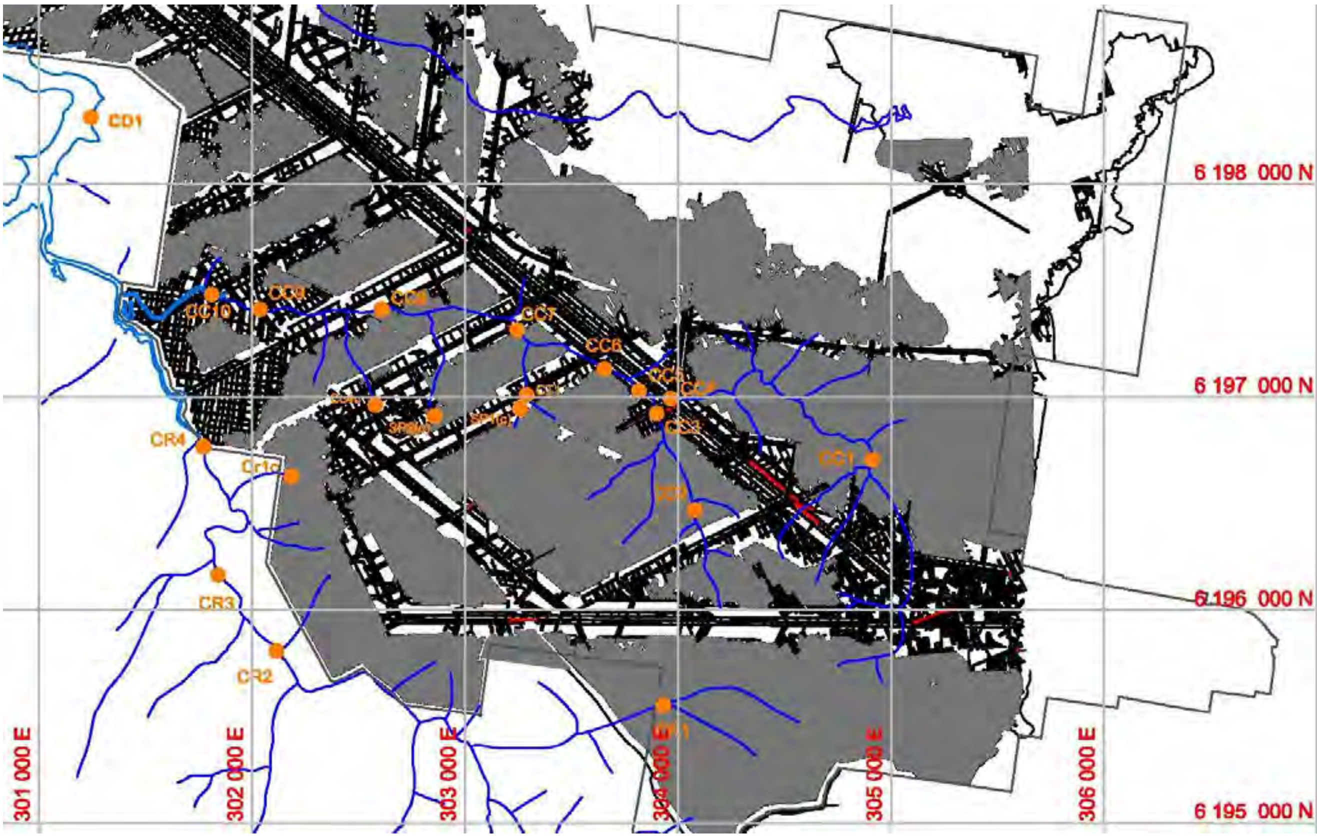

Figure 1 Stream Monitoring Sites and Bulli Workings

Figure 2 Stream Monitoring Sites and Balgownie Workings

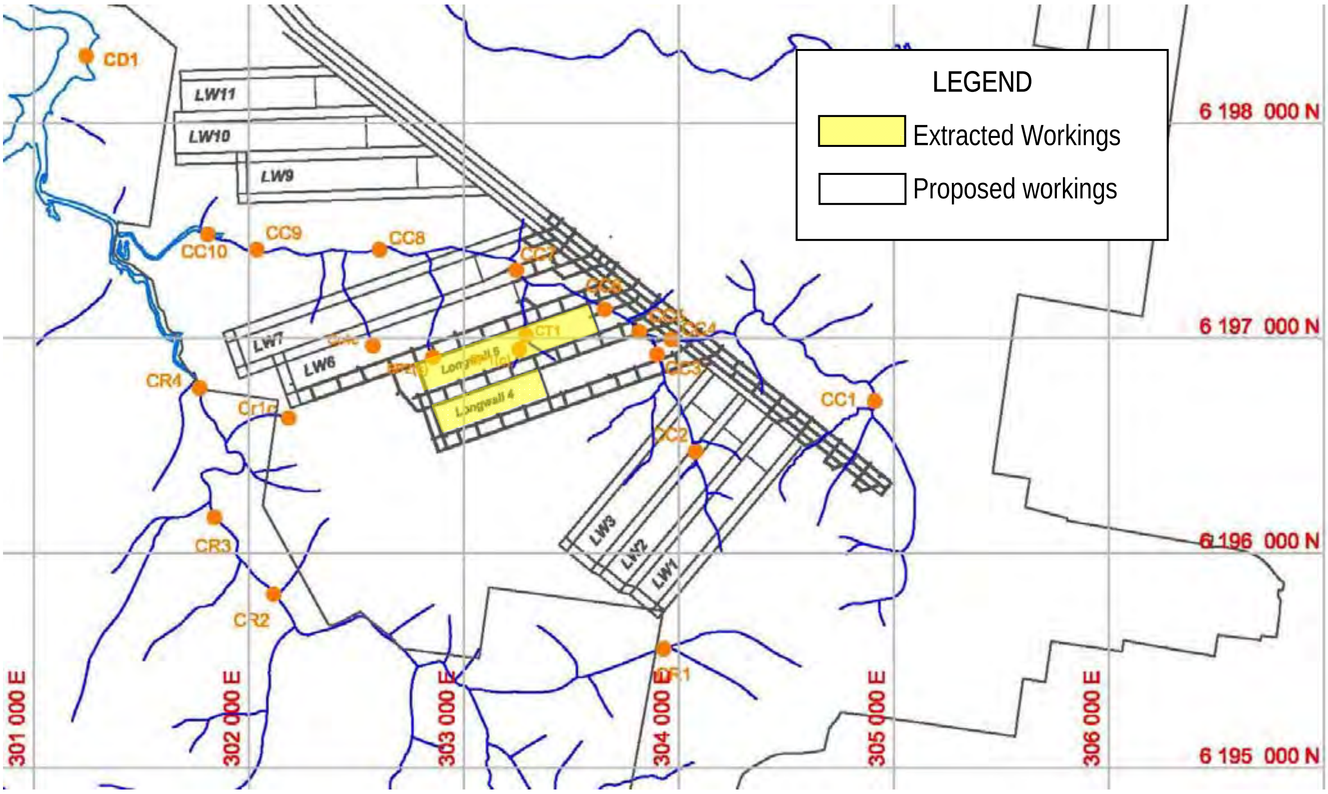

Figure 3 Stream Monitoring Sites and Wongawilli Workings

2.1.1 Cataract Creek

Cataract Creek field pH, electrical conductivity, temperature, dissolved oxygen and oxidation / reduction potential has been monitored using calibrated, hand held meters since August 2008 at the locations shown in **Table 1** and **Figures 1 to 3**.

The CC1 to CC4 tributary only overlies secondary extraction workings in the Bulli Seam, whilst it also overlies bord and pillar first workings in the Balgownie Seam and (in the lower reach), first workings in the Wongawilli Seam.

The CC2 to CC3 tributary overlies secondary extraction workings in the Bulli and Balgownie Seam, as well as proposed secondary extraction in the Wongawilli Seam.

Stream monitoring sites CC5 and CC6 overlie first workings in the Bulli, Balgownie and Wongawilli Seams, upstream of Longwalls 4 and 5.

Sites CC7 to CC8 overlie secondary pillar extraction workings in the Bulli and Balgownie Seams, and proposed first workings of the Wongawilli Seam, as well as being downstream of Longwalls 4 and 5 in the Wongawilli Seam.

Sites CC9 and CC10 overlie first workings in the Bulli Seams and do not overlie any proposed workings in the Balgownie or Wongawilli Seams.

Site CT1 is located in a tributary which overlies the Wongawilli Seam Longwall 5, with its headwaters located over Longwall 4.

Table 1 Cataract Creek Monitoring Sites

SITE	E (MGA)	N (MGA)	DESCRIPTION
CC1	304893	6196615	Tributary draining east of the escarpment to the east of proposed Panel A1 LW2
CC2	304107	6196418	Tributary draining east of the escarpment over proposed Panel A1 LW3
CC3	303937	6196961	Nthn tributary junction east of freeway, between proposed Panels A1 LW3 and A2 LW4
CC4	303964	6196992	Sthn tributary junction east of freeway, between proposed Panels A1 LW3 and A2 LW4
CC5	303852	6197005	Start of main Cataract Ck channel west of freeway upstream of proposed panel A2 LW5
CC6	303645	6197145	Adjacent to proposed Longwall 5
CT1	303300	6197020	2nd order tributary draining into Cataract Creek downstream of CC6 / upstream of CC7
CC7	303299	6196994	Adjacent to proposed Longwall 6, downstream of tributary CT1
CC8	302595	6197425	Over Longwall 8
CC9	302175	6197415	Upstream of dam high water level over proposed panel A2 LW9
CC10	301740	6197495	Creek site within creek high water level on western edge of proposed panel A2 LW9

NOTE: Co-ordinates supplied from GPS

2.1.2 Cataract River

Stream flow, height and water quality monitoring installations were installed by Gujarat (now WCL) on 12 April 2012 at locations shown in **Figures 1 to 3**, and as summarised in **Table 2**.

Table 2 Cataract River Stream Monitoring Sites

SITE	E (MGA)	N (MGA)	DESCRIPTION
CR1	303905	6195540	Upstream of Freeway
CR2	302175	6195745	At SCA weir flow monitoring site, downstream of Freeway
CR3	301915	6196130	Upstream of Swamp Crus1
CR4**	301780	6196770	Within high water section of Cataract Reservoir

NOTE: Co-ordinates supplied from GPS

**CR4 is currently not monitored as it lies within the FSL of Cataract Reservoir

2.1.3 Bellambi Creek

Apart from some short term, once off monitoring in mid 2008, no ongoing monitoring of Bellambi Creek has been conducted as there are no predicted subsidence effects on the main channel of the creek.

2.2 Stream Flow and Ponding Observations

2.2.1 Cataract Creek

The tributary containing monitoring site CC1 has only been observed to be dry on 22/1/2013, however it was flowing at CC4 at the same time. The stream reach contains significant iron hydroxide precipitation, indicating that groundwater baseflow from the Hawkesbury Sandstone is prevalent.

The CC2 to CC3 tributary has not dried out since monitoring began in mid 2008, and has been observed to generate significant iron precipitate from a seepage point in the stream headwaters over the proposed Wongawilli Seam Longwall 1 location. Subsequent iron hydroxide seepage points are evident along the tributary reach, particularly from 1st order side creeks, as either groundwater seepage or as creek “flow”. These iron hydroxide seeps are indicative of baseflow seepage out of the Hawkesbury Sandstone.

Both tributaries are typically steep in their headwaters, with the stream flowing over colluvial soil, then exposed Hawkesbury Sandstone / colluvial soil near the watershed, trending to exposed sandstone and boulder accumulations in the steeper sections, which migrate into sand / clay / colluvial stream beds in the flatter reaches.

No rock bar constrained pools are located in the upper headwaters, due to the steepness of the catchment, whilst the lower reaches are dominated by extended lengths of stream bed incised into sandy / clay colluvial soil, with occasional boulder / cobble constrained pools. No significant rock bar constrained pools are evident in either tributary, upstream of the freeway.

The fourth order stream channel at CC5, which has a sandy substrate, with no rock bar constrained pools has also been continuously flowing, however no flow (with ponding in the rock bar constrained pool) was observed at CC6 between late August and late

October, 2012.

Between CC7 and CC9, the creek is composed of interspersed incised channels in sandy clay colluvium, cobble / boulder constrained pools and rock bar constrained pools in exposed Bulgo Sandstone. No reduction in stream flow or drying out of pools has been observed in this reach since mid 2008.

Details of the pool types between CC5 and CC9 are outlined in Geoterra (2012) and are not reproduced here.

Downstream of CC5 the creek water becomes sequentially clearer, although ferruginous precipitation is observed along the entire reach down to the headwaters of the dam, particularly where first and second order tributaries enter the main channel.

Tributary CT1 has a notable development of ferruginous sandy sediment and discoloured runoff, and has often been observed to raise the ferruginous discolouration downstream of its confluence with Cataract Creek, upstream of site CC7.

No adverse effects on stream flow continuity or stream ponding have been observed in Cataract Creek due to previous mining in the Bulli, Balgownie or Wongawilli workings.

No mining induced cracking or compressional buckling of rock bars, or loss of pool holding capacity has been observed in the creek at any sites.

Pool height water level monitoring commenced in November 2010 under the management of Gujarat (now WCL) at sites CC3, CC4, CC7 and CC9. Site CT1 pool level monitoring was initiated in April 2012, whilst CC6, CC7 and CC8 commenced in January 2013 as shown in **Figure 4**.

The CT1 tributary, which drains off the Longwall 4 and 5 catchment area has dried up after extended lack of runoff.

During high rain periods, CC9 is inundated by Cataract Reservoir. The full supply level (FSL) of Cataract Reservoir extends approximately 100m upstream of CC9. As a result, volumetric flow monitoring at CC9 temporarily ceases during these periods.

Site CC10 is often inundated by Cataract Reservoir and is no longer regularly monitored.

Volumetric stream flow monitoring using either the cross sectional / flow velocity or temporary box notch weirs was initiated at CC3 and CC4 by Gujarat during April 2012 and subsequently at CC6, CC7 and CC8 in January 2013.

Conversion of the pool depths and weir / transect measured flows in a continuous volumetric flow record along with flow duration curves has been conducted by WRM Water and Environment (2014) and the reader is referred to this reference for further detail.

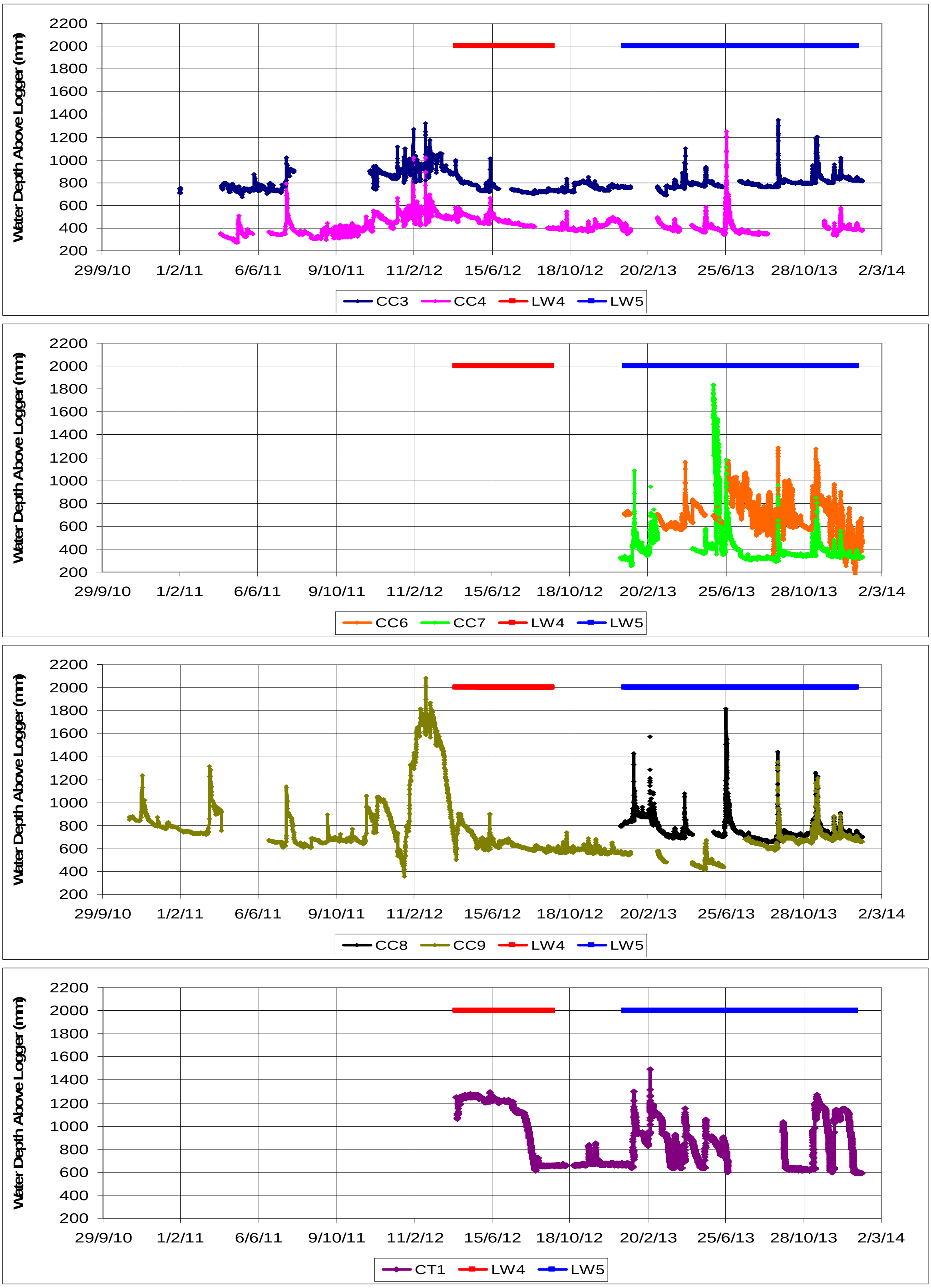

Figure 4 Cataract Creek Stream Pool Depths

2.2.2 Cataract River

The Cataract River between sites CR1 and CR4 has been continuously flowing during the monitoring period, and usually contains ferruginous precipitates.

No adverse effects on stream flow continuity or stream ponding have been observed in Cataract Creek.

No obvious mining induced cracking of rock bars and loss of pool holding capacity has been observed in the river.

Pool height water level monitoring, which commenced in April 2012 under the management of Gujarat, and is currently conducted at sites CR1, CR2 and CR3 as shown in **Figure 5**.

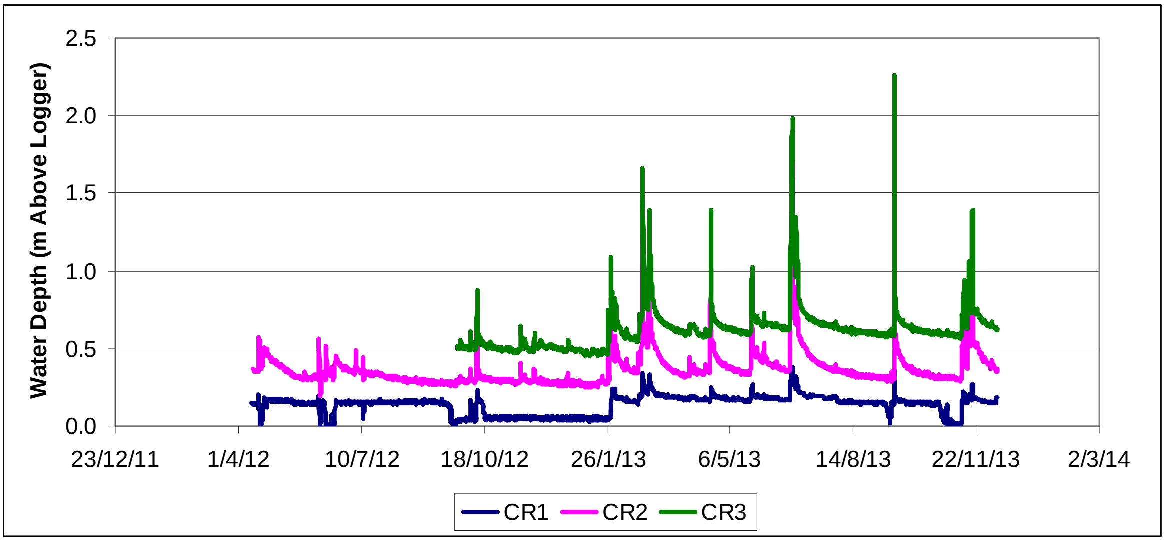

Figure 5 Cataract Creek Stream Pool Depths

Volumetric stream flow monitoring using the cross sectional / flow velocity method at sites CR1 and CR3 as well as an SCA weir at CR2 was initiated by Gujarat during April 2012.

Site CR4 was installed, but has not yet been used as it is under the high water of Cataract Reservoir after extended rain periods.

Site CR1 lies within the Russell Vale Colliery lease area and does not overlie any previous mining. Sites CR2, CR3 and CR4 overlie the old BHP Cordeaux Colliery Bulli seam bord and pillar workings.

All pools between Sites CR1 and CR3 do not show an enhanced pool drainage rate, and have not dried up during the monitoring period.

Volumetric stream flow monitoring using the cross sectional / flow velocity or the SCA weir at CC2 was initiated by Gujarat (now Wollongong Coal) in January 2013.

Conversion of the pool depths and weir / transect measured flows in a continuous volumetric flow record along with flow duration curves has been conducted by WRM Water and Environment (2014) and the reader is referred to this reference for further detail.

2.2.3 Bellambi Creek

No stream pool type, water depth or stream flow monitoring has been conducted in Bellambi Creek as it is not within the predicted 20mm subsidence zone.

2.3 Stream Water Quality Observations

2.3.1 Cataract Creek

The CC1 – CC5 and CD1 monitoring sites were installed by GeoTerra in August 2008, and were regularly monitored on a bi-monthly basis up until Gujarat (now Wollongong Coal) took over ongoing management and implementation of the field work, monitoring and laboratory analyses in July 2010. Since Gujarat took over the field monitoring, additional sites have been sequentially added, with the suite now containing Sites CC1 to CC10 and CT1.

Monitoring of field and laboratory water quality and general observation of the stream flow commenced in March 2012 and is conducted by WCL in the first order gully drainage sites Crus1c, Ccus3c and Ccus4c, which are downstream of upland swamps Crus1, Ccus3 and Ccus4, as well as in the SP1c swamp outflow.

Monitoring at these sites is conducted when there is flowing or ponded water in the ephemeral drainage gullies.

In addition to the current bi-monthly stream water depth, stream flow and stream water quality monitoring, photographic records of each monitoring site are taken during each field visit.

In general, enhanced rainfall in the catchment has the effect of reducing salinity, marginally raising pH, increasing dissolved oxygen, diluting ferruginous precipitates, diluting major metals and generally increasing nutrients, with the degree of change relating to the degree and duration of rainfall runoff dilution in the stream.

Cataract Creek's overall pH ranges from 4.39 to 6.91, with a median of 5.56 upstream at CC1, along with a relatively "flat" trend at all other sites from 6.1 to 6.3 as shown in **Figure 6**.

The stream pH is more acidic where it discharges out of the humic / fulvic acid dominated swamp areas, or Hawkesbury Sandstone seepage locations, then becomes more alkaline as it flows down the main stream, with no significant acidification downstream of upwelling seepage locations.

The stream's pH is outside the ANZECC 2000 South Eastern Australia Upland Stream criteria, which is not uncommon in natural catchments draining off Hawkesbury Sandstone in the Southern Coalfields.

The median creek salinity ranges from 130 - 145µS/cm, with a minor decrease with distance downstream as shown in **Figure 6**.

The locations which drain out of Hawkesbury Sandstone dominated catchment over previously subsided areas show the lowest median pH (highest acidity) as observed at Sites CC1 and CT1.

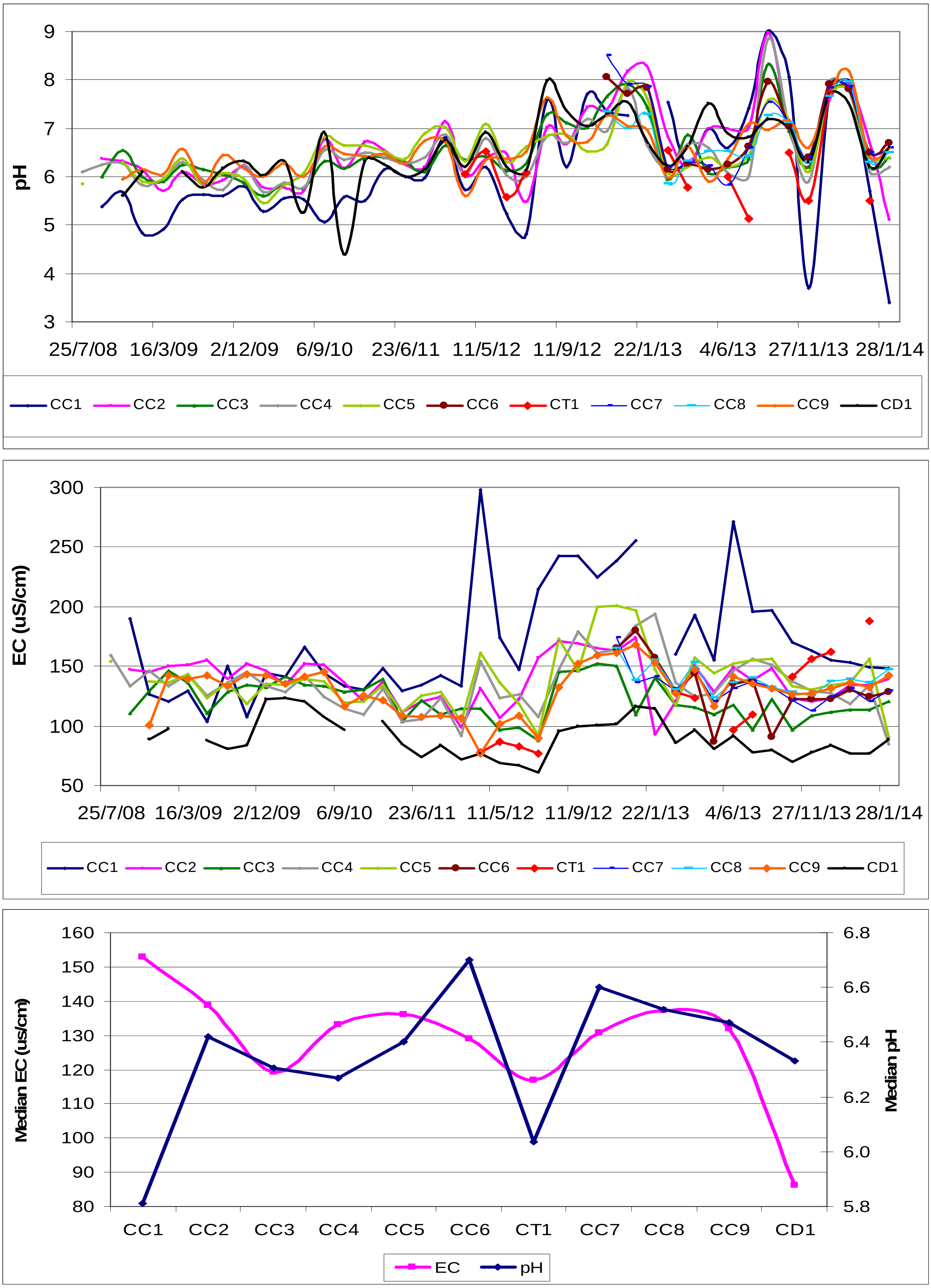

Figure 6 Cataract Creek Field Water Chemistry

As shown in **Figure 7**, filtered iron levels are variable with flow downstream, with higher levels associated with hydrous ferruginous groundwater baseflow seeps at locations such as CC2 and CT1. Numerous other, smaller seeps are relatively common in Cataract Creek, usually in association with first and second order tributary seeps into the main channel, however iron hydroxide is relatively ubiquitous in the creek both upstream and downstream of the freeway.

Due to the lack of pre mining data, it is not possible to ascertain whether the ferruginous seeps are caused by, or related to, historic mine subsidence.

Figure 7 also illustrates that median total manganese peaks at CC2 and CT1, with a general reduction with flow downstream of these sites.

The total and filtered median iron discharges into Cataract Reservoir at CC9 is 0.96mg/L and 0.26mg/L, whilst manganese is 0.08g/L and 0.01mg/L respectively, which is below the ANZECC 2000 criteria of 1.9mg/L.

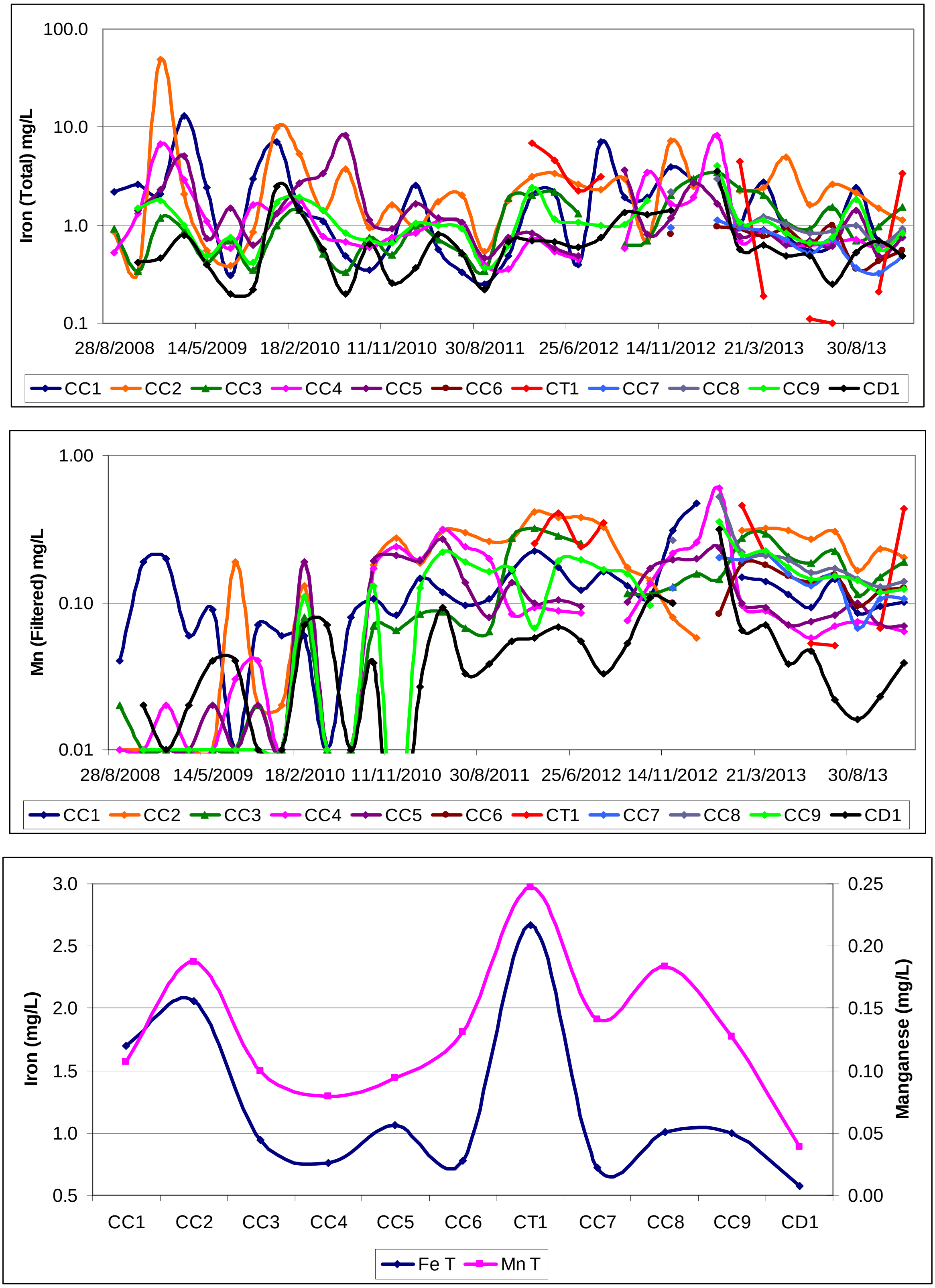

Figure 7 Cataract Creek Iron and Manganese

A peak in sulfate is present at CC2 and CT1 as shown in **Figure 8**, which corresponds with the lower pH and higher iron / manganese and represents the relatively enhanced dissolution of sulfuric acid following iron sulfide weathering as a result of shallow subsurface flow through cracks in the subsided Hawkesbury Sandstone.

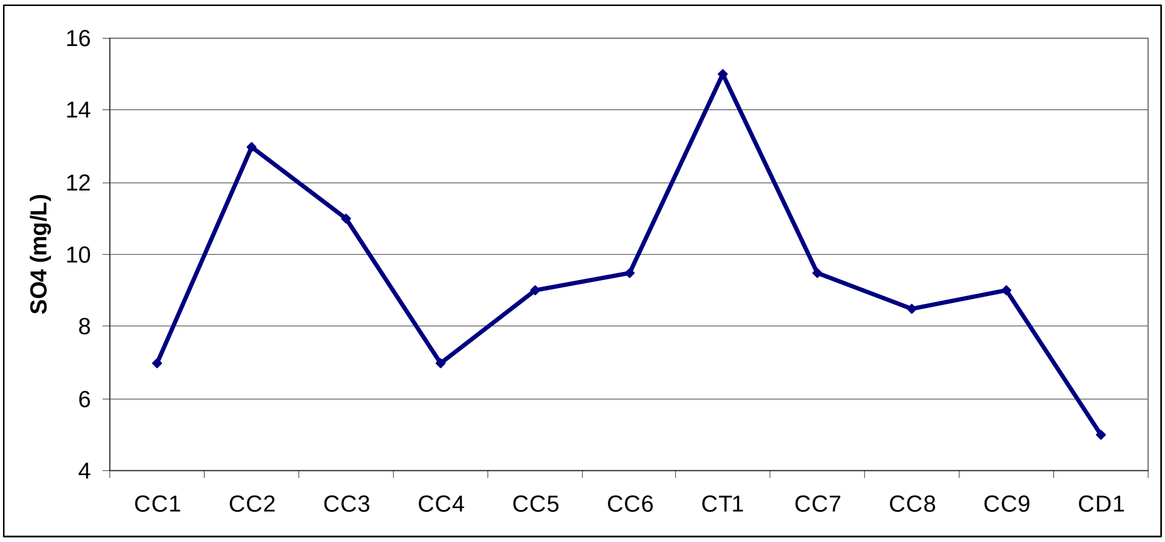

Figure 8 Cataract Creek Median Sulfate Levels

Monitoring to date, as shown in **Appendix A**, indicates the water quality of the creek is within the acceptable range for potable water, except for pH which is generally outside the ANZECC 2000 South Eastern Australia Upland Stream Criteria.

The creek can also be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines depending on the flow conditions at the time of sampling for:

- filtered zinc at CC1, CC4 and CD1, with a high variability;
- total phosphorous at all sites, generally;
- total nitrogen, at all sites, infrequently;
- occasionally filtered copper, and;
- aluminium on only one occasion (CC1 on 2/12/11), as although some values exceed 55µg/L, they do not exceed the ANZECC 2000 criteria as they are below pH 6.5.

Where the ferruginous deposits occur, the stream water quality can exceed ANZECC 2000 criteria between CC1 and CC5 for;

- filtered copper up to 0.004mg/L, very infrequently
- filtered zinc up to 0.12mg/L, infrequently
- filtered aluminium up to 0.1mg/L, very infrequently
- total nitrogen up to 1.9mg/L, very occasionally, and

- total phosphorous up to 0.27 mg/L, occasionally
- with a gradually rising pH with distance downstream from 5.54 – 6.1 and a relatively static salinity of 141µS/cm

Where Cataract Creek discharges into Cataract Reservoir at CC9, the above criteria parameters can be;

- pH, which is generally below pH 6.5;
- filtered copper (<0.004mg/L) and filtered lead (<0.0014mg/L), very rarely;
- filtered zinc (<0.029mg/L), occasionally, and;
- total nitrogen (<1.2mg/L) and total phosphorous (<0.11mg/L) occasionally.

During and after extraction of Longwalls 4 and 5, field water pH or electrical conductivity (EC) in Cataract Creek did not observably change, although minor variations in response to the quantum and duration of rainfall recharge in the catchment were observed.

No observable change in iron and manganese concentrations in Cataract Creek has occurred due to extraction of LW4 and LW5.

2.3.2 Cataract River

The CR1 – CR4 monitoring sites were installed by Gujarat (now Wollongong Coal) in May 2012, when bi-monthly monitoring of field and laboratory water quality and general observation of the stream flow commenced.

In addition to the current bi-monthly stream water depth, stream flow and stream water quality monitoring, photographic records of each monitoring site are taken during each field visit.

In general, enhanced rainfall in the catchment has the effect of reducing salinity, marginally raising pH, increasing dissolved oxygen, diluting ferruginous hydroxide discolouration, diluting major metals and generally increasing nutrients, with the degree of change relating to the degree and duration of rainfall runoff dilution in the stream.

Cataract River's pH ranges from 5.1 – 6.4, whilst salinity ranges from 52 - 117µS/cm as shown in **Figure 9**.

The stream's pH is outside the ANZECC 2000 South Eastern Australia Upland Stream criteria, which is not uncommon in natural catchments draining off Hawkesbury Sandstone in the Southern Coalfields.

All sites have been observed to have perennial flow.

Ongoing data collection will be used to assess longer term trends for iron, manganese and sulfate.

Monitoring to date as shown in **Appendix B** indicates the water quality for Cataract River is within the acceptable range for potable water, however is generally outside the ANZECC 2000 South Eastern Australia Upland Stream Criteria for pH. Depending on the flow conditions at the time of sampling, water quality can be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines for filtered zinc, total phosphorous and total nitrogen.

Where Cataract River discharges out of the Study Area, and into Cataract Reservoir at CR3, the above criteria parameters can be;

- pH, which is below 6.5;
- filtered copper (<0.002mg/L), very rarely;
- filtered zinc (<0.388mg/L), generally, and;
- total nitrogen (<1.2mg/L) and total phosphorous (<1.32mg/L) generally.

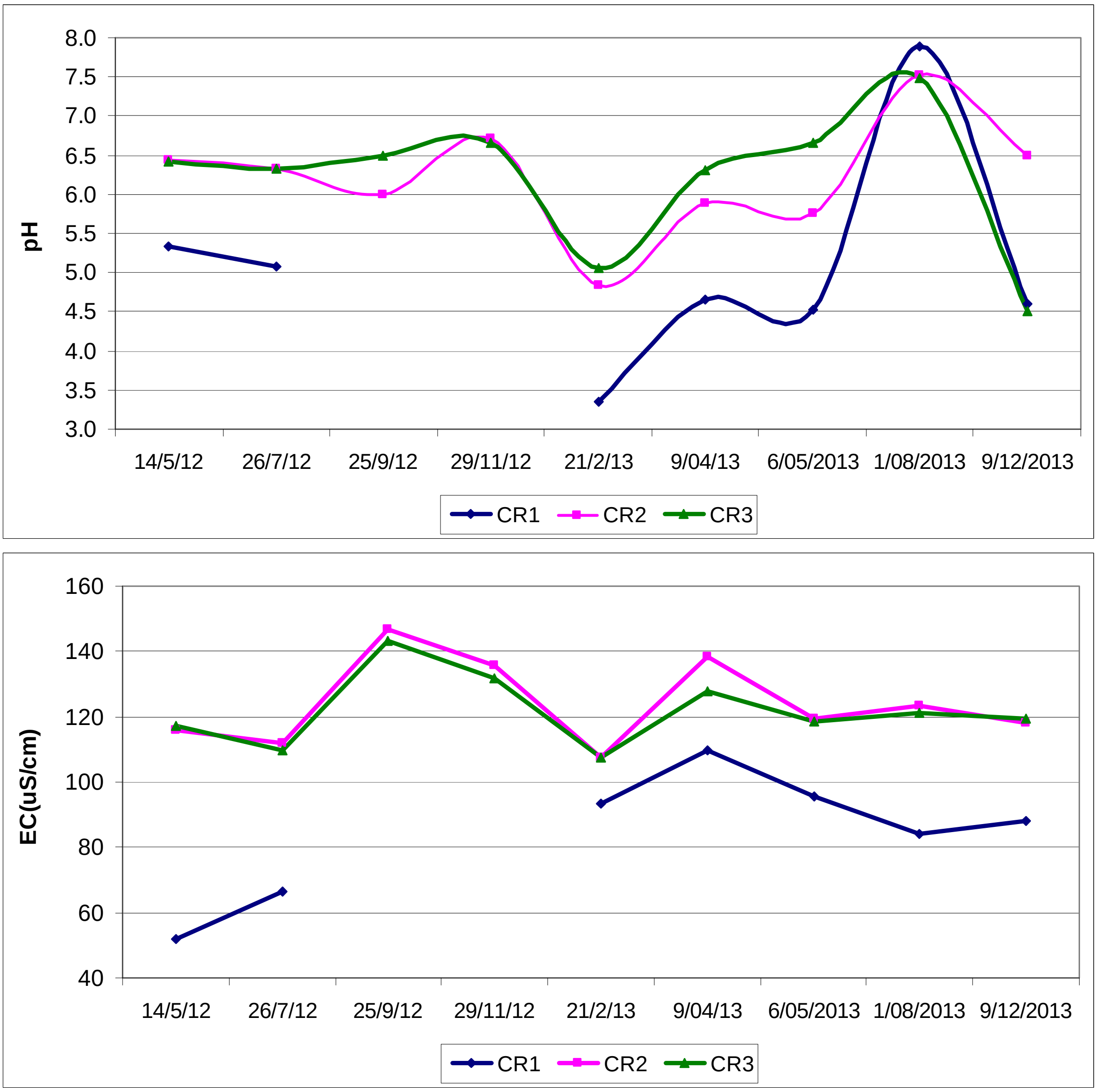

Figure 9 Cataract River Field Water Chemistry

2.3.3 Bellambi Creek

As the main channel of Bellambi Creek is outside the predicted 20mm subsidence zone, no ongoing water chemistry monitoring has been conducted.

3. LOSS AND RE-APPERANCE OF STREAM FLOW

3.1 Cataract Creek

No evidence of stream bed cracking, bedding delamination, flow loss or adverse effects on pool levels has been observed in Cataract Creek in the areas within, or adjacent to, where the main channel of the stream has been undermined by the Bulli, Balgownie or Wongawilli workings.

As a result, it is not possible to definitively establish the volumes and locations of water flow loss and stream flow re-entry in the creek, however it is obvious that groundwater seeps are present along the majority of the creek, downstream of the mid section of the proposed Longwall 1 in the Wongawilli Seam, based on the location of persistent iron hydroxide development at various locations along the creek.

As shown in **Figures 1** to **3**, Cataract Creek overlies the north west / south east and south west / north east oriented Bulli Seam bord and pillar workings as well as the south west / north east oriented longwalls in the underlying Balgownie Seam and is adjacent to Longwalls 4 and 5 in the Wongawilli Seam.

The tributaries between Sites CC1 - CC4 and CC2 – CC3 have been continuously flowing during all site visits and have not been observed to dry out, except for a short period in late January 2013 at CC1.

The fourth order stream channel between CC5 and CC9 has also been continuously flowing, although ferruginous precipitation is generally observed at site CC5 and downstream of tributary CT1.

Previous extraction in the overlying Bulli and Balgownie Seams occurred above Longwalls 4 and 5 as shown in **Figures 1** to **3**.

Up to 1.9m of subsidence was observed over Longwall 4 and 0.9m over Longwall 5 due to the previous extraction.

Wongawilli Seam Longwall 4 extraction caused up to 1.6m of subsidence, with a tilt of up to 30mm/m and tensile / compressive strain of up to +7.5 and -14 mm/m as shown in **Table 6**.

Subsequent extraction of Longwall 5 caused up to 1.8m of total maximum subsidence, with tilt up to 30mm/m and tensile / compressive strain up to +8.1 and –11.4mm/m over Longwalls 4 and 5 as shown in **Table 3**.

Valley Closure in Cataract Creek was not accurately measured for LW4, and reached up to 49mm after extraction of LW5 at creek closure survey location CC4 (as opposed to stream flow / chemistry monitoring site CC4), which is perpendicular to and downstream of Longwall 5, as well as 42mm at creek closure survey location CC1, which is in the creek as an extension of the LW4 centreline.

Note that the creek closure locations CC1 to CC4 do not equate to the creek geochemistry / pool level / flow monitoring locations of the same name.

Table 3 Wongawilli LW4 and LW5 Subsidence Summary

Longwall	Historical Subsidence (m)	Maximum Subsidence (mm)	Maximum Tilt (mm/m)	Maximum Tensile Strain (mm/m)	Maximum Compressive Strain (mm/m)	Maximum Cataract Creek Closure (mm)
Longwall 4	1.9	1.6	30	+7.5	-14.0	n/a
Longwall 5 (and 4)	0.9	1.8	30	+8.1	-11.4	49

4. POTENTIAL STREAM EFFECTS, IMPACTS AND CONSEQUENCES

4.1 Cataract Creek

4.1.1 Main Stream Flow and Ponding

As a worst case scenario, a potential risk to the integrity of stream flow and connectivity in Cataract Creek could be present in:

- the area of Longwalls 6 and 7, that may potentially undergo valley closure of up to 400mm, and;
- over Longwalls 1 to 3, that may potentially undergo valley closure of up to 650mm.

Based on current observations on the lack of observable stream bed cracking or delamination, it is not anticipated that the stream reaches containing exposed Newport and Garie Formations, Bald Hill Claystone or the upper Bulgo Sandstone will experience the same degree of surface cracking observed over Hawkesbury Sandstone reaches in other streams in the Southern Coalfields, due to the enhanced ductility of the exposed lithologies.

However, minor fracturing in the bed of Cataract Creek may occur, which may lead to minor diversion of stream flow or minor reduction in pool holding capacity.

The proponent has committed to developing a closure based trigger system for managing impacts on the creek with the exact values to be determined based on the best available predictive models and assessment of existing closure data from Longwalls 4 & 5. This will be undertaken in consultation with the appropriate regulatory authorities as part of the development of management plans for Cataract Creek.

It is not anticipated, however, that the total volume of water entering Cataract Creek will be observably affected due to stream bed or rock bar subsidence related fracturing.

Discussion of stream flow losses due to regional groundwater depressurisation and strata depressurisation directly over the proposed longwalls is covered in Geoterra, GES (2014).

4.1.2 Main Stream Rock Bars

A low potential risk to the integrity of rock bar constrained pools is predicted to be present in Cataract Creek in the area adjacent to Longwalls 5 and 6.

However, minor fracturing of rock bars in Cataract Creek may occur, which may lead to minor diversion of stream flow or minor reduction in pool holding capacity.

Although valley closure is likely to cause stream bed compression, fracturing or bedding delamination in the vicinity of Longwalls 1 to 3, there are no rock bar constrained pools in this reach over the proposed longwalls.

4.1.3 Tributaries

The tributaries which overlie the proposed workings may be at risk of subsidence related stream bed cracking, bedding delamination or enhancement of stream bed underflow.

4.1.4 Upland Swamp Outflow

A detailed significance and impact assessment of the Wonga East swamps is contained in (Biosis, 2014).

4.1.5 Main Stream Water Quality

Elevated iron and manganese as well as higher dissolved ions are currently prevalent where Hawkesbury Sandstone based groundwater seeps, or tributaries, enter the main channel of Cataract Creek.

Minor impacts on water quality due to the proposed longwall mining may occur due to reduced flow and / or increased interaction of groundwater and surface water such as reduced dissolved oxygen, higher dissolved ions and precipitates, as well as possibly lower pH and lower temperature variation due to more prevalent groundwater inflows.

Cataract Creek currently contains above (or outside) ANZECC criteria pH and zinc, and occasionally copper, as well nitrogen and phosphorous at its discharge point into Cataract Reservoir at Site CC9.

Based on the currently elevated levels of iron, manganese and associated zinc and copper, as well as nitrogen and phosphorous, and the lack of change in water quality due to extraction of Longwalls 4 and 5, no observable adverse change in stream water chemistry discharging into Cataract Reservoir is anticipated due to the proposed extraction of Longwalls 1 to 3, 6, 7 and 9 to 11.

4.1.6 Tributary Stream Water Quality

Elevated iron and manganese as well as higher dissolved ions are currently prevalent where Hawkesbury Sandstone based groundwater seeps discharge into the Cataract Creek tributaries.

Impacts on water quality due to the proposed longwall mining may occur due to reduced flow and / or increased interaction of groundwater and surface water such as reduced dissolved oxygen, higher dissolved ions and precipitates, as well as possibly lower pH and lower temperature variation due to more prevalent groundwater inflows.

4.2 Cataract River and Bellambi Creek

4.2.1 Main Stream Flow and Ponding

Negligible stream flow or ponding effects, impacts or consequences are anticipated to be generated in Cataract River or Bellambi Creek due to the low to absent levels of predicted valley closure associated with the proposed workings.

4.2.2 Main Stream Rock Bars

No potential risk to the integrity of rock bar constrained pools in Cataract River and Bellambi Creek is present.

4.2.3 Tributaries

The first order tributaries which overly the proposed 20mm subsidence zone are at low risk of subsidence related stream bed cracking, enhancement of stream bed underflow, discharge of ferruginous springs and reduced stream water quality at their confluence with Cataract River or Bellambi Creek.

However, it is anticipated that the total volume of water entering Cataract River or Bellambi Creek will not be observably affected.

4.2.4 Upland Swamp Outflow

A detailed significance and impact assessment of the Wonga East swamps is contained in (Biosis, 2014).

4.2.5 Main Stream and Tributary Water Quality

The headwaters of the first and second order streams draining off the predicted Wonga East subsidence area have the potential to undergo subsidence related bedrock cracking.

However, it is considered that the risk of adverse steam water quality changes are low, and that the quality of water entering Cataract River or Bellambi Creek from the headwater streams will not be observably affected.

4.3 Cataract Reservoir Water Quality

No observable change in Cataract Reservoir water quality is anticipated due to the proposed mining at Wonga East.

5. SURFACE WATER IMPACT PERFORMANCE MEASURES

The SCA's submission on the PPR included suggested subsidence impact performance measures. The proponent agrees with these peformance measures, except for special significance swamps. The proponent has also proposed performance measures for Bellambi Creek, which was not addressed in the SCA's submission.

The proponent will adhere to the following performance measures for surface water resources:

Cataract Reservoir

Negligible impacts including:

- negligible reduction in the quantity or quality of surface water inflows to the reservoir;
- negligible reduction in the quantity or quality of groundwater inflows to the reservoir;
- negligible increase in the quantity of water entering the groundwater system from the reservoir;
- negligible leakage from the reservoir to underground mine workings, and;
- no connective cracking between the reservoir surface and the mine.

Cataract Creek

Negligible impacts including:

- negligible diversion of flows or changes in the natural drainage behaviour of pools;
- negligible gas releases and iron staining;
- negligible increase in water cloudiness;
- negligible increase in bank erosion, and;
- negligible increase in sediment load.

Cataract River and Bellambi Creek

Negligible impacts including:

- negligible diversion of flows or changes in the natural drainage behaviour of pools;
- negligible gas releases and iron staining;
- negligible increase in water cloudiness;
- negligible increase in bank erosion, and;
- negligible increase in sediment load.

Special Significance Swamps

Minor impacts including:

- negligible erosion of the swamp surface;
- minor changes in the size of swamps;
- minor change in ecosystem functionality of the swamp;
- no significant change to the composition or distribution of species within the swamps; and
- maintenance (or restoration) of the structural integrity of controlling rockbars.

  These performance measures are consistent with the performance measures prescribed by the Subsidence Management Plan Approval for the nearby Dendrobium Colliery.

All other swamps

- no significant environmental consequences beyond predictions in the EA.

negligible impacts for a watercourse means no diversion of flow, no change in the natural drainage behaviour of pools and minimal iron staining, in accordance with the NSW Planning Assessment Commission (2009).

minor impacts include minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality, in accordance with Schedule 3, Specific Environmental Conditions – Mining Area for the Dendrobium Underground Coal Mine development consent conditions (NSW Department of Planning, 2008).

6. REFERENCES

Biosis, 2014 Russell Vale Colliery – Underground Expansion Project, Preferred Project Report – Biodiversity

Geoterra, 2012 Gujarat NRE Coking Coal Ltd Russell Vale Colliery Stream Assessment

Geoterra, GES 2014 Russell Vale Colliery Underground Expansion Project Preferred Project Report Wonga East Groundwater Assessment

Gujarat NRE Coking Coal, 2014 Gujarat NRE No.1 Colliery Geological Report on the Wonga East Area

NSW Department of Planning, 2008 Development Consent Conditions – Dendrobium Underground Coal Mine

NSW Planning Assessment Commission, 2009 The Metropolitan Coal Project Review Report

SCT Operations, 2013 Subsidence Assessment for Gujarat NRE Preferred Project Russell Vale No 1 Colliery

SCT Operations, 2014 Assessment of Groundwater Data for Russell Vale Colliery and Implications for Further Mining in the Wonga East Area

WRM Water & Environment, 2014 Russell Vale Colliery Wonga East Underground Expansion Project Surface Water Modelling

enquiries in regard to conclusions and recommendations made in this document. GeoTerra accept no responsibility for any consequences arising from any information or condition that was concealed, withheld, misrepresented, or otherwise not fully disclosed or available to GeoTerra.

The findings contained in this report are the result of discrete / specific methodologies used in accordance with normal practices and standards. To the best of our knowledge, they represent a reasonable interpretation of the general condition of the site in question. Under no circumstances, however, can it be considered that these findings represent the actual state of the site at all points.

Interpretations and recommendations provided in this report are opinions provided for our Client's sole use in accordance with the specified brief. As such they do not necessarily address all aspects of water, soil or rock conditions on the subject site. The responsibility of GeoTerra is solely to its client and it is not intended that this report be relied upon by any third party. This report shall not be reproduced either wholly or in part without the prior written consent of GeoTerra.

APPENDIX A

CATARACT CREEK LABORATORY ANALYSES

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													0.3	0.02				1.90	1.90	0.055	0.001	0.001	0.003	0.003	0.008	0.008	0.011	0.011							0.024 (III) / 0.013(V)	0.024 (III) / 0.013(V)				
28/8/2008	CC1	86	5	8	44	3	5	23	1.0	0.1			0.1	0.01		0.11	2.20	0.04	0.04	0.03	0.001		0.001		0.007		0.010		0.001		0.010		0.030		0.010		1			
5/11/2008	CC1	82	4	6	38	2	4	21	1.0	0.1			0.7	0.11		0.82	2.60	0.19	0.19	0.10	0.001		0.001		0.006		0.010		0.003		0.010		0.020		0.010		3			
9/1/2009	CC1	62	3	4	32	3	4	14	0.1	0.1			0.1	0.04		0.02	2.10	0.20	0.20	0.03	0.004		0.001		0.120		0.010		0.001		0.040		0.070		0.010		2			
17/3/2009	CC1	68	11	5	32	2	3	17	0.6	0.2			0.2	0.01		0.02	13.00	0.06	0.07	0.04	0.001		0.001		0.006		0.010		0.001		0.010		0.020		0.010		1			
14/5/2009	CC1	68	10	6	30	2	4	17	1.9	0.1			0.8	0.06		0.04	2.40	0.09	0.10	0.04	0.001		0.001		0.008		0.010		0.002		0.020		0.020		0.010		2			
23/7/2009	CC1	110	38	8	40	13	6	19	0.9	0.1			0.1	0.01		0.10	0.31	0.01	0.01	0.04	0.001		0.001		0.010		0.010		0.006		0.030		0.060		0.010		2			
2/10/2010	CC1	58	3	5	28	2	3	13	0.5	0.1			0.3	0.03		0.07	3.00	0.07	0.09	0.03	0.001		0.001		0.005		0.010		0.010		0.008		0.023		0.010		3			
2/12/2009	CC1	65	6	5	32	3	3	16	0.6	0.1			0.1	0.04		0.53	7.10	0.06	0.10	0.04	0.001		0.001		0.010		0.010		0.010		0.016		0.016		0.010		2			
18/2/2010	CC1	76	6	6	37	2	3	20	0.8	0.1			0.1	0.01		0.17	1.50	0.06	0.10	0.03	0.001		0.001		0.007		0.010		0.003		0.019		0.015		0.010		4			
5/5/2010	CC1	73	5	6	40	2	3	22	0.9	0.1			0.3	0.01		0.02	1.10	0.01	0.08	0.04	0.001		0.001		0.010		0.010		0.010		0.012		0.017		0.010		1			
8/7/2010	CC1	78	5	6	39	2	4	21	0.6	0.1			0.1	0.01		0.02	0.48	0.08	0.08	0.04	0.003		0.001		0.021		0.010		0.002		0.015		0.023		0.010		1			
6/9/2010	CC1	118	1	12	21	2	3	15	1.0	0.1			0.1	0.01		0.14	0.35	0.11	0.11	0.18	0.002		0.001		0.006		0.002		0.001		0.010		0.015		0.001		1			
11/11/2010	CC1	72	7	7	32	2	3	19	1.0	0.1			0.5	0.05	5.69	0.21	0.67	0.082	0.08	0.09	0.001		0.001		0.005		0.002		0.001		0.011		0.022		0.001		2			
31/1/2011	CC1	74	5	5	41	2	3	20	1.0	0.1			0.4	0.1	4.17	0.59	2.56	0.146	0.148	0.1	0.001		0.001		0.008		0.002		0.001		0.01		0.021		0.001		2			
8/4/2011	CC1	79	2	6	38	2	3	17	1.0	0.1			0.1	0.1	5.58	0.38	0.56	0.117	0.119	0.08	0.001		0.001		0.009		0.002		0.001		0.012		0.026		0.001		2			
23/6/2011	CC1	159	2	6	38	2	3	22	1.0	0.1			0.1	0.1	4.69	0.24	0.33	0.096	0.1	0.11	0.001		0.001		0.009		0.002		0.001		0.014		0.02		0.001		1			
30/8/2011	CC1	72	5	5	40	2	3	20	1.0	0.1			0.1	0.01	5.28	0.22	0.25	0.106	0.1	0.11	0.001		0.001		0.008		0.002		0.001		0.012		0.019		0.001		1			
2/12/2011	CC1	135	3	9	38	2	3	21	2.0	0.1			0.1	0.01	5.55	0.25	0.49	0.164	0.166	0.13	0.003		0.001		0.049		0.004		0.002		0.013		0.022		0.001		4			
5/4/2012	CC1	139	1	8	57	3	4	25	1.0	0.1			2	0.04	5.96	1.32	2.03	0.226	0.235	0.09	0.002		0.001		0.021		0.003		0.001		0.018		0.031		0.001		1			
11/5/2012	CC1	98	2	9	55	3	5	32	1.0	0.1			0.6	0.5	5.55	0.65	2.14	0.174	0.188	0.08	0.001		0.001		0.024		0.003		0.001		0.018		0.031		0.001		1			
25/6/2012	CC1	83	1	6	36	2	3	18	1.0	0.1	0.08	0.1	0.1	0.01	4.29	0.21	0.4	0.121	0.123	0.12	0.001		0.001		0.01		0.002		0.001		0.015		0.018		0.001		1		1.14	1.13
17/7/2012	CC1	94	5	7	47	2	4	22	1.0	0.1	0.02	0.2	0.2	0.05	5.24	0.41	6.97	0.161	0.137	0.06	0.001		0.001		0.008		0.002		0.001		0.015		0.028		0.001		11		1.57	1.39
22/8/2012	CC1	108	8	8	47	3	5	24	1.0	0.1	0.04	0.3	0.3	0.01	5.19	0.94	1.9	0.13	0.134	0.07	0.001		0.001		0.01		0.001		0.001		0.016		0.03		0.001		2		1.65	1.63
24/10/2012	CC1	115	4	7	54	3	4	25	3.0	0.1	0.02	0.7	0.7	0.06	4.94	0.46	1.9	0.108	0.229	0.07	0.002		0.001		0.163		0.002		0.001		0.012		0.025		0.001		4		1.75	1.64
14/11/2012	CC1	128	7	5	49	3	4	25	2.0	0.1	0.02	0.4	0.4	0.07		1.85	3.9	0.308	0.33	0.16	0.001		0.002		0.014		0.003		0.001		0.012		0.029		0.001		7		1.63	1.62
20/12/2012	CC1	152	8	3	49	4	5	24	5.0	0.1	0.02	1	1	0.07	5.08	1.27	2.92	0.474	0.53	0.12	0.002		0.001		0.013		0.003		0.001		0.02		0.032		0.001		4		1.6	1.78
7/3/2013	CC1	127	1	15	38	2	3	22	3.0	0.1	1.56	2.3	3.9	0.04	5.17	0.59	1.02	0.15	0.167	0.18	0.002	0.004	0.001	0.001	0.049	0.083	0.003	0.004	0.001	0.001	0.011	0.012	0.022		0.001	0.001	5		1.38	1.38
21/3/2013	CC1	168	-	9	43	2	3	22	4.0	0.2	0.02	0.4	0.4	0.01	5.4	0.55	2.76	0.14	0.194	0.1	0.002	0.003	0.001	0.001	0.026	0.017	0.003	0.003	0.001	0.001	0.011	0.013	0.022	0.025	0.001	0.001	4			
1/05/2013	CC1	86	4	8	45	2	3	20	2.0	0.1	0.01	0.2	0.2	0.05	6.1	0.46	0.84	0.114	0.103	0.1	0.001	0.001	0.001	0.001	0.011	0.01	0.002	0.002	0.001	0.001	0.011	0.011	0.023	0.021	0.001	0.001	3		1.52	1.27
4/06/2013	CC1	109	4	8	38	2	3	24	2.0	0.1	0.04	0.4	0.4	0.02	5.74	0.37	0.55	0.093	0.091	0.09	0.002	0.003	0.001	0.001	0.017	0.017	0.002	0.002	0.001	0.001	0.012	0.012	0.021	0.022	0.001	0.001	3		1.32	1.44
16/7/13	CC1	110	3	7	40	2	4	25	1.0	0.1	0.03	0.2	0.2	0.01	5.62	0.26	0.64	0.145	0.16	0.1	0.006	0.008	0.001	0.001	0.031	0.036	0.004	0.004	0.001	0.001	0.016	0.016	0.024	0.025	0.001	0.001	3	5	1.33	1.52
30/8/13	CC1	91	3	8	46	2	4	26	1.0	0.1	0.02	0.4	0.4	0.02	7.35	0.16	2.43	0.085	0.139	0.03	0.001	0.006	0.001	0.001	0.014	0.021	0.001	0.004	0.001	0.001	0.013	0.017	0.021	0.026	0.001	0.001	6	5	1.52	1.59
24/9/13	CC1	93	3	7	44	2	3	25	2.0	0.1	0.03	2.3	2.3	0.01	5.34	0.26	0.69	0.094	0.105	0.07	0.002	0.003	0.001	0.001	0.025	0.019	0.002	0.002	0.001	0.001	0.01	0.012	0.01	0.022	0.001	0.001	4	5	1.45	1.49
27/11/13	CC1	91	2	7	43	2	3	24	2.0	0.1	2.6	0.3	2.9	0.01	5.32	0.43	0.86	0.101	0.101	0.11	0.001	0.002	0.001	0.001	0.008	0.013	0.002	0.001	0.001	0.001	0.009	0.01	0.02	0.02	0.001	0.001	3	5	1.4	1.44

ST Dev	29	6	2	8	2	1	4	1.0	0.0	0.77	0.7	0.9	0.09	0.66	0.42	2.53	0.086	0.092	0.04	0.001	0.002	0.000	0.000	0.033	0.024	0.004	0.001	0.003	0.000	0.006	0.002	0.011	0.002	0.004	0.000	2	0	0.17	0.17
Max	168	38	15	57	13	6	32	5.0	0.2	2.60	2.3	3.9	0.50	7.35	1.85	13.00	0.474	0.530	0.18	0.006	0.008	0.002	0.001	0.163	0.083	0.010	0.004	0.010	0.001	0.040	0.017	0.070	0.026	0.010	0.001	11	5	1.75	1.78
Min	58	1	3	21	2	3	13	0.1	0.1	0.01	0.1	0.1	0.01	4.17	0.02	0.25	0.010	0.010	0.03	0.001	0.001	0.001	0.001	0.005	0.010	0.001	0.001	0.001	0.001	0.008	0.010	0.010	0.020	0.001	0.001	1	5	1.14	1.13
Median	91	4	7	40	2	3	22	1.0	0.1	0.03	0.4	0.3	0.03	5.34	0.26	1.70	0.107	0.113	0.09	0.001	0.003	0.001	0.001	0.010	0.018	0.003	0.003	0.001	0.001	0.012	0.012	0.022	0.022	0.001	0.001	2	5	1.52	1.49

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt
ANZECC													0.3	0.02				1.90	1.90	0.055
28/8/2008	CC2	80	25	16	22	7	5	14	1.2	0.1			0.1	0.01		0.05	0.85	0.01	0.01	0.01
5/11/2008	CC2	77	23	14	21	6	5	14	1.1	0.1			0.3	0.04		0.07	0.33	0.01	0.01	0.02
9/1/2009	CC2	72	25	13	20	6	5	13	0.4	0.1			1.9	0.27		0.02	49.00	0.01	0.51	0.01
17/3/2009	CC2	80	34	14	23	6	5	17	1.0	0.2			0.2	0.01		0.02	2.10	0.01	0.03	0.01
14/5/2009	CC2	94	32	19	23	7	6	19	1.0	0.1			0.2	0.01		0.04	0.55	0.01	0.05	0.01
23/7/2009	CC2	89	21	18	28	8	6	15	1.2	0.1			0.1	0.01		0.11	0.39	0.19	0.20	0.01
2/10/2010	CC2	75	27	14	22	6	5	16	0.9	0.1			0.1	0.01		0.04	0.86	0.02	0.04	0.02
2/12/2009	CC2	75	27	14	22	6	5	15	0.9	0.1			0.1	0.07		0.20	9.80	0.02	0.53	0.01
18/2/2010	CC2	69	12	10	26	3	4	15	0.7	0.1			0.2	0.01		0.08	5.30	0.13	0.21	0.01
5/5/2010	CC2	79	25	15	26	5	4	19	1.0	0.1			0.4	0.02		0.05	1.40	0.01	0.04	0.01
8/7/2010	CC2	77	28	14	24	5	5	15	0.9	0.1			0.1	0.02		0.18	3.70	0.01	0.04	0.01
6/9/2010	CC2	117	24	12	21	6	4	14	1.0	0.1			0.1	0.01		0.15	0.95	0.18	0.19	0.02
10/11/2010	CC2	65	16	13	25	4	4	12	1.0	0.1			0.1	0.11	7.27	0.43	1.62	0.274	0.27	0.01
31/1/2011	CC2	79	21	14	27	6	4	14	1.0	0.1			0.2	0.05	7.36	0.23	0.94	0.185	0.187	0.01
8/4/2011	CC2	72	12	12	23	5	4	12	1.0	0.1			0.1	0.16	7.44	0.6	1.73	0.308	0.318	0.01
23/6/2011	CC2	153	11	12	36	6	4	16	1.0	0.1			0.2	0.01	6.87	0.75	2.02	0.298	0.324	0.01
30/8/2011	CC2	81	11	13	23	6	4	14	1.0	0.1			0.1	0.01	8.33	0.52	0.54	0.262	0.265	0.01
2/12/2011	CC2	107	8	13	22	3	3	13	1.0	0.1			0.1	0.01	6.57	0.73	1.77	0.269	0.274	0.05
5/4/2012	CC2	98	4	16	21	4	4	12	1.0	0.1			0.8	0.05	7.81	1	3.14	0.411	0.437	0.01
11/5/2012	CC2	60	15	13	19	5	4	14	1.0	0.1			2.4	2.65	7.02	0.8	3.36	0.382	0.396	0.01
25/6/2012	CC2	74	5	20	17	5	4	12	1.0	0.1	0.69	0.3	1	0.02	6.22	0.96	2.6	0.382	0.396	0.01
17/7/2012	CC2	64	19	12	19	5	3	12	1.0	0.1	0.03	0.1	0.1	0.01	7.09	0.58	2.29	0.328	0.323	0.01
22/8/2012	CC2	95	10	18	23	6	4	13	1.0	0.1	0.91	1	1.9	0.03	7.34	0.27	2.97	0.175	0.262	0.01
24/10/2012	CC2	85	18	14	22	5	4	16	2.0	0.1	0.02	0.2	0.2	0.02	6.95	0.16	0.72	0.142	0.13	0.01
14/11/2012	CC2	77	17	14	27	5	4	14	1.0	0.1	3.31	0.8	4.1	0.05		0.22	7.27	0.079	0.277	0.01
20/12/2012	CC2	98	20	12	22	6	4	14	1.0	0.1	0.02	0.1	0.1	0.02	7.22	0.16	2.49	0.058	0.184	0.01
7/3/2013	CC2	109	1	13	26	3	3	14	1.0	0.1	2.82	1.9	4.7	0.06	5.79	0.71	2.22	0.312	0.31	0.04
21/3/2013	CC2	69	16	11	21	4	3	13	1.0	0.1	0.02	0.3	0.3	0.01	6.91	0.59	2.42	0.322	0.352	0.01
1/05/2013	CC2	55	16	13	27	5	4	12	1.0	0.1	0.02	0.3	0.3	0.02	7.45	0.47	4.96	0.31	0.342	0.01
4/06/2013	CC2	87	14	11	21	4	4	14	1.0	0.1	0.07	0.5	0.6	0.02	7.36	0.6	1.61	0.269	0.285	0.01
16/7/13	CC2	74	12	10	18	4	3	13	1.0	0.1	0.01	0.1	0.1	0.01	6.94	0.82	2.64	0.306	0.322	0.01
30/8/13	CC2	66	23	12	22	5	4	15	1.0	0.1	0.04	0.1	0.1	0.02	9.72	0.2	2.11	0.164	0.192	0.01
24/9/13	CC2	65	13	10	22	4	3	13	1.0	0.1	0.02	0.3	0.3	0.01	6.89	0.46	1.49	0.231	0.243	0.02
27/11/13	CC2	76	10	11	27	3	3	13	1.0	0.1	0.05	0.1	0.2	0.02	6.6	0.42	1.14	0.202	0.251	0.02
	ST Dev	19	8	2	4	1	1	2	0.2	0.0	1.10	0.5	1.1	0.45	0.79	0.30	8.24	0.132	0.139	0.01
	Max	153	34	20	36	8	6	19	2.0	0.2	3.31	1.9	4.7	2.65	9.72	1.00	49.00	0.411	0.530	0.05
	Min	55	1	10	17	3	3	12	0.4	0.1	0.01	0.1	0.1	0.01	5.79	0.02	0.33	0.010	0.010	0.01
	Median	77	17	13	22	5	4	14	1.0	0.1	0.04	0.3	0.2	0.02	7.09	0.25	2.06	0.188	0.264	0.01

	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC	0.001	0.001	0.003	0.003	0.008	0.008	0.011	0.011							0.024 (III) / 0.013(V)	0.024 (III) / 0.013(V)				
28/8/2008	0.001		0.001		0.004		0.010		0.001		0.010		0.060		0.010		2			
5/11/2008	0.001		0.001		0.002		0.010		0.011		0.070		0.050		0.010		2			
9/1/2009	0.001		0.001		0.008		0.010		0.013		0.070		0.080		0.010		3			
17/3/2009	0.001		0.001		0.001		0.010		0.012		0.050		0.050		0.010		2			
14/5/2009	0.001		0.001		0.001		0.010		0.015		0.040		0.040		0.010		2			
23/7/2009	0.001		0.001		0.005		0.010		0.015		0.070		0.030		0.010		1			
2/10/2010	0.001		0.001		0.001		0.010		0.013		0.055		0.047		0.010		1			
2/12/2009	0.001		0.001		0.003		0.010		0.010		0.060		0.046		0.010		2			
18/2/2010	0.001		0.001		0.010		0.010		0.002		0.040		0.031		0.010		6			
5/5/2010	0.001		0.001		0.003		0.010		0.007		0.051		0.041		0.010		1			
8/7/2010	0.001		0.001		0.002		0.010		0.010		0.049		0.037		0.010		1			
6/9/2010	0.001		0.001		0.010		0.002		0.010		0.102		0.051		0.001		1			
10/11/2010	0.001		0.001		0.015		0.004		0.008		0.092		0.041		0.001		1			
31/1/2011	0.004		0.001		0.033		0.004		0.012		0.102		0.049		0.001		4			
8/4/2011	0.001		0.001		0.01		0.004		0.009		0.096		0.039		0.001		1			
23/6/2011	0.001		0.001		0.011		0.005		0.009		0.102		0.04		0.001		1			
30/8/2011	0.001		0.001		0.006		0.004		0.01		0.099		0.042		0.001		1			
2/12/2011	0.001		0.001		0.028		0.006		0.008		0.07		0.028		0.001		2			
5/4/2012	0.001		0.001		0.012		0.005		0.009		0.102		0.038		0.001		1			
11/5/2012	0.001		0.001		0.008		0.004		0.011		0.104		0.04		0.001		1			
25/6/2012	0.001		0.001		0.011		0.004		0.01		0.099		0.037		0.001		1		1	1.1
17/7/2012	0.001		0.001		0.005		0.003		0.011		0.103		0.042		0.001		2		1.17	1.02
22/8/2012	0.002		0.001		0.015		0.002		0.01		0.085		0.039		0.001		1		1.22	1.22
24/10/2012	0.001		0.001		0.016		0.001		0.009		0.076		0.04		0.001		2		1.27	1.33
14/11/2012	0.001		0.001		0.007		0.001		0.01		0.082		0.042		0.001		1		1.39	1.21
20/12/2012	0.001		0.001		0.005		0.001		0.01		0.075		0.043		0.001		1		1.27	1.26
7/3/2013	0.001	0.003	0.001	0.001	0.03	0.081	0.005	0.007	0.007	0.006	0.07	0.068	0.030		0.001	0.001	2		1	1.03
21/3/2013	0.001	0.001	0.001	0.001	0.024	0.018	0.004	0.005	0.009	0.01	0.091	0.102	0.038	0.041	0.001	0.001	2		1.14	1.04
1/05/2013	0.001	0.001	0.001	0.002	0.011	0.016	0.004	0.004	0.009	0.008	0.084	0.102	0.041	0.040	0.001	0.001	2		1.35	1.13
4/06/2013	0.001	0.004	0.001	0.003	0.012	0.024	0.004	0.004	0.008	0.009	0.102	0.102	0.036	0.042	0.001	0.001	1		1.1	1.14
16/7/13	0.002	0.001	0.001	0.001	0.014	0.015	0.004	0.004	0.009	0.008	0.086	0.096	0.033	0.037	0.001	0.001	2	5	0.96	1.01
30/8/13	0.001	0.001	0.001	0.001	0.005	0.005	0.002	0.002	0.01	0.011	0.089	0.118	0.038	0.041	0.001	0.001	2	5	1.33	1.26
24/9/13	0.005	0.001	0.001	0.001	0.036	0.044	0.005	0.005	0.007	0.008	0.074	0.076	0.074	0.033	0.001	0.001	2	5	1.09	1.01
27/11/13	0.001	0.001	0.001	0.001	0.012	0.017	0.004	0.004	0.007	0.008	0.071	0.084	0.03	0.037	0.001	0.001	2	5	1.19	0.98
ST Dev	0.001	0.001	0.000	0.001	0.009	0.024	0.003	0.001	0.003	0.002	0.023	0.016	0.01	0.003	0.004	0.000	1	0	0.14	0.11
Max	0.005	0.004	0.001	0.003	0.036	0.081	0.010	0.007	0.015	0.011	0.104	0.118	0.08	0.042	0.010	0.001	6	5	1.39	1.33
Min	0.001	0.001	0.001	0.001	0.001	0.005	0.001	0.002	0.001	0.006	0.010	0.068	0.03	0.033	0.001	0.001	1	5	0.96	0.98
Median	0.001	0.001	0.001	0.001	0.010	0.018	0.004	0.004	0.010	0.008	0.079	0.099	0.04	0.040	0.001	0.001	2	5	1.18	1.12

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													0.3	0.02				1.90	1.90	0.055	0.001	0.001	0.003	0.003	0.008	0.008	0.011	0.011							0.024 (III) / 0.013(V)	0.024 (III) / 0.013(V)				
28/8/2008	CC3	69	12	16	21	5	4	12	1.0	0.1			0.1	0.01		0.17	0.92	0.02	0.03	0.01	0.001		0.001		0.004		0.010		0.010		0.080		0.030		0.010		1			
5/11/2008	CC3	70	13	14	21	5	4	12	0.9	0.1			0.2	0.12		0.20	0.34	0.01	0.03	0.04	0.001		0.001		0.002		0.010		0.007		0.060		0.040		0.010		2			
9/1/2009	CC3	66	14	12	22	5	5	12	0.1	0.1			0.1	0.04		0.06	1.20	0.01	0.05	0.01	0.001		0.001		0.005		0.010		0.008		0.060		0.060		0.010		2			
17/3/2009	CC3	73	18	14	24	5	4	14	0.8	0.1			0.1	0.01		0.11	0.87	0.01	0.02	0.02	0.001		0.001		0.001		0.010		0.008		0.040		0.040		0.010		2			
14/5/2009	CC3	85	24	15	27	5	5	17	0.6	0.1			0.1	0.01		0.04	0.43	0.01	0.04	0.01	0.001		0.001		0.005		0.010		0.008		0.090		0.050		0.010		2			
23/7/2009	CC3	78	14	14	27	5	5	15	1.0	0.1			0.1	0.01		0.09	0.69	0.01	0.02	0.01	0.001		0.001		0.006		0.010		0.011		0.060		0.060		0.010		1			
2/10/2010	CC3	69	16	15	23	5	4	15	0.9	0.1			0.1	0.01		0.16	0.35	0.02	0.02	0.01	0.001		0.001		0.004		0.010		0.004		0.050		0.037		0.010		2			
2/12/2009	CC3	66	17	13	22	5	4	14	0.9	0.1			0.1	0.01		0.36	0.98	0.01	0.14	0.02	0.001		0.001		0.004		0.010		0.002		0.051		0.037		0.010		2			
18/2/2010	CC3	73	9	6	34	3	3	18	0.6	0.1			0.2	0.01		0.08	1.40	0.08	0.10	0.01	0.001		0.001		0.011		0.010		0.003		0.025		0.024		0.010		3			
5/5/2010	CC3	72	15	14	27	4	4	16	0.8	0.1			0.1	0.01		0.07	0.51	0.01	0.01	0.01	0.001		0.001		0.004		0.010		0.004		0.040		0.032		0.010		1			
8/7/2010	CC3	72	16	14	24	5	4	14	0.7	0.1			0.1	0.01		0.04	0.33	0.01	0.01	0.01	0.001		0.001		0.005		0.010		0.009		0.045		0.034		0.010		1			
6/9/2010	CC3	107	11	5	26	3	3	15	1.0	0.1			0.2	0.01		0.42	0.75	0.07	0.07	0.19	0.001		0.001		0.005		0.001		0.001		0.023		0.027		0.001		1			
10/11/2010	CC3	77	5	7	26	3	3	16	1.0	0.1			0.3	0.03	6.02	0.29	0.5	0.065	0.066	0.05	0.002		0.001		0.03		0.002		0.001		0.02		0.024		0.001		1			
31/1/2011	CC3	80	21	5	39	3	3	17	1.0	0.1			0.1	0.01	5.18	0.51	1	0.084	0.083	0.04	0.001		0.001		0.005		0.001		0.001		0.023		0.027		0.001		1			
8/4/2011	CC3	80	5	6	33	3	3	15	1.0	0.1			0.3	0.2	6.32	0.44	0.71	0.086	0.089	0.05	0.001		0.001		0.006		0.001		0.001		0.019		0.024		0.001		1			
23/6/2011	CC3	132	6	6	31	3	3	20	1.0	0.1			0.1	0.01	4.93	0.33	0.52	0.067	0.07	0.04	0.001		0.001		0.005		0.001		0.001		0.019		0.023		0.001		1			
30/8/2011	CC3	78	5	6	35	3	3	19	2.0	0.1			0.1	0.02	5.76	0.32	0.34	0.064	0.063	0.03	0.001		0.001		0.014		0.002		0.001		0.02		0.023		0.001		1			
2/12/2011	CC3	87	5	11	21	3	3	13	1.0	0.1			0.4	0.01	5.79	0.62	1.88	0.274	0.283	0.04	0.003		0.001		0.023		0.004		0.004		0.048		0.022		0.001		1			
5/4/2012	CC3	83	8	9	21	3	3	11	1.0	0.1			0.4	0.04	6.58	0.73	2.04	0.322	0.354	0.03	0.001		0.001		0.015		0.003		0.005		0.052		0.025		0.001		1			
11/5/2012	CC3	99	9	12	19	3	3	13	1.0	0.1			3.7	3.93	5.86	0.67	2.21	0.283	0.305	0.03	0.001		0.001		0.016		0.003		0.006		0.054		0.025		0.001		1			
25/6/2012	CC3	69	8	10	18	3	3	11	1.0	0.1	2.56	1.1	3.7	0.01	5.25	0.62	1.32	0.251	0.258	0.03	0.001		0.001		0.014		0.003		0.05		0.05		0.023		0.001		1		0.88	0.88
22/8/2012	CC3	75	9	9	19	4	3	11	1.0	0.1	0.02	0.1	0.1	0.01	6.35	0.28	0.62	0.116	0.123	0.01	0.001		0.001		0.014		0.002		0.005		0.05		0.027		0.001		1		0.9	0.92
24/10/2012	CC3	79	10	13	21	3	3	14	1.0	0.1	0.01	0.1	0.1	0.01	6.25	0.45	0.7	0.114	0.143	0.02	0.001		0.001		0.009		0.001		0.004		0.051		0.035		0.001		1		1.06	1.03
14/11/2012	CC3	86	10	13	27	4	3	13	1.0	0.1	0.01	0.2	0.2	0.01		1.41	2.04	0.127	0.148	0.03	0.001		0.001		0.426		0.001		0.004		0.049		0.028		0.001		2		1.23	1.04
20/12/2012	CC3	84	10	11	23	4	3	13	1.0	0.1	0.12	0.1	0.1	0.01	6.41	0.75	2.93	0.157	0.225	0.02	0.001		0.001		0.007		0.001		0.005		0.046		0.028		0.001		1		1.08	1.01
23/1/2013	CC3	79	10	12	4	4	3	16	1.0	0.1	0.22	0.5	0.7	0.01	6.06	0.49	3.48	0.144	0.293	0.02	0.001		0.001		0.006		0.001		0.004		0.04		0.029		0.001		2		1.44	1.17
7/3/2013	CC3	71	4	8	23	3	3	13	1.0	0.1	0.09	0.2	0.3	0.01	5.31	0.66	2.36	0.276	0.298	0.05	0.001	0.001	0.001	0.001	0.016	0.023	0.004	0.003	0.004	0.004	0.04	0.044	0.023		0.001	0.001	2		0.9	0.96
21/3/2013	CC3	95	8	11	18	3	3	12	1.0	0.1	0.04	0.1	0.1	0.01	5.96	0.64	2	0.295	0.32	0.03	0.001	0.001	0.001	0.001	0.022	0.016	0.003	0.004	0.005	0.006	0.054	0.06	0.026	0.028	0.001	0.001	2		0.9	0.92
1/05/2013	CC3	115	7	10	21	3	3	12	1.0	0.1	0.03	0.1	0.1	0.01	6.26	0.54	1.08	0.207	0.226	0.07	0.001	0.001	0.001	0.001	0.025	0.012	0.003	0.003	0.005	0.005	0.051	0.055	0.026	0.025	0.001	0.001	1		0.94	0.92
4/06/2013	CC3	77	7	10	21	3	3	13	1.0	0.1	0.16	0.4	0.6	0.02	6.28	0.56	0.92	0.185	0.186	0.02	0.001	0.002	0.001	0.001	0.024	0.028	0.003	0.003	0.005	0.005	0.050	0.054	0.023	0.026	0.001	0.001	2		0.94	0.96
16/7/13	CC3	72	8	10	16	3	3	12	1.0	0.1	0.03	0.1	0.1	0.01	5.99	0.6	1.52	0.223	0.238	0.03	0.001	0.001	0.001	0.001	0.016	0.016	0.003	0.003	0.005	0.005	0.051	0.053	0.026	0.027	0.001	0.001	2	5	0.82	0.92
30/8/13	CC3	55	10	12	21	3	3	13	1.0	0.1	0.01	0.1	0.1	0.01	9.02	0.37	0.7	0.114	0.113	0.01	0.001	0.001	0.001	0.001	0.012	0.012	0.002	0.002	0.005	0.006	0.056	0.055	0.026	0.027	0.001	0.001	2	5	1.04	0.96
25/9/13	CC3	58	7	10	21	3	3	12	1.0	0.1	0.05	0.1	0.2	0.01	6.03	0.34	0.96	0.15	0.163	0.03	0.001	0.001	0.001	0.001	0.014	0.015	0.003	0.003	0.005	0.005	0.044	0.047	0.044	0.023	0.001	0.001	1	5	0.94	0.92
29/11/13	CC3	66	7	11	22	3	3	13	1.0	0.1	0.05	0.1	0.2	0.01	5.75	0.52	1.54	0.189	0.22	0.04	0.001	0.002	0.001	0.001	0.014	0.017	0.003	0.003	0.005	0.005	0.044	0.048	0.022	0.025	0.001	0.001	2	5	0.99	0.96
	ST Dev	16	5	3	6	1	1	2	0.3	0.0	0.67	0.3	0.9	0.67	0.81	0.28	0.78	0.099	0.11	0.03	0.000	0.000	0.000	0.000	0.072	0.006	0.004	0.001	0.008	0.001	0.016	0.005	0.010	0.002	0.004	0.000	1	0	0.16	0.07
	Max	132	24	16	39	5	5	20	2.0	0.1	2.56	1.1	3.7	3.93	9.02	1.41	3.48	0.322	0.35	0.19	0.003	0.002	0.001	0.001	0.426	0.028	0.010	0.004	0.050	0.006	0.090	0.060	0.060	0.028	0.010	0.001	3	5	1.44	1.17
	Min	55	4	5	4	3	3	11	0.1	0.1	0.01	0.1	0.1	0.01	4.93	0.04	0.33	0.010	0.01	0.01	0.001	0.001	0.001	0.001	0.001	0.012	0.001	0.002	0.001	0.004	0.019	0.044	0.022	0.023	0.001	0.001	1	5	0.82	0.88
	Median	77	10	11	22	3	3	13	1.0	0.1	0.05	0.1	0.1	0.01	6.02	0.40	0.94	0.100	0.12	0.03	0.001	0.001	0.001	0.001	0.010	0.016	0.003	0.003	0.005	0.005	0.050	0.054	0.027	0.026	0.001	0.001	1	5	0.94	0.96

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt
ANZECC													0.3	0.02				1.90	1.90	0.055
28/8/2008	CC4	75	9	8	32	4	4	17	1.0	0.1			0.1	0.01		0.12	0.52	0.01	0.01	0.03
5/11/2008	CC4	71	10	6	30	4	4	15	1.0	0.1			0.3	0.06		0.42	1.30	0.01	0.02	0.08
9/1/2009	CC4	66	14	4	30	4	4	15	0.2	0.1			0.1	0.06		0.39	6.70	0.02	0.17	0.01
17/3/2009	CC4	74	19	5	31	4	4	17	0.9	0.1			0.1	0.01		0.67	2.90	0.01	0.02	0.03
14/5/2009	CC4	72	15	7	29	4	4	16	0.7	0.1			0.2	0.01		0.11	1.10	0.01	0.03	0.02
23/7/2009	CC4	81	14	8	34	4	4	20	0.9	0.1			0.1	0.01		0.11	0.58	0.03	0.03	0.02
2/10/2010	CC4	72	19	5	31	4	4	18	1.0	0.1			0.2	0.01		0.19	1.60	0.04	0.06	0.03
2/12/2009	CC4	63	17	6	27	4	4	16	1.0	0.1			0.1	0.01		0.77	1.30	0.01	0.05	0.02
18/2/2010	CC4	70	12	9	28	3	4	15	0.5	0.1			0.1	0.01		0.12	1.80	0.19	0.20	0.02
5/5/2010	CC4	75	11	10	35	4	4	19	0.8	0.1			0.1	0.01		0.11	0.77	0.01	0.01	0.01
8/7/2010	CC4	70	14	7	33	4	4	18	0.7	0.1			0.1	0.01		0.14	0.67	0.01	0.01	0.02
6/9/2010	CC4	101	13	12	24	4	4	12	1.0	0.1			0.1	0.01		0.32	0.60	0.17	0.18	0.01
10/11/2010	CC4	70	11	11	25	4	3	12	1.0	0.1			0.1	0.04	5.38	0.38	0.75	0.238	0.23	0.02
31/1/2011	CC4	67	9	13	30	4	3	13	1.0	0.1			0.6	0.01	6.21	0.26	0.83	0.195	0.201	0.01
8/4/2011	CC4	41	8	10	24	4	3	12	1.0	0.1			0.2	0.05	7.79	0.58	1.11	0.315	0.328	0.03
23/6/2011	CC4	130	7	10	22	4	3	15	1.0	0.1			0.1	0.02	5.79	0.53	1.05	0.241	0.268	0.02
30/8/2011	CC4	65	7	11	24	4	3	14	1.0	0.1			0.1	0.01	6.9	0.38	0.4	0.199	0.205	0.02
2/12/2011	CC4	111	4	8	29	3	3	18	1.0	<0.1			0.1	0.01	5.16	0.18	0.36	0.084	0.087	0.06
5/4/2012	CC4	98	5	6	37	3	3	16	1.0	0.1			0.1	0.03	5.69	0.42	0.73	0.093	0.096	0.04
11/5/2012	CC4	109	5	7	33	3	3	19	1.0	0.1			0.7	0.7	5	0.38	0.54	0.088	0.088	0.03
25/6/2012	CC4	78	5	6	29	3	3	16	1.0	0.1	0.06	0.1	0.1	0.01	4.53	0.33	0.45	0.085	0.056	0.04
22/8/2012	CC4	89	7	7	31	4	4	16	1.0	0.1	0.04	0.1	0.4	0.01	5.15	0.43	0.58	0.075	0.082	0.02
24/10/2012	CC4	97	11	8	33	4	3	18	1.0	0.1	0.15	0.5	0.6	0.05	5.28	0.47	3.44	0.135	0.162	0.01
14/11/2012	CC4	84	90	5	29	4	3	17	1.0	0.1	0.03	0.1	0.1	0.01		0.87	1.64	0.216	0.227	0.04
20/12/2012	CC4	99	12	3	26	4	3	16	1.0	0.1	0.52	0.2	0.7	0.05	5.65	0.86	1.92	0.255	0.252	0.03
23/1/2013	CC4	90	23	2	8	8	4	18	1.0	0.1	0.02	0.6	0.6	0.01	6.56	0.38	8.16	0.597	0.605	0.01
7/3/2013	CC4	92	4	6	31	3	3	18	1.0	0.1	0.08	0.2	0.3	0.01	4.73	0.34	0.7	0.096	0.097	0.07
21/3/2013	CC4	136	7	6	29	3	3	16	1.0	0.1	0.05	0.2	0.2	0.01	4.96	0.56	0.89	0.088	0.098	0.04
1/05/2013	CC4	66	5	6	29	3	3	16	1.0	0.1	0.08	0.1	0.1	0.01	5.46	0.41	0.66	0.07	0.074	0.03
4/06/2013	CC4	94	7	7	31	3	3	18	1.0	0.1	0.14	0.3	0.4	0.01	5.44	0.42	0.62	0.058	0.077	0.05
16/7/13	CC4	93	5	6	29	3	3	18	1.0	0.1	0.07	0.1	0.2	0.03	5.15	0.3	0.65	0.069	0.072	0.04
30/8/13	CC4	68	7	6	30	3	3	18	1.0	0.1	0.03	0.1	0.1	0.01	7.27	0.36	0.72	0.074	0.077	0.02
25/9/13	CC4	71	6	7	31	3	3	17	1.0	0.1	0.06	0.1	0.1	0.01	5.27	0.3	0.58	0.07	0.074	0.06
29/11/13	CC4	70	5	8	24	2	3	17	1.0	0.1	0.16	0.1	0.3	0.01	5.08	0.33	0.88	0.064	0.07	0.06
	ST Dev	20	15	2	5	1	0	2	0.2	0.0	0.13	0.2	0.2	0.12	0.85	0.20	1.68	0.120	0.12	0.02
	Max	136	90	13	37	8	4	20	1.0	0.1	0.52	0.6	0.7	0.70	7.79	0.87	8.16	0.597	0.61	0.08
	Min	41	4	2	8	2	3	12	0.2	0.1	0.02	0.1	0.1	0.01	4.53	0.11	0.36	0.010	0.01	0.01
	Median	75	9	7	30	4	3	17	1.0	0.1	0.07	0.1	0.1	0.01	5.38	0.38	0.76	0.080	0.08	0.03

		Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC		0.001	0.001	0.003	0.003	0.008	0.008	0.011	0.011							0.024 (III) / 0.013(V)	0.024 (III) / 0.013(V)				
28/8/2008	CC4	0.001		0.001		0.001		0.010		0.006		0.060		0.030		0.010		1			
5/11/2008	CC4	0.001		0.001		0.002		0.010		0.002		0.030		0.030		0.010		3			
9/1/2009	CC4	0.002		0.001		0.011		0.010		0.001		0.040		0.050		0.010		3			
17/3/2009	CC4	0.001		0.001		0.001		0.010		0.002		0.030		0.030		0.010		3			
14/5/2009	CC4	0.001		0.001		0.001		0.010		0.002		0.020		0.020		0.010		3			
23/7/2009	CC4	0.001		0.001		0.004		0.010		0.003		0.030		0.030		0.010		1			
2/10/2010	CC4	0.001		0.001		0.002		0.010		0.002		0.034		0.033		0.010		3			
2/12/2009	CC4	0.001		0.001		0.003		0.010		0.003		0.032		0.029		0.010		3			
18/2/2010	CC4	0.001		0.001		0.012		0.010		0.002		0.036		0.026		0.010		3			
5/5/2010	CC4	0.001		0.001		0.002		0.010		0.001		0.024		0.025		0.010		1			
8/7/2010	CC4	0.001		0.001		0.014		0.010		0.005		0.042		0.034		0.010		1			
6/9/2010	CC4	0.001		0.001		0.021		0.001		0.005		0.059		0.032		0.001		1			
10/11/2010	CC4	0.001		0.001		0.022		0.004		0.005		0.054		0.029		0.001		1			
31/1/2011	CC4	0.001		0.001		0.017		0.003		0.006		0.057		0.031		0.001		1			
8/4/2011	CC4	0.001		0.001		0.016		0.004		0.004		0.053		0.026		0.001		2			
23/6/2011	CC4	0.001		0.001		0.017		0.004		0.005		0.057		0.027		0.001		1			
30/8/2011	CC4	0.001		0.001		0.017		0.003		0.006		0.055		0.027		0.001		1			
2/12/2011	CC4	0.001		0.001		0.015		0.002		0.002		0.018		0.022		0.001		2			
5/4/2012	CC4	0.001		0.001		0.009		0.002		0.001		0.021		0.026		0.001		1			
11/5/2012	CC4	0.001		0.001		0.006		0.002		0.001		0.022		0.025		0.001		1			
25/6/2012	CC4	0.001		0.001		0.005		0.002		0.001		0.021		0.023		0.001		<1		1.04	1.09
22/8/2012	CC4	0.001		0.001		0.007		0.002		0.001		0.022		0.024		0.001		<1		1.16	1.22
24/10/2012	CC4	0.001		0.001		0.005		0.001		0.001		0.024		0.033		0.001		2		1.32	1.26
14/11/2012	CC4	0.008		0.001		0.018		0.002		0.001		0.024		0.026		0.001		2		1.1	1.21
20/12/2012	CC4	0.001		0.001		0.012		0.002		0.001		0.024		0.027		0.001		<1		1.04	1.17
23/1/2013	CC4	0.001		0.001		0.005		0.001		0.001		0.028		0.036		0.001		3		1.49	1.54
7/3/2013	CC4	0.001	0.001	0.001	0.001	0.005	0.006	0.001	0.001	0.001	0.001	0.016	0.016	0.023		0.001	0.001	2		1.08	1.18
21/3/2013	CC4	0.001	0.001	0.001	0.001	0.008	0.005	0.001	0.001	0.001	0.001	0.020	0.023	0.024	0.028	0.001	0.001	2		1.08	1.09
1/05/2013	CC4	0.001	0.001	0.001	0.001	0.007	0.005	0.001	0.001	0.001	0.001	0.019	0.023	0.022	0.025	0.001	0.001	2		1.04	1.09
4/06/2013	CC4	0.001	0.002	0.001	0.001	0.005	0.025	0.001	0.002	0.001	0.001	0.019	0.021	0.019	0.022	0.001	0.001	2		1.16	1.18
16/7/13	CC4	0.001	0.001	0.001	0.001	0.005	0.008	0.001	0.002	0.001	0.001	0.020	0.02	0.024	0.025	0.001	0.001	2	5	1.04	1.18
30/8/13	CC4	0.001	0.001	0.001	0.001	0.005	0.006	0.001	0.002	0.001	0.001	0.025	0.024	0.025	0.024	0.001	0.001	2	7	1.11	1.18
25/9/13	CC4	0.001	0.001	0.001	0.001	0.006	0.005	0.001	0.001	0.001	0.001	0.019	0.018	0.019	0.022	0.001	0.001	1	5	1.14	1.14
29/11/13	CC4	0.001	0.003	0.001	0.001	0.005	0.008	0.001	0.002	0.001	0.001	0.017	0.018	0.021	0.021	0.001	0.001	2	8	0.94	1.09
	ST Dev	0.001	0.001	0.000	0.000	0.006	0.007	0.004	0.001	0.002	0.000	0.014	0.003	0.006	0.002	0.004	0.000	1	2	0.14	0.11
	Max	0.008	0.003	0.001	0.001	0.022	0.025	0.010	0.002	0.006	0.001	0.060	0.024	0.050	0.028	0.010	0.001	3	8	1.49	1.54
	Min	0.001	0.001	0.001	0.001	0.001	0.005	0.001	0.001	0.001	0.001	0.016	0.016	0.019	0.021	0.001	0.001	1	5	0.94	1.09
	Median	0.001	0.001	0.001	0.001	0.006	0.006	0.002	0.002	0.001	0.001	0.025	0.021	0.026	0.024	0.001	0.001	2	6	1.09	1.18

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													0.3	0.02				1.90	1.90	0.055	0.001	0.001	0.003	0.003	0.008	0.008	0.011	0.011							0.024 (III) / 0.013(V)	0.024 (III) / 0.013(V)				
5/11/2008	CC5	75	15	11	26	5	4	14	0.9	0.1			0.1	0.07		0.50	1.40	0.01	0.03	0.06	0.001		0.001		0.003		0.010		0.001		0.040		0.040		0.010		3			
9/1/2009	CC5	70	19	11	23	6	4	13	0.1	0.1			0.1	0.04		0.05	2.30	0.01	0.12	0.02	0.002		0.001		0.004		0.010		0.006		0.050		0.060		0.010		2			
17/3/2009	CC5	75	20	12	26	5	4	14	0.9	0.1			0.1	0.01		0.18	5.10	0.01	0.03	0.02	0.001		0.001		0.001		0.010		0.004		0.030		0.040		0.010		2			
14/5/2009	CC5	74	21	11	26	5	5	16	0.6	0.1			0.2	0.01		0.11	0.73	0.02	0.03	0.01	0.001		0.001		0.004		0.010		0.009		0.040		0.040		0.010		2			
23/7/2009	CC5	80	16	12	29	5	5	16	1.0	0.1			0.1	0.02		0.09	1.50	0.01	0.02	0.01	0.001		0.001		0.003		0.010		0.010		0.040		0.030		0.010		1			
2/10/2010	CC5	82	19	14	29	5	4	16	0.8	0.1			0.1	0.01		0.17	0.62	0.02	0.03	0.01	0.001		0.001		0.003		0.010		0.006		0.042		0.034		0.010		2			
2/12/2009	CC5	67	19	11	24	5	4	15	0.9	0.1			0.1	0.01		0.47	1.30	0.01	0.15	0.02	0.001		0.001		0.003		0.010		0.005		0.040		0.034		0.010		2			
18/2/2010	CC5	70	13	9	28	4	4	15	0.5	0.1			0.4	0.01		0.09	2.70	0.19	0.84	0.02	0.001		0.001		0.010		0.010		0.001		0.035		0.025		0.010		2			
5/5/2010	CC5	75	14	11	30	4	4	17	0.8	0.1			0.1	0.01		0.10	3.40	0.01	0.08	0.04	0.001		0.001		0.012		0.010		0.003		0.089		0.047		0.010		2			
8/7/2010	CC5	75	17	13	27	4	4	16	0.7	0.1			0.1	0.04		0.06	8.30	0.01	0.10	0.02	0.001		0.001		0.002		0.010		0.009		0.032		0.027		0.010		1			
6/9/2010	CC5	101	6	12	20	4	4	12	1.0	0.1			0.1	0.01		0.29	1.14	0.19	0.20	0.02	0.001		0.001		0.033		0.003		0.005		0.050		0.033		0.001		1			
10/11/2010	CC5	89	1	13	22	4	3	14	1.0	0.1			0.1	0.13	7.24	0.51	0.92	0.209	0.202	0.02	0.001		0.001		0.033		0.003		0.004		0.044		0.03		0.001		2			
31/1/2011	CC5	66	24	9	34	4	3	15	1.0	0.1			0.3	0.08	6.18	0.53	1.65	0.194	0.212	0.02	0.001		0.001		0.014		0.002		0.004		0.044		0.031		0.001		1			
8/4/2011	CC5	43	8	9	25	4	3	13	1.0	0.1			0.2	0.01	7.59	0.57	1.19	0.272	0.274	0.03	0.001		0.001		0.024		0.003		0.003		0.044		0.024		0.001		2			
23/6/2011	CC5	148	7	8	27	4	3	19	1.0	0.1			0.2	0.02	5.51	0.48	1.06	0.137	0.169	0.03	0.001		0.001		0.009		0.002		0.002		0.031		0.027		0.001		1			
30/8/2011	CC5	80	6	6	35	4	3	18	1.0	0.1			0.1	0.01	5.79	0.44	0.46	0.08	0.081	0.02	0.001		0.001		0.008		0.002		0.001		0.022		0.025		0.001		1			
2/12/2011	CC5	111	5	10	25	4	3	17	1.0	0.1			0.1	0.03	5.17	0.4	0.75	0.137	0.146	0.06	0.002		0.001		0.039		0.003		0.002		0.025		0.022		0.001		3			
5/4/2012	CC5	88	3	5	37	3	3	16	1.0	0.1			0.4	0.05	5.74	0.4	0.82	0.1	0.107	0.03	0.001		0.001		0.006		0.002		0.001		0.021		0.029		0.001		1			
11/5/2012	CC5	99	8	8	32	4	3	19	2.0	0.1			0.3	0.13	5.12	0.39	0.58	0.104	0.107	0.03	0.001		0.001		0.006		0.002		0.002		0.023		0.026		0.001		1			
25/6/2012	CC5	79	5	8	29	3	3	17	1.0	0.1	0.2	0.2	0.4	0.01	4.56	0.36	0.49	0.094	0.097	0.04	0.001		0.001		0.006		0.002		0.001		0.021		0.023		0.001		1		1.08	1.14
22/8/2012	CC5	91	11	8	29	5	4	16	2.0	0.1	0.18	0.2	0.1	0.4	5.34	0.35	3.68	0.101	0.112	0.02	0.001		0.001		0.007		0.001		0.001		0.03		0.027		0.001		1		1.2	1.33
24/10/2012	CC5	97	15	9	30	5	3	17	1.0	0.1	0.07	0.5	0.6	0.03	5.6	0.46	0.8	0.171	0.15	0.01	0.001		0.001		0.005		0.001		0.001		0.025		0.032		0.001		3		1.33	1.26
14/11/2012	CC5	89	15	7	26	6	3	16	1.0	0.1	1.22	0.7	1.9	0.02		0.42	1.18	0.197	0.189	0.02	0.001		0.001		0.005		0.001		0.002		0.028		0.029		0.001		2		1.18	1.27
20/12/2012	CC5	85	20	9	28	7	4	15	1.0	0.1	0.03	0.1	0.1	0.01	6.26	0.49	2.7	0.2	0.284	0.02	0.001		0.001		0.008		0.001		0.002		0.031		0.033		0.001		1		1.38	1.36
23/1/2013	CC5	78	22	10	7	7	4	15	2.0	0.1	0.58	0.5	1.1	0.01	6.32	0.58	1.66	0.236	0.241	0.02	0.001		0.001		0.009		0.002		0.004		0.039		0.036		0.001		3		1.44	1.378
7/3/2013	CC5	135	8	5	32	4	3	18	1.0	0.1	0.25	0.2	0.4	0.01	4.89	0.49	0.77	0.099	0.103	0.07	0.001	0.001	0.001	0.001	0.07	0.006	0.001	0.001	0.001	0.001	0.016	0.016	0.026		0.001	0.001	2		1.17	1.26
21/3/2013	CC5	67	8	6	29	3	3	16	1.0	0.1	0.05	0.2	0.2	0.01	4.92	0.53	0.89	0.093	0.101	0.04	0.001	0.001	0.001	0.001	0.005	0.009	0.001	0.002	0.001	0.001	0.019	0.023	0.024	0.027	0.001	0.001	2		1.1	1.09
1/05/2013	CC5	80	6	6	30	3	3	16	1.0	0.1	0.42	0.4	0.8	0.02	5.3	0.38	0.62	0.071	0.076	0.02	0.001	0.001	0.001	0.001	0.007	0.032	0.001	0.001	0.001	0.001	0.020	0.02	0.023	0.024	0.001	0.001	2		1.09	1.09
4/06/2013	CC5	95	12	7	30	5	3	17	1.0	0.1	0.22	0.3	0.5	0.01	5.56	0.37	0.69	0.074	0.078	0.05	0.001	0.001	0.001	0.001	0.009	0.01	0.001	0.002	0.001	0.001	0.020	0.02	0.024	0.028	0.001	0.001	2		1.23	1.24
16/7/13	CC5	89	5	6	29	3	3	18	1.0	0.1	0.04	0.2	0.2	0.03	5.18	0.34	0.61	0.082	0.0.72	0.04	0.001	0.001	0.001	0.001	0.005	0.009	0.001	0.002	0.001	0.001	0.022	0.021	0.025	0.027	0.001	0.001	2	5	1.04	1.18
30/8/13	CC5	69	10	7	31	4	3	18	1.0	0.1	0.18	0.3	0.5	0.01	7.68	0.32	1.42	0.099	0.109	0.02	0.001	0.001	0.001	0.001	0.006	0.012	0.001	0.001	0.001	0.001	0.024	0.025	0.028	0.03	0.001	0.001	2	5	1.22	1.23
25/9/13	CC5	72	7	7	30	3	3	17	1.0	0.1	0.06	0.2	0.3	0.03	5.18	0.28	0.48	0.071	0.067	0.05	0.001	0.001	0.001	0.001	0.005	0.008	0.001	0.001	0.001	0.001	0.017	0.02	0.017	0.023	0.001	0.001	1	5	1.13	1.14
29/11/13	CC5	69	7	8	25	3	3	17	1.0	0.1	0.06	0.1	0.2	0.01	5.09	0.33	0.74	0.069	0.077	0.05	0.001	0.002	0.001	0.001	0.006	0.014	0.001	0.002	0.001	0.001	0.018	0.019	0.021	0.023	0.001	0.001	2	5	1.01	1.14
	ST Dev	20	6	2	5	1	1	2	0.4	0.0	0.32	0.2	0.4	0.07	0.87	0.16	1.60	0.076	0.145	0.016	0.000	0.000	0.000	0.000	0.014	0.008	0.004	0.001	0.003	0.000	0.014	0.003	0.008	0.003	0.004	0.000	1	0	0.13	0.10
	Max	148	24	14	37	7	5	19	2.0	0.1	1.22	0.7	1.9	0.40	7.68	0.58	8.30	0.272	0.840	0.070	0.002	0.002	0.001	0.001	0.070	0.032	0.010	0.002	0.010	0.001	0.089	0.025	0.060	0.030	0.010	0.001	3	5	1.44	1.38
	Min	43	1	5	7	3	3	12	0.1	0.1	0.03	0.1	0.1	0.01	4.56	0.05	0.46	0.010	0.020	0.010	0.001	0.001	0.001	0.001	0.001	0.006	0.001	0.001	0.001	0.001	0.016	0.016	0.017	0.023	0.001	0.001	1	5	1.01	1.09
	Median	80	11	9	29	4	3	16	1.0	0.1	0.18	0.2	0.2	0.01	5.51	0.38	1.06	0.094	0.107	0.020	0.001	0.001	0.001	0.001	0.006	0.010	0.002	0.002	0.002	0.001	0.030	0.020	0.028	0.027	0.001	0.001	2	5	1.18	1.24

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													0.3	0.02				1.90	1.90	0.055	0.001	0.001	0.003	0.003	0.008	0.008	0.011	0.011							0.024 (III) / 0.013(V)	0.024 (III) / 0.013(V)				
14/11/2012	CC6	95	16	11	28	6	3	15	1.0	0.1					0.34	0.26	0.8	0.099	0.11	0.03	0.001	0.006	0.001	0.01	0.001	0.02	0.038	0.004		0.14					0.005	0.002				
23/1/2013	CC6	71	17	10	6	6	3	15	1.0	0.1					0.13	0.47	0.97	0.084	0.105	0.032	0.001	0.001	0.001	0.005	0.001	0.02	0.032	0.003	6.52	0.08					0.005	0.003				
7/3/2013	CC6	110	7	7	29	3	3	16	1.0	0.1	0.06	0.2	0.3	0.01	5.22	0.42	0.93	0.182	0.185	0.07	0.001	0.001	0.001	0.001	0.01	0.012	0.002	0.002	0.002	0.003	0.028	0.029	0.024		0.001	0.001	2		1.1	1.09
21/3/2013	CC6	78		9	24	3	3	14	1.0	0.2	0.07	0.1	0.2	1.46	5.63	0.39	0.76	0.181	0.183	0.03	0.001	0.001	0.001	0.001	0.016	0.006	0.002	0.002	0.003	0.004	0.038	0.039	0.026	0.027	0.001	0.001	2			
1/05/2013	CC6	51	9	10	31	4	3	13	1.0	0.1	0.03	0.3	0.3	0.01	6.12	0.3	0.92	0.152	0.142	0.02	0.001	0.005	0.001	0.001	0.009	0.016	0.002	0.003	0.003	0.002	0.031	0.033	0.025	0.023	0.001	0.001	2		1.26	1.01
4/06/2013	CC6	88	8	8	27	4	3	15	1.0	0.1	0.05	0.2	0.2	0.01	5.95	0.34	0.63	0.137	0.135	0.05	0.001	0.001	0.001	0.001	0.012	0.015	0.002	0.002	0.003	0.003	0.033	0.038	0.023	0.027	0.001	0.001	1		1.09	1.1
16/7/13	CC6	76	6	8	22	3	3	15	1.0	0.1	0.09	0.1	0.2	0.05	5.64	0.3	0.99	0.154	0.149	0.03	0.001	0.001	0.001	0.001	0.01	0.012	0.002	0.002	0.003	0.003	0.037	0.039	0.026	0.026	0.001	0.001	2	5	0.91	1.05
30/8/13	CC6	59	10	10	23	4	3	15	1.0	0.1	0.01	0.1	0.1	0.01	8.11	0.11	0.36	0.095	0.1	0.02	0.001	0.001	0.001	0.001	0.008	0.006	0.002	0.002	0.004	0.004	0.043	0.048	0.028	0.028	0.001	0.001	2	5	1.06	1.1
25/9/13	CC6	61	8	9	25	3	3	14	1.0	0.1	0.07	0.2	0.3	0.02	5.78	0.19	0.43	0.119	0.122	0.03	0.001	0.001	0.001	0.001	0.01	0.012	0.001	0.002	0.003	0.003	0.032	0.033	0.032	0.023	0.001	0.001	1	5	1.05	1.01
29/11/13	CC6	66	7	10	21	3	3	15	1.0	0.1	0.05	0.1	0.2	0.01	5.78	0.24	0.55	0.125	0.129	0.03	0.001	0.002	0.001	0.001	0.009	0.011	0.002	0.002	0.003	0.003	0.031	0.034	0.022	0.024	0.001	0.001	2	5	0.94	1.05
	ST Dev	18	4	1	7	1	0	1	0.0	0.0	0.03	0.1	0.1	0.51	2.56	0.11	0.23	0.035	0.030	0.015	0.000	0.002	0.000	0.003	0.005	0.005	0.014	0.001	2.172	0.047	0.005	0.006	0.003	0.002	0.002	0.001	0	0	0.12	0.04
	Max	110	17	11	31	6	3	16	1.0	0.2	0.09	0.3	0.3	1.46	8.11	0.47	0.99	0.182	0.185	0.070	0.001	0.006	0.001	0.010	0.016	0.020	0.038	0.004	6.520	0.140	0.043	0.048	0.032	0.028	0.005	0.003	2	5	1.26	1.10
	Min	51	6	7	6	3	3	13	1.0	0.1	0.01	0.1	0.1	0.01	0.13	0.11	0.36	0.084	0.100	0.020	0.001	0.001	0.001	0.001	0.001	0.006	0.001	0.002	0.002	0.002	0.028	0.029	0.022	0.023	0.001	0.001	1	5	0.91	1.01
	Median	74	8	10	25	4	3	15	1.0	0.1	0.06	0.2	0.2	0.01	5.71	0.30	0.78	0.131	0.132	0.030	0.001	0.001	0.001	0.001	0.010	0.012	0.002	0.002	0.003	0.003	0.033	0.036	0.026	0.026	0.001	0.001	2	5	1.06	1.05

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													0.3	0.02				1.90	1.90	0.055	0.001		0.003		0.008		0.011								0.024 (III) / 0.013(V)					
5/4/2012	CT1	42	2	9	13	1	2	8	1.0	0.1			0.3	0.01	4.98	2.87	6.88	0.254	0.343	0.17	0.001		0.001		0.033		0.004		0.002		0.038		0.019		0.001		4			
11/5/2012	CT1	73	3	15	16	2	3	11	1.0	0.1			0.3	0.24	5.77	3.38	4.6	0.406	0.427	0.03	0.001		0.001		0.023		0.004		0.003		0.077		0.026		0.001		1			
25/6/2012	CT1	53	3	9	14	1	2	9	1.0	0.1	0.07	0.1	0.1	0.01	4.65	1.86	2.24	0.24	0.254	0.04	0.001		0.001		0.02		0.003		0.003		0.05		0.017		0.001		1		0.64	0.61
17/7/2012	CT1	46	18	10	12	2	3	10	1.0	0.1	0.03	0.1	0.1	0.01	5.59	2.17	3.09	0.351	0.334	0.01	0.001		0.001		0.015		0.003		0.004		0.058		0.022		0.001		1		0.91	0.78
7/3/2013	CT1	100	4	17	22	3	3	13	1.0	0.1	0.01	0.1	0.1	0.01	5.71	4.1	4.43	0.454	0.449	0.04	0.001	0.001	0.001	0.001	0.092	0.092	0.019	0.019	0.006	0.006	0.078	0.082	0.034		0.001	0.001	2		1.05	0.96
21/3/2013	CT1	67	2	16	16	2	3	11	1.0	0.1	0.02	0.2	0.2	0.01	6.06	0.13	0.19	0.21	0.183	0.05	0.001	0.001	0.001	0.001	0.076	0.077	0.009	0.01	0.006	0.006	0.078	0.079	0.025	0.026	0.001	0.001	1		0.82	0.85
4/06/2013	CT1	64	<1	10	14	1	2	11	1.0	0.1	3.76	1.5	5.3	0.02	5.72	0.05	0.11	0.053	0.06	0.03	0.001	0.004	0.001	0.001	0.044	0.049	0.005	0.005	0.005	0.005	0.048	0.047	0.017	0.018	0.001	0.001	2		0.6	0.69
16/7/13	CT1	67	2	15	11	2	3	11	1.0	0.1	0.01	0.2	0.2	0.01	6.33	0.06	0.1	0.051	0.096	0.04	0.001	0.001	0.001	0.001	0.04	0.043	0.005	0.006	0.007	0.006	0.060	0.061	0.022	0.020	0.001	0.001	2	5	0.66	0.85
25/9/13	CT1	78	8	28	13	4	5	13	1.0	0.1	0.02	0.1	0.1	0.05	8.15	0.11	0.21	0.067	0.067	0.03	0.001	0.001	0.001	0.001	0.047	0.048	0.006	0.006	0.010	0.011	0.1	0.105	0.100	0.044	0.001	0.001	1	5	1.11	1.2
29/11/13	CT1	96	9	32	22	5	5	15	1.0	0.1	0.02	0.1	0.1	0.01	8.01	2.94	3.4	0.436	0.419	0.02	0.001	0.001	0.001	0.001	0.079	0.066	0.012	0.011	0.011	0.011	0.153	0.155	0.053	0.054	0.001	0.001	1	5	1.47	1.34
	ST Dev	19	5	8	4	1	1	2	0.0	0.0	1.32	0.5	1.6	0.07	1.15	1.57	2.37	0.158	0.153	0.045	0.000	0.001	0.000	0.000	0.027	0.019	0.005	0.005	0.003	0.003	0.033	0.038	0.026	0.016	0.000	0.000	1	0	0.30	0.25
	Max	100	18	32	22	5	5	15	1.0	0.1	3.76	1.5	5.3	0.24	8.15	4.10	6.88	0.454	0.449	0.170	0.001	0.004	0.001	0.001	0.092	0.092	0.019	0.019	0.011	0.011	0.153	0.155	0.100	0.054	0.001	0.001	4	5	1.47	1.34
	Min	42	2	9	11	1	2	8	1.0	0.1	0.01	0.1	0.1	0.01	4.65	0.05	0.10	0.051	0.060	0.010	0.001	0.001	0.001	0.001	0.015	0.043	0.003	0.005	0.002	0.005	0.038	0.047	0.017	0.018	0.001	0.001	1	5	0.60	0.61
	Median	67	3	15	14	2	3	11	1.0	0.1	0.02	0.1	0.2	0.01	5.75	2.02	2.67	0.247	0.294	0.035	0.001	0.001	0.001	0.001	0.042	0.058	0.005	0.008	0.006	0.006	0.069	0.081	0.024	0.026	0.001	0.001	1	5	0.87	0.85

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													0.3	0.02				1.90	1.90	0.055	0.001	0.001	0.003	0.003	0.008	0.008	0.011	0.011							0.024 (III) / 0.013(V)	0.024 (III) / 0.013(V)				
14/11/2012	CC7	91	15	11	29	5	3	14	2.0	0.1	0.02	0.1	0.1	0.02		0.37	0.95	0.126	0.116	0.01	0.004		0.001		0.007		0.001		0.003		0.041		0.032		0.001		2		1.35	1.16
23/1/2013	CC7	77	22	8	7	7	4	15	2.0	0.1	0.06	0.3	0.4	0.01	6.42	0.48	1.12	0.203	0.202	0.01	0.001		0.001		0.008		0.001		0.003		0.039		0.036		0.001		3		1.37	1.38
7/3/2013	CC7	122	6	8	29	3	3	16	1.0	0.1	0.02	0.2	0.2	0.01	5.26	0.41	0.95	0.196	0.204	0.04	0.001	0.001	0.001	0.001	0.015	0.017	0.004	0.003	0.003	0.003	0.033	0.032	0.024		0.001	0.001	2		1.1	1.09
21/3/2013	CC7	54	9	11	24	4	3	13	1.0	0.1	0.04	0.2	0.2	0.01	5.7	0.31	0.88	0.213	0.203	0.03	0.001	0.001	0.001	0.001	0.011	0.015	0.002	0.003	0.003	0.003	0.041	0.042	0.027	0.028	0.001	0.001	1		1.09	1.01
1/05/2013	CC7	56	9	10	31	4	3	12	1.0	0.1	0.09	0.1	0.2	0.19	6.19	0.22	0.72	0.156	0.183	0.02	0.001	0.001	0.001	0.001	0.009	0.011	0.002	0.002	0.003	0.003	0.030	0.041	0.025	0.030	0.001	0.001	1		1.26	0.97
4/06/2013	CC7	82	8	9	25	4	3	16	1.0	0.1	1.19	0.5	1.7	0.01	5.95	0.28	0.51	0.13	0.144	0.04	0.001	0.001	0.001	0.001	0.012	0.017	0.002	0.002	0.003	0.003	0.033	0.036	0.022	0.024	0.001	0.001	2		1.05	1.14
16/7/13	CC7	79	7	8	22	3	3	15	1.0	0.1	0.06	0.1	0.1	0.04	5.66	0.3	0.72	0.152	0.159	0.04	0.001	0.001	0.001	0.001	0.009	0.01	0.003	0.003	0.003	0.003	0.035	0.038	0.026	0.027	0.001	0.001	2	5	0.93	1.05
30/8/13	CC7	65	10	10	23	4	3	15	1.0	0.1	0.04	0.2	0.2	0.02	8.18	0.09	0.37	0.067	0.065	<0.01	0.001	0.001	0.001	0.001	0.005	0.007	0.001	0.001	0.004	0.004	0.037	0.039	0.03	0.026	0.001	0.001	2	5	1.06	1.1
25/9/13	CC7	62	7	9	22	3	3	14	1.0	0.1	0.06	0.1	0.2	0.03	5.82	0.11	0.32	0.106	0.11	0.03	0.001	0.001	0.001	0.001	0.015	0.012	0.001	0.002	0.003	0.003	0.034	0.035	0.034	0.024	0.001	0.001	2	5	0.95	1.01
29/11/13	CC7	69	7	10	21	3	3	14	1.0	0.1	0.06	0.1	0.2	0.01	5.86	0.13	0.48	0.106	0.11	0.03	0.001	0.002	0.001	0.001	0.015	0.018	0.002	0.002	0.003	0.003	0.033	0.034	0.023	0.023	0.001	0.001	2	5	0.94	1.01
	ST Dev	20	5	1	7	1	0	1	0.4	0.0	0.36	0.1	0.5	0.06	0.84	0.13	0.27	0.048	0.049	0.012	0.001	0.000	0.000	0.000	0.004	0.004	0.001	0.001	0.000	0.000	0.004	0.003	0.005	0.003	0.000	0.000	1	0	0.16	0.12
	Max	122	22	11	31	7	4	16	2.0	0.1	1.19	0.5	1.7	0.19	8.18	0.48	1.12	0.213	0.204	0.040	0.004	0.002	0.001	0.001	0.015	0.018	0.004	0.003	0.004	0.004	0.041	0.042	0.036	0.030	0.001	0.001	3	5	1.37	1.38
	Min	54	6	8	7	3	3	12	1.0	0.1	0.02	0.1	0.1	0.01	5.26	0.09	0.32	0.067	0.065	0.010	0.001	0.001	0.001	0.001	0.005	0.007	0.001	0.001	0.003	0.003	0.030	0.032	0.022	0.023	0.001	0.001	1	5	0.93	0.97
	Median	73	9	10	24	4	3	15	1.0	0.1	0.06	0.2	0.2	0.02	5.86	0.29	0.72	0.141	0.152	0.030	0.001	0.001	0.001	0.001	0.010	0.014	0.002	0.002	0.003	0.003	0.035	0.037	0.027	0.026	0.001	0.001	2	5	1.08	1.07

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													0.3	0.02				1.90	1.90	0.055	0.001		0.003		0.008		0.011								0.024 (III) / 0.013(V)					
14/11/2012	CC8	92	16	8	30	5	3	14	1.0	0.1	0.01	0.1	0.1	0.02		0.38	2.18	0.265	0.278	0.02	0.001		0.001		0.005		0.001		0.005		0.068		0.036		0.001		2		1.33	1.13
23/1/2013	CC8	71	25	3	6	6	4	16	1.0	0.1	0.06	0.3	0.4	0.01	6.54	0.44	2.94	0.528	0.576	0.02	0.001		0.001		0.005		0.002		0.005		0.067		0.039		0.001		3		1.35	1.35
7/3/2013	CC8	94	8	8	27	3	3	16	1.0	0.1	0.04	0.1	0.1	0.01	5.52	0.57	1.03	0.22	0.231	0.08	0.001	0.001	0.001	0.001	0.023	0.018	0.002	0.002	0.004	0.004	0.041	0.044	0.031		0.001	0.001	2		1.09	1.09
21/3/2013	CC8	58	15	9	21	4	3	14	1.0	0.1	0.03	0.1	0.1	0.01	6.08	0.61	1.21	0.21	0.216	0.02	0.001	0.001	0.001	0.001	0.014	0.012	0.003	0.003	0.004	0.004	0.052	0.056	0.030	0.032	0.001	0.001	2		1.08	1.06
1/05/2013	CC8	34	11	10	30	4	3	13	1.0	0.1	0.03	0.4	0.4	0.01	6.43	0.75	1.03	0.196	0.186	0.02	0.001	0.001	0.001	0.001	0.01	0.011	0.002	0.002	0.004	0.004	0.044	0.049	0.029	0.028	0.001	0.001	1		1.27	1.01
4/06/2013	CC8	76	10	8	24	4	3	15	1.0	0.1	2.84	0.6	3.4	0.04	6.14	0.57	0.83	0.16	0.157	0.02	0.001	0.001	0.001	0.001	0.014	0.017	0.002	0.002	0.004	0.004	0.044	0.047	0.027	0.028	0.001	0.001	2		1.04	1.1
16/7/13	CC8	79	10	8	20	3	3	15	1.0	0.1	0.04	0.2	0.2	0.01	6.11	0.48	0.88	0.171	0.164	0.03	0.001	0.001	0.001	0.001	0.011	0.015	0.002	0.003	0.004	0.004	0.049	0.052	0.030	0.030	0.001	0.001	2	5	0.93	1.05
30/8/13	CC8	63	12	10	23	4	3	14	1.0	0.1	0.02	0.2	0.2	0.01	8.37	0.32	0.99	0.145	0.153	0.01	0.001	0.001	0.001	0.001	0.005	0.007	0.001	0.001	0.004	0.004	0.055	0.059	0.03	0.032	0.001	0.001	2	5	1.1	1.06
25/9/13	CC8	68	12	10	22	4	3	15	1.0	0.1	0.13	0.1	0.2	0.02	6.63	0.35	0.62	0.128	0.133	0.02	0.001	0.001	0.001	0.001	0.011	0.011	0.001	0.002	0.004	0.004	0.049	0.051	0.049	0.03	0.001	0.001	1	5	1.07	1.1
29/11/13	CC8	70	14	11	19	4	3	16	1.0	0.1	0.04	0.1	0.1	0.01	6.57	0.37	0.91	0.14	0.139	0.02	0.001	0.002	0.001	0.001	0.014	0.015	0.002	0.003	0.004	0.004	0.052	0.05	0.03	0.03	0.001	0.001	2	5	1.04	1.14
	ST Dev	17	5	2	7	1	0	1	0.0	0.0	0.88	0.2	1.0	0.01	0.79	0.14	0.72	0.12	0.132	0.020	0.000	0.000	0.000	0.000	0.006	0.004	0.001	0.001	0.000	0.000	0.009	0.005	0.007	0.002	0.000	0.000	1	0	0.14	0.09
	Max	94	25	11	30	6	4	16	1.0	0.1	2.84	0.6	3.4	0.04	8.37	0.75	2.94	0.53	0.576	0.080	0.001	0.002	0.001	0.001	0.023	0.018	0.003	0.003	0.005	0.004	0.068	0.059	0.049	0.032	0.001	0.001	3	5	1.35	1.35
	Min	34	8	3	6	3	3	13	1.0	0.1	0.01	0.1	0.1	0.01	5.52	0.32	0.62	0.13	0.133	0.010	0.001	0.001	0.001	0.001	0.005	0.007	0.001	0.001	0.004	0.004	0.041	0.044	0.027	0.028	0.001	0.001	1	5	0.93	1.01
	Median	71	12	9	23	4	3	15	1.0	0.1	0.04	0.2	0.2	0.01	6.43	0.46	1.01	0.18	0.175	0.020	0.001	0.001	0.001	0.001	0.011	0.014	0.002	0.002	0.004	0.004	0.051	0.051	0.030	0.030	0.001	0.001	2	5	1.09	1.10

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													0.3	0.02				1.90	1.90	0.055	0.001	0.001	0.003	0.003	0.008	0.008	0.011	0.011							0.024 (III) / 0.013(V)	0.024 (III) / 0.013(V)				
5/11/2008	CC9	52	14	5	20	2	3	13	0.8	0.1			0.6	0.08		0.82	1.50	0.01	0.04	0.08	0.001		0.001		0.001		0.010		0.003		0.020		0.020		0.010		6			
9/1/2009	CC9	68	25	9	22	7	4	12	0.1	0.1			0.1	0.06		0.28	1.80	0.01	0.02	0.01	0.001		0.001		0.003		0.010		0.005		0.060		0.110		0.010		2			
17/3/2009	CC9	80	28	11	25	6	4	16	1.0	0.1			0.1	0.01		0.21	1.00	0.01	0.02	0.03	0.001		0.001		0.001		0.010		0.003		0.050		0.040		0.010		2			
14/5/2009	CC9	81	21	12	27	6	5	17	0.7	0.1			0.1	0.01		0.03	0.49	0.01	0.02	0.01	0.001		0.001		0.001		0.010		0.009		0.030		0.030		0.010		2			
23/7/2009	CC9	78	18	11	29	5	5	17	0.9	0.1			0.1	0.04		0.09	0.74	0.01	0.01	0.02	0.001		0.001		0.003		0.010		0.007		0.050		0.030		0.010		1			
2/10/2010	CC9	69	22	13	23	5	4	15	0.9	0.1			0.1	0.01		0.12	0.42	0.01	0.01	0.01	0.001		0.001		0.001		0.010		0.008		0.056		0.040		0.010		2			
2/12/2009	CC9	71	20	11	23	6	4	14	1.0	0.1			0.1	0.01		0.34	1.70	0.01	0.11	0.02	0.001		0.001		0.003		0.010		0.002		0.051		0.039		0.010		2			
18/2/2010	CC9	72	15	8	29	4	3	16	0.6	0.1			0.4	0.01		0.24	1.90	0.11	0.30	0.03	0.001		0.001		0.009		0.010		0.001		0.043		0.028		0.010		3			
5/5/2010	CC9	64	17	7	26	3	3	17	0.7	0.1			0.1	0.01		0.03	1.40	0.01	0.03	0.02	0.001		0.001		0.003		0.010		0.002		0.042		0.033		0.010		1			
8/7/2010	CC9	70	19	11	25	5	4	15	0.7	0.1			0.1	0.01		0.05	0.83	0.01	0.02	0.01	0.001		0.001		0.001		0.001		0.007		0.041		0.033		0.010		1			
7/9/2010	CC9	90	8	11	25	4	4	13	1.0	0.1			0.1	0.02		0.34	0.70	0.13	0.14	0.02	0.001		0.001		0.008		0.001		0.004		0.062		0.036		0.001		1			
11/11/2010	CC9	62	1	13	23	4	3	14	1.0	0.1			1.2	0.11	4.81	0.23	0.66	0.002	0.148	0.03	0.004		0.014		0.029		0.001		0.144		0.001		0.051		0.001		1			
31/1/2011	CC9	96	26	8	32	4	3	14	1.0	0.1			0.4	0.11	6.02	0.3	1.04	0.125	0.133	0.01	0.001		0.001		0.005		0.001		0.005		0.056		0.035		0.001		2			
8/4/2011	CC9	53	8	8	24	4	3	13	1.0	0.1			0.3	0.02	8.04	0.4	1	0.222	0.239	0.03	0.001		0.001		0.009		0.002		0.003		0.048		0.025		0.001		2			
23/6/2011	CC9	100	9	8	25	4	3	18	1.0	0.1			0.1	0.02	5.52	0.83	0.92	0.19	0.208	0.07	0.002		0.001		0.01		0.002		0.003		0.052		0.028		0.001		1			
30/8/2011	CC9	66	14	9	26	4	3	15	1.0	0.1			0.1	0.01	6.49	0.36	0.37	0.163	0.158	0.02	0.001		0.001		0.008		0.002		0.003		0.053		0.029		0.001		1			
2/12/2011	CC9	91	8	10	20	4	3	15	1.0	0.1			0.1	0.01	5.75	0.29	0.62	0.167	0.171	0.04	0.001		0.001		0.018		0.002		0.004		0.041		0.025		0.001		2			
5/4/2012	CC9	51	2	3	16	1	1	10	1.0	0.1			1.2	0.07	2.13	0.69	2.45	0.067	0.417	0.11	0.001		0.001		0.008		0.001		0.001		0.009		0.01		0.001		5			
11/5/2012	CC9	96	9	10	20	4	3	15	1.0	0.1			0.1	0.01	5.64	0.29	1.16	0.192	0.212	0.02	0.001		0.001		0.012		0.002		0.004		0.051		0.028		0.001		1			
26/6/2012	CC9	68	12	8	22	3	3	13	1.0	0.1	0.04	0.2	0.2	0.02	4.8	0.52	1.08	0.196	0.214	0.04	0.001		0.001		0.024		0.002		0.004		0.051		0.028		0.001		1		1.03	0.96
17/7/2012	CC9	55	7	8	24	3	2	12	1.0	0.1	0.03	0.1	0.1	0.01	5.45	0.54	0.98	0.169	0.158	0.03	0.001		0.001		0.006		0.001		0.004		0.047		0.027		0.001		1		0.98	0.84
22/8/2012	CC9	87	13	10	23	4	3	13	1.0	0.1	0.02	0.1	0.1	0.1	5.88	0.47	1.02	0.157	0.157	0.02	0.001		0.001		0.008		0.001		0.004		0.054		0.031		0.001		1		1.12	1.01
24/10/2012	CC9	80	14	9	23	4	3	15	2.0	0.1	0.02	0.3	0.3	0.02	6	0.59	1.8	0.096	0.191	0.01	0.001		0.001		0.005		0.001		0.003		0.055		0.034		0.001		3		1.12	1.15
23/1/2013	CC9	70	24	4	5	5	4	16	2.0	0.1	0.13	0.4	0.5	0.01	5.68	0.69	4.06	0.356	0.356	0.01	0.001		0.001		0.006		0.001		0.004		0.059		0.035		0.001		4		1.32	1.33
7/3/2013	CC9	95	7	8	27	3	3	16	1.0	0.1	3.75	0.9	4.6	0.02	5.41	0.47	1.08	0.212	0.213	0.04	0.001	0.001	0.001	0.001	0.017	0.023	0.002	0.002	0.003	0.003	0.042	0.043	0.029		0.001	0.001	2		1.07	1.09
21/3/2013	CC9	64	12	9	21	4	3	14	1.0	0.1	0.08	0.2	0.3	0.01	5.94	0.4	1.13	0.225	0.22	0.02	0.001	0.001	0.001	0.001	0.01	0.012	0.002	0.003	0.005	0.004	0.058	0.058	0.032	0.033	0.001	0.001	2		1.02	1.06
1/05/2013	CC9	28	11	9	30	4	3	13	1.0	0.1	0.01	0.2	0.2	0.01	6.33	0.37	0.84	0.174	0.174	0.02	0.001	0.001	0.001	0.001	0.009	0.011	0.002	0.002	0.004	0.003	0.045	0.053	0.030	0.030	0.001	0.001	2		1.25	1.01
4/06/2013	CC9	80	9	8	24	3	3	15	1.0	0.1	0.18	0.2	0.4	0.01	5.88	0.39	0.66	0.144	0.14	0.04	0.001	0.001	0.001	0.001	0.01	0.013	0.002	0.001	0.004	0.004	0.045	0.049	0.025	0.028	0.001	0.001	2		1.02	1.05
16/7/13	CC9	77	10	8	20	3	3	13	1.0	0.1	0.03	0.1	0.1	0.01	5.86	0.36	0.74	0.151	0.166	0.03	0.001	0.001	0.001	0.001	0.009	0.011	0.002	0.002	0.004	0.004	0.050	0.053	0.028	0.031	0.001	0.001	2	5	0.93	1.96
30/8/13	CC9	62	12	9	22	4	3	15	1.0	0.1	0.04	0.3	0.3	0.02	7.98	0.24	1.81	0.141	0.149	0.04	0.001	0.001	0.001	0.001	0.005	0.012	0.001	0.002	0.004	0.004	0.058	0.06	0.031	0.032	0.001	0.001	2	9	1.05	1.1
25/9/13	CC9	67	12	10	25	4	3	15	1.0	0.1	0.04	0.1	0.1	0.02	6.37	0.13	0.56	0.117	0.122	0.02	0.001	0.001	0.001	0.001	0.016	0.014	0.001	0.002	0.004	0.004	0.041	0.043	0.041	0.029	0.001	0.001	2	5	1.15	1.1
29/11/13	CC9	61	14	10	16	4	3	16	1.0	0.1	0.29	0.1	0.4	0.01	6.18	0.23	0.83	0.123	0.142	0.04	0.002	0.001	0.001	0.001	0.016	0.014	0.002	0.002	0.004	0.004	0.052	0.053	0.029	0.03	0.001	0.001	2	12	0.94	1.14
	ST Dev	16	7	2	5	1	1	2	0.3	0.0	1.02	0.2	0.8	0.03	1.16	0.21	0.72	0.088	0.099	0.022	0.001	0.000	0.002	0.000	0.007	0.004	0.004	0.001	0.025	0.000	0.014	0.006	0.016	0.002	0.004	0.000	1	3	0.11	0.27
	Max	100	28	13	32	7	5	18	2.0	0.1	3.75	0.9	4.6	0.11	8.04	0.83	4.06	0.356	0.417	0.110	0.004	0.001	0.014	0.001	0.029	0.023	0.010	0.003	0.144	0.004	0.062	0.060	0.110	0.033	0.010	0.001	6	12	1.32	1.96
	Min	28	1	3	5	1	1	10	0.1	0.1	0.01	0.1	0.1	0.01	2.13	0.03	0.37	0.002	0.010	0.010	0.001	0.001	0.001	0.001	0.001	0.011	0.001	0.001	0.001	0.003	0.001	0.043	0.010	0.028	0.001	0.001	1	5	0.93	0.84
	Median	70	13	9	24	4	3	15	1.0	0.1	0.04	0.2	0.1	0.01	5.88	0.34	1.00	0.128	0.153	0.020	0.001	0.001	0.001	0.001	0.008	0.013	0.002	0.002	0.004	0.004	0.050	0.053	0.030	0.030	0.001	0.001	2	7	1.05	1.09

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													0.3	0.02				1.90	1.90	0.055	0.001	0.001	0.003	0.003	0.008	0.008	0.011	0.011							0.024 (III) / 0.013(V)	0.024 (III) / 0.013(V)				
28/8/2008	CD1	52	7	6	21	2	2	12	0.8	0.1			0.3	0.01		0.31	0.42	0.02	0.02	0.05	0.004		0.001		0.009		0.010		0.001		0.010		0.030		0.010		5			
5/11/2008	CD1	46	7	6	19	1	2	12	0.8	0.1			1.1	0.10		0.28	0.46	0.01	0.02	0.03	0.001		0.001		0.001		0.010		0.001		0.010		0.020		0.010		7			
9/1/2009	CD1	44	5	3	20	2	2	11	0.4	0.1			0.8	0.04		0.07	0.79	0.02	0.03	0.03	0.001		0.001		0.007		0.010		0.001		0.090		0.070		0.010		5			
14/5/2009	CD1	60	17	6	21	2	2	17	1.1	0.1			0.4	0.01		0.03	0.40	0.04	0.07	0.01	0.001		0.001		0.009		0.010		0.007		0.020		0.030		0.010		5			
23/7/2009	CD1	78	30	7	25	3	3	21	0.9	0.1			0.1	0.01		0.07	0.20	0.04	0.06	0.03	0.001		0.001		0.020		0.010		0.001		0.020		0.050		0.010		3			
2/10/2010	CD1	55	7	6	23	2	3	14	0.7	0.1			0.3	0.01		0.12	0.22	0.01	0.02	0.01	0.001		0.001		0.002		0.010		0.002		0.005		0.025		0.010		3			
2/12/2009	CD1	63	17	6	24	4	3	14	1.2	0.1			0.3	0.01		0.92	2.50	0.01	0.17	0.01	0.001		0.001		0.002		0.010		0.001		0.041		0.029		0.010		4			
18/2/2010	CD1	61	10	6	26	3	3	14	0.5	0.1			0.1	0.01		0.20	1.40	0.07	0.17	0.02	0.001		0.001		0.007		0.010		0.002		0.026		0.019		0.010		4			
5/5/2010	CD1	65	12	6	27	3	3	15	0.6	0.1			0.2	0.01		0.03	0.57	0.07	0.02	0.02	0.001		0.001		0.004		0.010		0.001		0.020		0.020		0.010		2			
8/7/2010	CD1	54	9	6	22	2	2	14	0.7	0.1			0.1	0.01		0.06	0.20	0.01	0.01	0.02	0.001		0.001		0.015		0.010		0.001		0.040		0.027		0.010		4			
6/9/2010	CD1	86	4	5	21	2	2	13	1.0	0.1			0.4	0.01		0.22	0.64	0.04	0.05	0.03	0.001		0.001		0.005		0.001		0.001		0.020		0.019		0.001		4			
11/11/2010	CD1	70	4	7	24	2	2	12	1.0	0.1			0.8	0.05	0.94	0.18	0.26	0.001	0.055	0.06	0.001		0.079		0.014		0.001		0.057		0.005		0.014		0.001		7			
31/1/2011	CD1	44	12	5	26	1	2	13	1.0	0.1			0.3	0.02	1.08	0.13	0.37	0.027	0.039	0.02	0.001		0.001		0.007		0.002		0.001		0.009		0.014		0.001		5			
8/4/2011	CD1	58	1.0	10	21	2	2	11	1.0	0.1			3.7	0.21	1.97	0.29	0.8	0.092	0.105	0.04	0.001		0.001		0.007		0.001		0.001		0.01		0.012		0.001		6			
23/6/2011	CD1	99	3	4	22	2	2	15	1.0	0.1			0.3	0.06	2.6	0.17	0.51	0.033	0.05	0.08	0.001		0.001		0.005		0.001		0.001		0.013		0.012		0.001		4			
30/8/2011	CD1	35	2	4	16	1	2	12	1.0	0.1			0.1	0.01	1.54	0.21	0.22	0.038	0.039	0.08	0.001		0.001		0.005		0.001		0.001		0.01		0.011		0.001		4			
2/12/2011	CD1	66	2	5	20	1	2	12	1.0	0.1			1.2	0.05	1.37	0.3	0.67	0.055	0.066	0.07	0.002		0.001		0.022		0.001		0.001		0.009		0.011		0.001		5			
5/4/2012	CD1	42	2	3	16	1	1	9	1.0	0.1			3.2	0.04	1.98	0.33	0.7	0.058	0.074	0.12	0.002		0.001		0.023		0.001		0.001		0.008		0.01		0.001		5			
11/5/2012	CD1		8	4	17	1	2	11	1.0	0.1			0.9	0.54	1.98	0.36	0.67	0.068	0.077	0.14	0.001		0.001		0.006		0.001		0.001		0.008		0.01		0.001		5			
26/6/2012	CD1	36	6	4	16	1	1	9	1.0	0.1	0.02	0.2	0.2	0.02	1.86	0.42	0.6	0.055	0.057	0.1	0.001		0.001		0.006		0.001		0.001		0.009		0.009		0.001		5		0.65	0.52
17/7/2012	CD1	37	5	3	17	1	1	8	1.0	0.1	0.14	0.2	0.3	0.05	1.9	0.35	0.75	0.033	0.026	0.09	0.001		0.001		0.005		0.001		0.001		0.009		0.011		0.001		4		0.64	0.48
22/8/2012	CD1	62	3	4	18	1	2	9	1.0	0.1	0.01	0.6	0.6	0.6	1.62	0.39	1.34	0.053	0.074	0.07	0.001		0.001		0.005		0.001		0.001		0.01		0.011		0.001		3		0.65	0.61
24/10/2012	CD1	62	4	5	19	1	1	12	1.0	0.1	0.02	0.6	0.6	0.05	1.28	0.39	1.28	0.108	0.108	0.04	0.001		0.001		0.005		0.001		0.001		0.011		0.014		0.001		4		0.72	0.65
14/11/2012	CD1	64	3	4	19	1	2	10	1.0	0.1	0.29	0.4	0.7	0.01		0.6	1.4	0.1	0.105	0.06	0.001		0.001		0.005		0.001		0.001		0.008		0.013		0.001		4		0.68	0.65
23/1/2013	CD1	50	10	3	3	3	2	13	4.0	0.1	0.03	1	1	0.01	0.1	0.66	3.51	0.314	0.357	0.03	0.001		0.001		0.006		0.001		0.001		0.012		0.022		0.001		5		1	0.98
7/3/2013	CD1	105	2	3	22	1	2	12	1.0	0.1	0.01	0.5	0.5	0.01	1.76	0.25	0.56	0.065	0.069	0.12	0.002	0.002	0.001	0.001	0.01	0.012	0.001	0.001	0.001	0.001	0.01	0.010	0.011		0.001	0.001	6		0.72	0.76
21/3/2013	CD1	41	3	4	17	1	1	10	1.0	0.1	0.06	0.5	0.6	0.01	1.47	0.31	0.63	0.07	0.081	0.08	0.001	0.001	0.001	0.001	0.015	0.016	0.002	0.001	0.001	0.001	0.010	0.02	0.012	0.013	0.001	0.001	5		0.62	0.59
1/05/2013	CD1		3							0.1	0.01	0.4	0.4	0.01		0.26	0.48	0.038	0.042	0.04	0.001	0.001	0.001	0.001	0.006	0.006	0.001	0.001	0.001	0.001	0.007	0.008	0.012	0.011	0.001	0.001	5			
4/06/2013	CD1	59	2	5	17	2	2	12	1.0	0.1	0.42	0.5	0.9	0.01	1.99	0.19	0.49	0.047	0.051	0.04	0.001	0.004	0.001	0.001	0.011	0.028	0.001	0.001	0.001	0.001	0.012	0.014	0.014	0.014	0.001	0.001	4		0.62	0.79
16/7/13	CD1	40	2	4	13	1	1	9	1.0	0.1	0.02	0.4	0.4	0.08	1.07	0.3	0.25	0.022	0.022	0.2	0.001	0.001	0.001	0.001	0.006	0.005	0.001	0.001	0.001	0.001	0.008	0.008	0.010	0.010	0.001	0.001	7	5	0.49	0.47
30/8/13	CD1	44	2	4	15	1	1	11	1.0	0.1	0.17	0.6	0.8	0.01	1.95	0.22	0.52	0.016	0.019	0.1	0.001	0.001	0.001	0.002	0.008	0.014	0.001	0.001	0.001	0.001	0.011	0.012	0.011	0.011	0.001	0.001	6	5	0.55	0.64
25/9/13	CD1	43	2	4	20	1	1	9	1.0	0.1	0.03	0.3	0.3	0.01	1.4	0.22	0.7	0.023	0.032	0.12	0.001	0.002	0.001	0.001	0.005	0.01	0.001	0.001	0.001	0.001	0.009	0.01	0.009	0.01	0.001	0.001	6	5	0.69	0.52
29/11/13	CD1	41	2	5	15	1	1	10	1.0	0.1	0.03	0.2	0.2	0.01	1.52	0.23	0.49	0.039	0.048	0.07	0.002	0.003	0.001	0.001	0.008	0.008	0.001	0.002	0.001	0.001	0.009	0.01	0.01	0.011	0.001	0.001	2	5	0.57	0.57
	ST Dev	17	6	2	5	1	1	3	0.6	0.0	0.13	0.2	0.8	0.14	0.53	0.18	0.68	0.054	0.065	0.044	0.001	0.001	0.014	0.000	0.005	0.007	0.004	0.000	0.010	0.000	0.016	0.004	0.013	0.002	0.004	0.000	1	0	0.12	0.14
	Max	105	30	10	27	4	3	21	4.0	0.1	0.42	1.0	3.7	0.60	2.60	0.92	3.51	0.314	0.357	0.200	0.004	0.004	0.079	0.002	0.023	0.028	0.010	0.002	0.057	0.001	0.090	0.020	0.070	0.014	0.010	0.001	7	5	1.00	0.98
	Min	35	1	3	3	1	1	8	0.4	0.1	0.01	0.2	0.1	0.01	0.10	0.03	0.20	0.001	0.010	0.010	0.001	0.001	0.001	0.001	0.001	0.005	0.001	0.001	0.001	0.001	0.005	0.008	0.009	0.010	0.001	0.001	2	5	0.49	0.47
	Median	55	4	5	20	1	2	12	1.0	0.1	0.03	0.5	0.4	0.01	1.58	0.25	0.57	0.039	0.051	0.050	0.001	0.002	0.001	0.001	0.006	0.011	0.001	0.001	0.001	0.001	0.010	0.010	0.013	0.011	0.001	0.001	5	5	0.65	0.61

APPENDIX B

CATARACT RIVER LABORATORY ANALYSES

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe	Fe T	Mn	Mn T	Al	Cu	Pb	Zn	Ni	Li	Ba	Sr	As	DOC	TA	TC
ANZECC													**0.25**	**0.02**				**1.9**	**1.9**	**0.055**	**0.001**	**0.003**	**0.008**	**0.011**				**0.024 (III) / 0.013(V)**			
12/04/12	CR1	42	1	2	12	1	1	7	1	0.1	0.02	0.20	0.2	0.06	3.39	1.7	1.4	0.039	0.036	0.540	0.001	0.001	0.011	0.002	0.001	0.003	0.004	0.002	6	0.38	0.30
14/05/12	CR1	40	3	4	14	1	1	9	1	0.1	0.02	1.20	1.2	1.32	2.96	1.82	1.55	0.055	0.045	0.460	0.001	0.001	0.010	0.002	0.001	0.003	0.005	0.002	5	0.54	0.47
26/7/12	CR1	54	5	6	14	1	1	8	1	0.1	0.02	0.60	0.6	0.05	3.11	0.99	1.71	0.038	0.042	0.360	0.001	0.001	0.011	0.002	0.001	0.003	0.005	0.001	4	0.62	0.43
21/2/13	CR1	82	1	17	21	1	2	11	1	0.1	0.05	0.10	0.2	0.01	3.33	0.19	0.2	0.061	0.059	0.730	0.003	0.002	0.042	0.004	0.001	0.010	0.018	0.001	7	0.95	0.78
9/04/13	CR1	43	1	9	19	1	2	11	1	0.1	0.01	0.10	0.1	0.01	3.62	0.38	0.35	0.047	0.044	0.560	0.002	0.002	0.033	0.003	0.002	0.006	0.024	0.001	7	0.72	0.69
5/06/13	CR1	66	1	6	15	1	1	10	1	0.1	0.01	0.10	0.10	0.2	3.1	0.24	0.24	0.03	0.029	0.570	0.001	0.001	0.021	0.002	0.001	0.004	0.010	0.001	7	0.55	0.52
1/08/13	CR1	54	1	6	12	1	1	9	1	0.1			0.1	0.01		0.46	0.45	0.038	0.041	0.410	0.001	0.001	0.016	0.002	0.001	0.004	0.008	0.001	5	0.46	0.39
9/12/13	CR1	49	1	7	17	1	1	10	1	0.1	0.01	0.20	0.2	0.01	3.37	0.4	0.55	0.065	0.066	0.430	0.002	0.001	0.023	0.004	0.001	0.005	0.012	0.001	7	0.63	0.52
	ST Dev	14	1	4	3	0	0	1	0	0.0	0.01	0.41	0.39	0.45	0.22	0.66	0.63	0.013	0.012	0.118	0.001	0.000	0.012	0.001	0.000	0.002	0.007	0.000	1	0.17	0.16
	Max	82	5	17	21	1	2	11	1	0.1	0.05	1.20	1.20	1.32	3.62	1.82	1.71	0.065	0.066	0.730	0.003	0.002	0.042	0.004	0.002	0.010	0.024	0.002	7	0.95	0.78
	Min	40	1	2	12	1	1	7	1	0.1	0.01	0.10	0.10	0.01	2.96	0.19	0.20	0.030	0.029	0.360	0.001	0.001	0.010	0.002	0.001	0.003	0.004	0.001	4	0.38	0.30
	Median	52	1	6	15	1	1	10	1	0.1	0.02	0.20	0.20	0.03	3.33	0.43	0.50	0.043	0.043	0.500	0.001	0.001	0.019	0.002	0.001	0.004	0.009	0.001	7	0.59	0.50
13/04/12	CR2	85	10	6	23	4	3	15	1	0.1	0.03	0.70	0.7	0.04	5.77	1	0.51	0.116	0.115	0.070	0.001	0.001	0.008	0.001	0.002	0.042	0.028	0.001	2	0.97	1.10
14/05/12	CR2	74	8	6	21	3	2	14	1	0.1	0.08	0.60	0.7	0.52	4.86	1.1	0.47	0.133	0.114	0.070	0.001	0.001	0.009	0.001	0.002	0.046	0.030	0.001	2	0.88	0.92
26/7/12	CR2	56	9	6	20	4	2	12	1	0.1	0.03	0.10	0.1	0.01	4.88	0.78	0.8	0.094	0.089	0.050	0.001	0.001	0.005	0.001	0.002	0.047	0.026	0.001	2	0.87	0.89
25/9/12	CR2	72	13	6	25	4	3	13	1	0.1	0.06	0.20	0.3	0.02	5.04	0.28	1..07	0.082	0.098	0.020	0.001	0.001	0.005	0.001	0.003	0.056	0.037	0.001	<1	0.96	1.01
29/11/12	CR2	84	12	5	24	5	3	12	4	0.1	0.04	0.20	0.2	0.18	4.45	0.75	1.36	0.068	0.069	0.050	0.001	0.001	0.005	0.001	0.002	0.043	0.028	0.001	2	1.02	1.12
21/2/13	CR2	71	8	8	22	3	2	11	1	0.1	0.06	0.10	0.10	0.01	4.44	0.14	0.86	0.013	0.068	0.030	0.026	0.024	0.028	0.020	0.001	0.012	0.012	0.003	4	0.95	0.84
9/04/13	CR2	77	11	6	22	4	3	14	1	0.1	0.02	0.10	0.1	0.01	5.64	0.38	0.78	0.098	0.089	0.050	0.001	0.001	0.009	0.001	0.003	0.050	0.038	0.001	3	0.97	1.06
5/06/13	CR2	67	8	6	22	3	2	14	1	0.1	0.04	0.10	0.1	0.05	5.08	0.3	0.54	0.078	0.073	0.060	0.001	0.001	0.005	0.001	0.002	0.036	0.028	0.001	2	0.91	0.92
1/08/13	CR2	73	8	6	24	3	2	13	1	0.1			0.4	0.01		0.33	0.67	0.075	0.078	0.060	0.001	0.001	0.006	0.001	0.002	0.047	0.028	0.001	2	0.96	0.88
9/12/13	CR2	68	9	6	25	3	2	13	1	0.1	0.04	0.20	0.2	0.01	5.24	0.21	0.92	0.08	0.089	0.040	0.001	0.001	0.006	0.001	0.003	0.050	0.036	0.001	4	1.01	0.88
	ST Dev	8	2	1	2	1	1	1	1	0.0	0.02	0.23	0.24	0.16	0.46	0.35	0.27	0.032	0.017	0.016	0.008	0.007	0.007	0.006	0.001	0.012	0.007	0.001	1	0.05	0.10
	Max	85	13	8	25	5	3	15	4	0.1	0.08	0.70	0.70	0.52	5.77	1.10	1.36	0.133	0.115	0.070	0.026	0.024	0.028	0.020	0.003	0.056	0.038	0.003	4	1.02	1.12
	Min	56	8	5	20	3	2	11	1	0.1	0.02	0.10	0.10	0.01	4.44	0.14	0.47	0.013	0.068	0.020	0.001	0.001	0.005	0.001	0.001	0.012	0.012	0.001	2	0.87	0.84
	Median	73	9	6	23	4	2	13	1	0.1	0.04	0.20	0.20	0.02	5.04	0.36	0.78	0.081	0.089	0.050	0.001	0.001	0.006	0.001	0.002	0.047	0.028	0.001	2	0.96	0.92

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe	Fe T	Mn	Mn T	Al	Cu	Pb	Zn	Ni	Li	Ba	Sr	As	DOC	TA	TC
ANZECC													**0.25**	**0.02**				**1.9**	**1.9**	**0.055**	**0.001**	**0.003**	**0.008**	**0.011**				**0.024 (III) / 0.013(V)**			
13/04/12	CR3	79	9	5	20	3	2	13	1	0.1	0.04	0.60	0.6	0.02	5.61	1.11	0.36	0.151	0.143	0.060	0.001	0.001	0.008	0.002	0.002	0.046	0.032	0.001	1	0.85	0.88
8/05/12	CR3	99	8	6	22	4	3	14	1	0.1	0.04	0.20	0.2	0.03	4.95	0.93	0.26	0.115	0.096	0.060	0.001	0.001	0.128	0.001	0.002	0.036	0.026	0.001	1	0.91	1.06
26/7/12	CR3	53	9	6	20	3	2	12	1	0.1	0.04	0.20	0.2	0.02	4.85	0.34	0.78	0.077	0.083	0.050	0.001	0.001	0.009	0.001	0.002	0.040	0.023	0.001	2	0.95	0.84
25/9/12	CR3	97	3	16	23	4	3	12	1	0.1	1.64	1.10	2.7	0.1	5.05	0.31	1.09	0.083	0.101	0.020	0.001	0.001	0.022	0.001	0.002	0.050	0.033	0.001	1	1.04	0.97
29/11/12	CR3	77	14	5	22	4	2	11	1	0.1	0.06	0.30	0.4	0.03	4.37	0.52	1.51	0.051	0.058	0.040	0.001	0.001	0.011	0.001	0.002	0.040	0.028	0.001	2	1.00	0.87
21/2/13	CR3	75	10	8	23	3	2	12	1	0.1	0.07	0.10	0.10	0.01	4.5	0.28	0.97	0.06	0.075	0.100	0.002	0.001	0.013	0.001	0.002	0.032	0.027	0.001	4	1.02	0.86
9/04/13	CR3	95	10	9	21	4	3	14	1	0.1	0.33	0.20	0.5	0.01	5.44	0.36	0.79	0.094	0.086	0.040	0.003	0.001	0.013	0.001	0.002	0.044	0.035	0.001	3	0.92	1.06
5/06/13	CR3	70	1	11	22	3	3	15	1	0.1	0.7	0.40	1.1	0.63	5.06	0.32	0.54	0.08	0.076	0.070	0.001	0.001	0.011	0.001	0.002	0.036	0.026	0.001	2	0.85	1.05
1/08/13	CR3	72	8	6	24	3	2	13	1	0.1			9.7	0.1		0.3	0.69	0.074	0.083	0.050	0.001	0.001	0.008	0.001	0.002	0.040	0.026	0.001	3	0.96	0.88
9/12/13	CR3	66	1	14	25	3	2	14	1	0.1	1.23	0.30	1.5	0.01	5.22	0.26	0.98	0.102	0.089	0.060	0.001	0.001	0.010	0.001	0.003	0.048	0.010	0.001	4	1.00	0.95

ST Dev	15	4	4	2	1	1	1	0	0.0	0.60	0.31	2.92	0.19	0.40	0.30	0.37	0.029	0.022	0.021	0.001	0.000	0.037	0.000	0.000	0.006	0.007	0.000	1	0.07	0.09
Max	99	14	16	25	4	3	15	1	0.1	1.64	1.10	9.70	0.63	5.61	1.11	1.51	0.151	0.143	0.100	0.003	0.001	0.128	0.002	0.003	0.050	0.035	0.001	4	1.04	1.06
Min	53	1	5	20	3	2	11	1	0.1	0.04	0.10	0.10	0.01	4.37	0.26	0.26	0.051	0.058	0.020	0.001	0.001	0.008	0.001	0.002	0.032	0.010	0.001	1	0.85	0.84
Median	76	9	7	22	3	2	13	1	0.1	0.07	0.30	0.55	0.03	5.05	0.33	0.79	0.082	0.085	0.055	0.001	0.001	0.011	0.001	0.002	0.040	0.027	0.001	2	0.96	0.92

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe	Fe T	Mn	Mn T	Al	Cu	Pb	Zn	Ni	Li	Ba	Sr	As	DOC	TA	TC
ANZECC													**0.25**	**0.02**				**1.9**	**1.9**	**0.055**	**0.001**	**0.003**	**0.008**	**0.011**				**0.024 (III) / 0.013(V)**			
17/04/12	CR4	49	8	4	17	1	1	10	1	0.1	0.02	0.40	0.4	0.07	2.04	1.78	0.72	0.107	0.086	0.100	0.002	0.001	0.388	0.001	0.001	0.010	0.012	0.001	6		

Appendix F

RUSSELL VALE COLLIERY WONGA EAST UNDERGROUND EXPANSION PROJECT SURFACE WATER MODELLING

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RUSSELL VALE COLLIERY WONGA EAST UNDERGROUND EXPANSION PROJECT SURFACE WATER MODELLING

Wollongong Coal Limited
May 2014

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REPORT TITLE: Russell Vale Colliery Wonga East Underground Expansion Project Surface Water Modelling
CLIENT: Wollongong Coal Limited
REPORT NUMBER: 0637-07-A4

Revision Number	Report Date	Report Author	Reviewer
A2	31 March 2014	CW	MB
A4	30 May 2014	CW	MB

For and on behalf of
WRM Water & Environment Pty Ltd

Michael Batchelor
Director

EXECUTIVE SUMMARY

This report describes the geometry of the catchments and streams potentially impacted by mining subsidence induced by the proposed underground expansion of the Wonga East workings of Russell Vale Colliery longwall mining project. It also outlines hydrological modelling undertaken to determine the relative contribution of the potentially affected catchments to runoff in the receiving waters.

The catchments of Cataract Creek, Bellambi Creek and Cataract River will potentially be affected by the Wonga East workings. The proposed Wonga East workings do not underlie the Cataract Creek, Bellambi Creek or Cataract River channels. However, the western end of the predicted subsidence associated with Panel 6 and Panel 7 approaches close to the eastern bank of the high water extent of the Lake Cataract backwater. The mine panels are to be laid out in accordance with the Sydney Catchment Authority (SCA) requirements for clearance from the reservoir.

Catchment Physical Characteristics

Catchment geometry and stream longitudinal profiles were extracted from an airborne laser scanning survey acquired over the Study Area on 20th October 2009, and are described below:

1. Cataract Creek is approximately 5.5km long from its headwaters to the upstream reaches of Lake Cataract. It is a 4th order stream for most of its length. The proposed Wonga East workings are located between Chainage 2,500 m and Chainage 4,500 m. Approximately 2.5 km of the stream reach is located upstream, 2.0 km within and 0.9 km downstream of the 20 mm subsidence zone. Channel invert elevations fall from approximately 340 m AHD to 285m AHD. Of the total Cataract Creek catchment area of 5.2 km^2, 1.9 km^2 is located upstream of the potential subsidence zone, and 3.2 km^2 has been identified as potentially subsided by the proposed workings.

2. Cataract River is approximately 6.7km long from its headwaters to the upstream reaches of the Lake Cataract storage. The proposed Wonga East workings and its associated 20mm subsidence zone do not underlie the Cataract River. The predicted 20mm subsidence zone runs adjacent to the Lake Cataract backwater for a distance of about 350m. It is a 3rd order stream upstream of the Link Road crossing and 4th order from the confluence just downstream of the crossing to the Lake Cataract backwater. Channel invert elevations fall from approximately 430m AHD to 285m AHD. Of the total Cataract River catchment area of 11.6km^2, 0.5km^2 has been identified as potentially subsided by the proposed workings with 11.1km^2 outside of the 20mm subsidence zone.

3. Of the total Bellambi Creek catchment area of 9.3 km^2, 8.9 km^2 is located downstream of the potential subsidence zone, and 0.4 km^2 has been identified as potentially subsided by the proposed workings.

4. Of the total Lake Cataract catchment area of 127.8 km^2, 4.4km^2 is identified as potentially subsided.

Swamps

Potentially affected swamps adjacent to the project make up around 0.9% of the Lake Cataract catchment, and 1.1% of the Cataract Creek catchment. Approximately 64% of the potentially affected swamps in the project area are within the proposed subsidence zone.

Catchment Rainfall

Rainfall in the study area is highly variable, with mean annual rainfall ranging from less than 1,000mm/a in the west of the Study Area to over 1,800mm/a on the eastern escarpment. Historical records show significant variations in rainfall from north to south during specific events.

Streamflow

While water levels are monitored in pools along Cataract Creek and Cataract River, insufficient data is available to derive long-term streamflow records for the potentially affected streams. However, streamflow data is available from gauges on headwater streams flowing into Lake Cataract: Bellambi Creek at South Bulli No. 1 (<5 years) and Loddon River at Bulli Appin Road (<19 years). The streamflow records from these two gauges show similar responses to rainfall– with persistent baseflow being a notable feature, but contributing a relatively small proportion of total runoff.

The SCA operated a streamflow gauge in the Cataract River at Jordon's Crossing over the period from August 1986 to July 2013. The streamflow at this location is heavily influenced by releases from water storages upstream of the gauge. Therefore, the data from this gauge is mostly unsuitable for the analysis of natural streamflow conditions in the Cataract River.

The streamflow records were extended by simulating catchment behaviour using the Australian Water Balance Model (AWBM) rainfall-runoff model and historical climate data. Given the limited availability of representative rainfall data, the AWBM gave a reasonable representation of the observed streamflow records.

Daily runoff from other catchments in the upper Study Area was estimated using the AWBM model, with the model parameters transposed from the adjacent Bellambi Creek catchment. The model reproduces similar baseflow behaviour to that observed in recently collected pool monitoring data. However, the Bellambi Creek data showed a number of historical cease to flow periods which did not occur in the Loddon River data and could not be replicated by the AWBM when calibrated to other features of observed runoff. This behaviour would be consistent with a loss of streamflow to seepage of approximately 0.3ML/d, but could also be due to inaccuracies in the flow data.

The adopted Bellambi Creek calibration shows no cease-to-flow events. This is consistent with recent observations in Cataract Creek (though recent conditions have not been as dry as the period of Bellambi Creek flow record). Based on catchment modelling, over the long term, baseflow makes up approximately 32% of total flow. Average daily streamflow is significantly larger than median daily due to the impact of a small number of large surface flow events. Modelled average daily streamflow at CC9 on Cataract Creek is 11.2 ML/d of which 3.5ML/d is baseflow. Median baseflow at this location is 2.2ML/d.

Lake Cataract Reservoir Behaviour

A simple daily timestep spreadsheet model of the Lake Cataract catchment was used to generate a historical time series of inflows to Lake Cataract. The spatial variability of rainfall across the catchment, make runoff modelling to the lake difficult. However, it was possible to simulate the historical behaviour of the reservoir during dry periods, including all inflows and outflows, using historical records of storage and release data provided by the SCA.

Impact Assessment – Streamflow

Subsidence induced cracking could potentially affect streamflow in the reaches overlying and downstream of the proposed workings. Other investigations have concluded that these impacts would normally be restricted to short reaches, where flow infiltrates into cracks in the bed, then remerges further downstream. Based on the available subsidence assessments, it is not possible to directly predict the magnitude of these losses or the lengths of streams likely to be impacted.

In the absence of long-term streamflow records on Cataract Creek, the impact of losses from the affected reaches due to mine subsidence was estimated by extracting a constant daily loss rate from the simulated streamflow record. The loss of low flows in Cataract Creek at the reporting locations just downstream of the proposed 20mm subsidence zone resulted in the following modelled changes to low flow characteristics:

A loss of 0.3ML/d would:

- reduce the frequency of flows greater than 1.0ML/d from around 78% to 72%.
- reduce the frequency of flows greater than 0.1ML/d from around 99% to 91%.
- increase the maximum cease to flow period length from 0 to 83 days.
- increase the median duration of cease to flow periods from 0 to 12 days.

A loss of 0.5ML/d would

- reduce the frequency of 1.0ML/d flows to 69%.
- reduce the frequency of 0.1ML/d flows to 86%.
- increase the maximum cease to flow period length from 0 to 101 days.
- increase the median duration of cease to flow periods from 0 to 9.5 days.

A potential mechanism for the loss of streamflow in Cataract Creek is the loss of flow to the underground workings via cracking in the tributary catchments overlying the subsidence area. The potential impact on Cataract Creek of losing flow in these 9 mapped unnamed tributaries was assessed by removing these areas from the catchment model and examining the effect on key streamflow characteristics at CC9 (which is located upstream of the Lake Cataract free surface level). Catchment areas downstream of the underground workings were left in the model to continue to contribute to streamflow in Cataract Creek. The impact of loss of streamflow in a tenth tributary, Tributary 10, was also examined separately (as its confluence with Cataract Creek is located well downstream of CC9).

The effect of catchment losses was assumed to be proportionally the same for all flows - the magnitude of losses is higher during large flow events. The following observations can be drawn from the modelling results:

- Loss of streamflow from the catchment areas of all mapped tributaries upstream of CC9 would reduce the median total flow rate by 0.9ML/d (from 2.54ML/d to 1.64ML/d). Median baseflow would reduce by 0.61ML/d (from 1.71ML/d to 1.10ML/d). The loss of all tributary streamflow to the underground workings via subsidence cracking is very improbable;
- The loss of streamflow from the catchment area of Tributary 1 makes up the bulk of this loss – with the median total flow rate reducing by 0.37ML/d (from 2.54ML/d to 2.17ML/d). Median baseflow would reduce by 0.25ML/d (from 1.71ML/d to 1.46ML/d);
- Loss of streamflow from the catchment areas of the individual tributaries 2-9 would be minimal as each of these tributaries make up less than 6.1% of the total catchment to CC9;
- The loss of streamflow from the catchment area of Tributary 10 would reduce the median total flow rate from this tributary by 0.04ML/d (from 0.08ML/d to 0.04ML/d). Median baseflow would reduce by 0.02ML/d (from 0.05ML/d to 0.03ML/d).

Impact Assessment – Reservoir Yield

The reservoir yield model was used to investigate the potential for additional catchment inflow losses to prevent the reservoir from supplying water demands under historical conditions. Additional losses would have had very little impact on historical Lake Cataract water levels.

The maximum modelled reduction in stored volume occurs in mid-2007 and ranges from 940ML for a loss of 0.5ML/d to 1,385ML for a loss of 10ML/d. Losses of 10ML/d would not have caused the Lake Cataract Reservoir water volume to fall below 10% of capacity. Such loss rates are very large, and unlikely to eventuate given the underlying geology and proposed mining method.

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1 INTRODUCTION

1.1 BACKGROUND

WRM Water and Environment was engaged by Wollongong Coal Limited to assist in assessment of the potential surface water impacts of the proposed expansion of the Russell Vale Colliery Wonga East underground operations.

This study describes the existing surface water hydrology of the potentially affected streams, and the hydrological modelling undertaken to quantify the potential impacts. The modelling has been undertaken to address components of the Director General's Requirements (DGRs) for the project relating to the potential impacts on flows in watercourses and the associated reliability of water supplies from Cataract Dam.

The study draws on estimates of the extent of mine subsidence and the potential for cracking of the ground surface along watercourses. This report focuses on surface water hydrology, whilst the potential impacts on other features of the streams and upland swamps are covered by associated studies.

1.2 UPDATED REPORT

The previous version of this document (Report No. 0637-07-A2 dated the 31st March 2014) was submitted to the New South Wales Department of Planning and Infrastructure as part of the Preliminary Residual Matters Report (Hansen Bailey, 2014) for the Russell Vale Colliery Underground Expansion Project. Since submitting this report, additional modelling has been undertaken to assess the potential impact of subsidence cracking in tributaries on the streamflow in Cataract Creek.

This report includes details on the methodology and results of this modelling in sections 8.2.3 and 8.3.3.

The results of the Cataract Creek streamflow loss impact have also been updated to include the full period of available climate data. The previous report quoted results from analysis of a truncated dataset that commenced in 1960. Updated results can be found in Section 8.3.2.

1.3 PROJECT DESCRIPTION

The proposed workings are contained within the Russell Vale Colliery in Consolidated Coal Lease 745 (CCL745) and Mining Lease 1575 (ML1575), which are located approximately 13km northwest of Wollongong. These areas are shown in Figure 1.1.

Coal will be extracted from the Wongawilli Seam by longwall extraction from 5 new panels in the Wonga East area.

1.4 STUDY AREA

The Study Area includes the catchments of potentially affected and adjacent streams in the vicinity of the project. As shown in Figure 1.1, the Study Area extends approximately 20km west from the Illawarra Escarpment and comprises the catchments of Lake Cataract.

Lake Cataract is a component of the Upper Nepean water supply scheme, and is managed by the Sydney Catchment Authority (SCA).

Figure 1.1 Study Area

1.5 SCOPE OF WORK

The following tasks were completed under the scope of this study:

- Delineate drainage catchments over the mine subsidence area,
- Produce longitudinal profiles over the proposed workings,
- Assess streams in terms of gradient, length, and order,
- Assess rainfall residuals for the nearest long-term rainfall gauge,
- Obtain streamflow from nearby streamflow gauges if relevant to the site catchments,
- Obtain hydrological data pertaining to Lake Cataract:
  - spill volumes,
  - stored volume,
  - water extractions, and
  - surface evaporation.
- Prepare and calibrate a rainfall-runoff model of the Lake Cataract catchment to generate a daily time series of inflows to the dam,
- Assess the contribution of the mine subsidence areas to the total runoff to Lake Cataract over a range of flow conditions,
- Assess the impact of the potential loss of flow due to subsidence-induced cracking on streamflow in the creeks crossing the proposed subsidence area.

2 CATCHMENT CHARACTERISTICS

2.1 LAKE CATARACT CATCHMENT

Ground surface elevations in the Lake Cataract catchment vary from 485m AHD near Mount Keira on the eastern escarpment to 150 m AHD at the confluence of Wallandoola Creek and the Cataract River, at the downstream (western) end of the Study Area. The underlying geology predominantly comprises Hawkesbury Sandstone, however the Bald Hill Claystone and Bulgo Sandstone are exposed in the valley floor of Cataract Creek. Steep rocky outcrops and cliffs are present in some areas, while some headwater streams drain upland headwater swamps on the higher eastern plateau via ephemeral gullies incised into the sandstone.

Cataract Dam has significantly altered streamflow from the upstream catchment since its construction in 1907. The dam has a capacity of 97,190 ML and controls a catchment area of 130km^2. Flows downstream of the dam are further regulated by Broughton's Pass weir, which diverts water supplies to the Macarthur Water Treatment Plant via Cataract Tunnel.

There has been a long history of coal mining under the Upper Nepean water supply catchments. Mining activities by previous owners of Russell Vale Colliery and the decommissioned BHP Billiton Cordeaux Colliery longwall as well as other old bord and pillar workings have caused adverse subsidence impacts in the Study Area. Longwall mining in the Appin, Westcliff and Northcliff workings approximately 2.5 km to the north of the Lease Area have also resulted in adverse impacts on surface water quality and quantity (Short, 2007).

Surface infrastructure associated with mining affects relatively small portions of the catchment, and as the SCA's Metropolitan Special Area is a restricted access area, the Study Area is otherwise largely undeveloped and in a natural condition.

2.2 WONGA EAST CATCHMENTS

The Wonga East area is predominantly drained by Cataract Creek, and to a much lesser degree, Bellambi Creek and the Cataract River. Cataract Creek joins the Cataract River within the impoundment of Lake Cataract.

As shown in Figure 2.1, parts of the upper catchments have been cleared for powerlines and access tracks. The Southern Freeway/Mount Ousley Road also crosses the eastern portion of these catchments. Three upland swamps are present in the Cataract River catchment.

Longwall mining of the Balgownie Seam as well as bord and pillar extraction of the Bulli Seam has previously been conducted under Cataract Creek. The most recent activities were associated with mining of Longwall Panels 4 and 5 to the south of Cataract Creek.

As shown in Figure 2.1, the proposed Wonga East workings underlie Cataract Creek. Figure 2.2 shows the western end of Panel 7 and its associated predicted 20 mm subsidence zone will encroach close to the eastern bank of the high water extent of the Lake Cataract backwater.

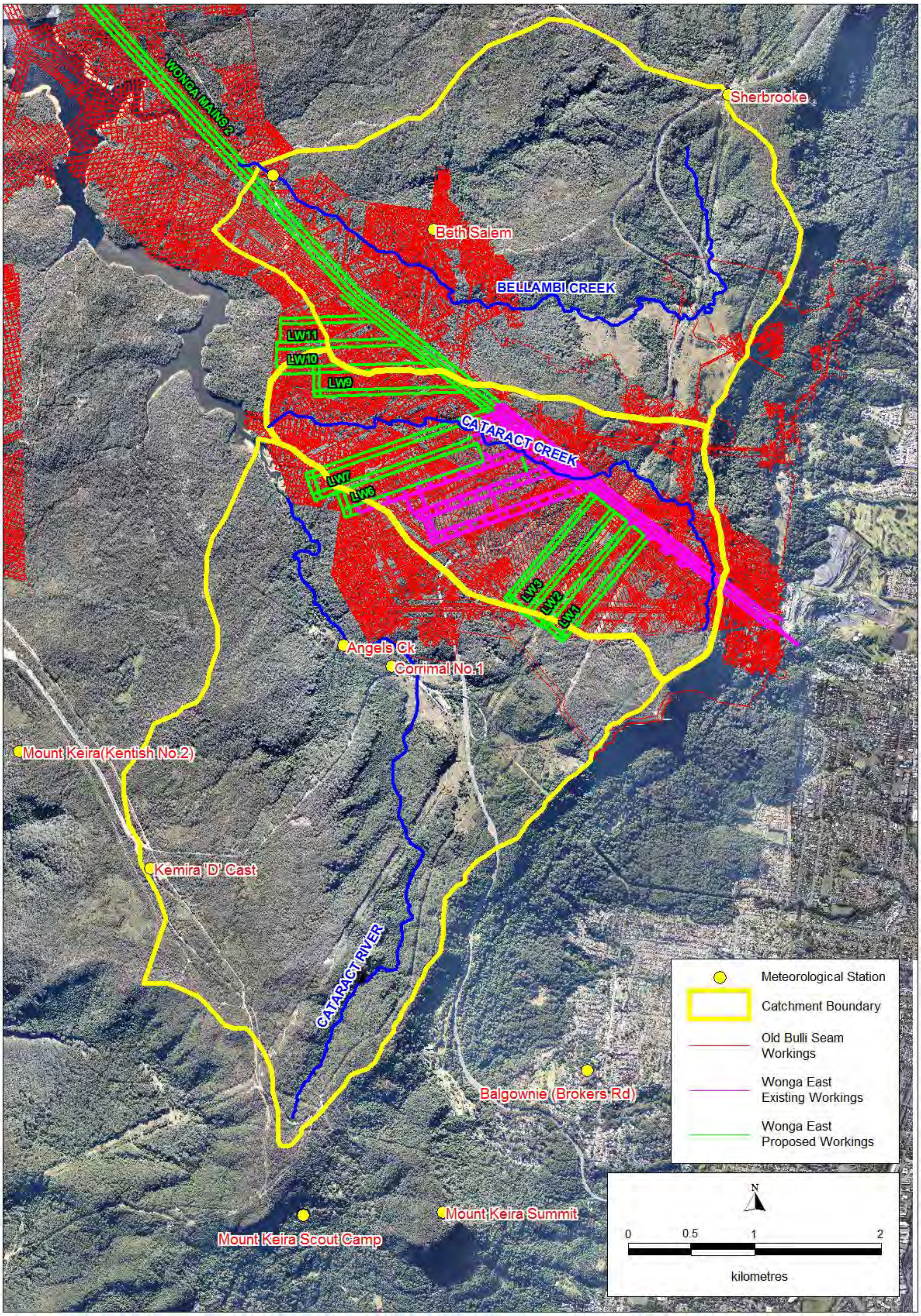


Figure 2.1 Cataract River and Cataract Creek Catchment Areas

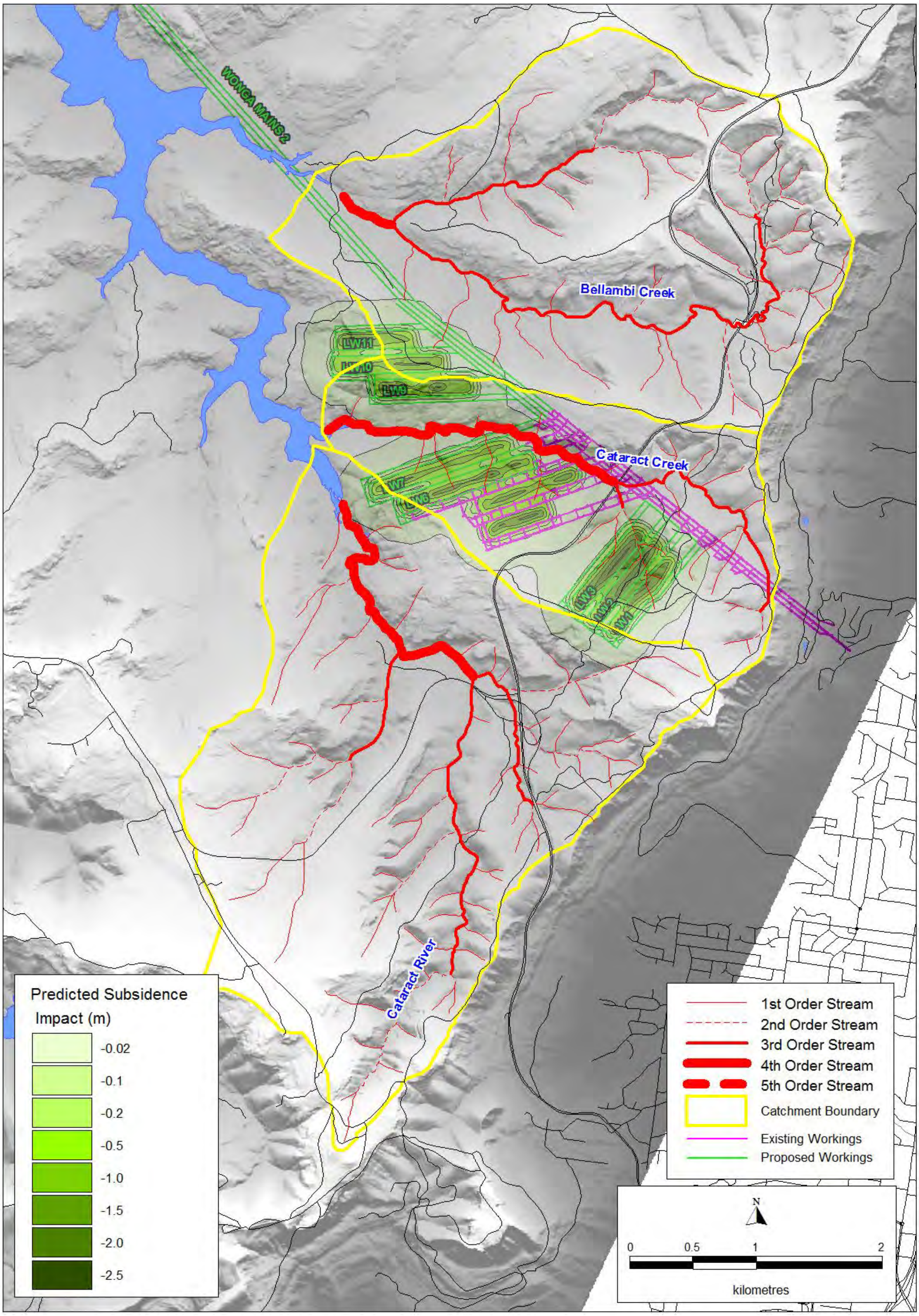


Figure 2.2 Stream Order – Cataract River, Cataract Creek and Bellambi Creek

3 STREAM GEOMETRY

3.1 GENERAL

Longitudinal profiles of each of the potentially affected watercourses were produced from a digital terrain model derived using airborne laser scanning (ALS) survey acquired over the Study Area on 20th October 2009. The accuracy of well-defined points in the survey data is quoted as better than 100mm, based on comparison with ground survey in cleared areas (AAM Hatch, 2009). Ground survey cross-sections were obtained at the Cataract Creek pool level monitoring locations by Southern Cross Surveyors in September 2013.

3.2 CATARACT CREEK

As shown in Figure 2.2, Cataract Creek is a 4th order stream for most of its length.

A longitudinal profile of Cataract Creek is shown in Figure 3.1 (its alignment is shown in Figure 3.3). Cataract Creek is approximately 5.5km long from its headwaters to the upstream reaches of the Lake Cataract storage. Channel invert elevations fall from approximately 340m AHD to 285m AHD. The channel is relatively gently sloping at a gradient of 0.9%, for most of its length - the exception being the steep upstream 0.5km reach, which slopes at 2.5%

The proposed Wonga East workings are located between Chainage 2,500m and Chainage 4,500m. Approximately 2.5km of the stream reach is located upstream, 2km within and 0.9km downstream of the 20mm subsidence zone.

Channel cross-sections at three locations along Cataract Creek are shown in Figure 3.2. The cross-section at Chainage 240m was created using ALS data only. The cross-sections at chainages 2,600 and 4,600 were created using a combination of ground survey and ALS data.

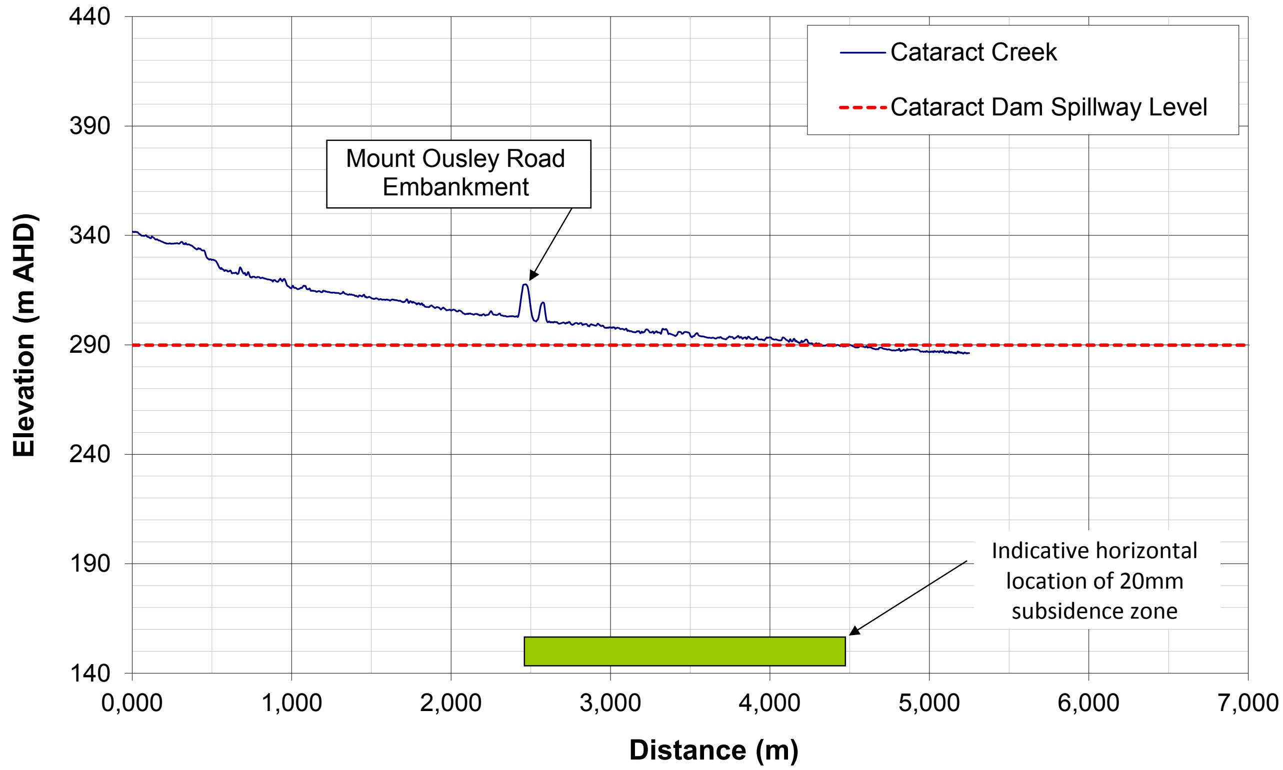


Figure 3.1 Longitudinal Profile Cataract Creek

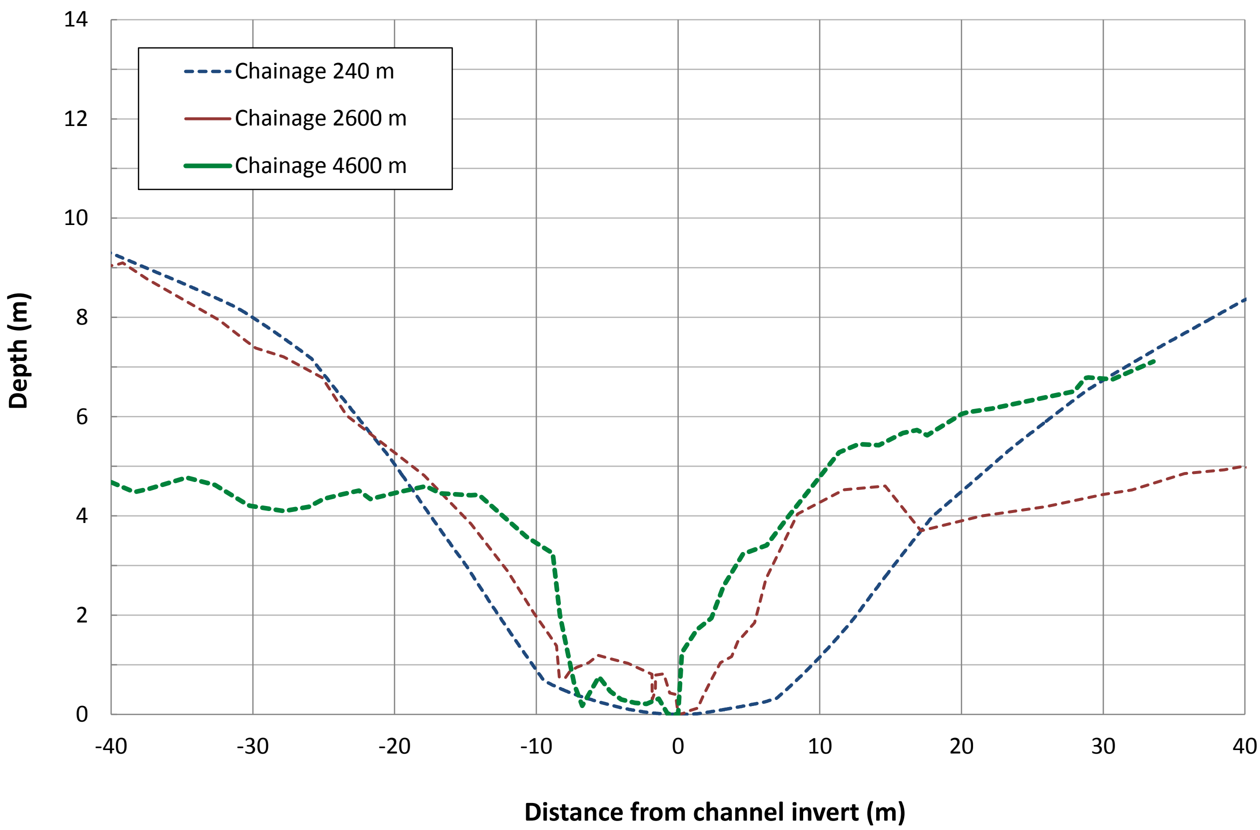


Figure 3.2 Cross-sections of Cataract Creek

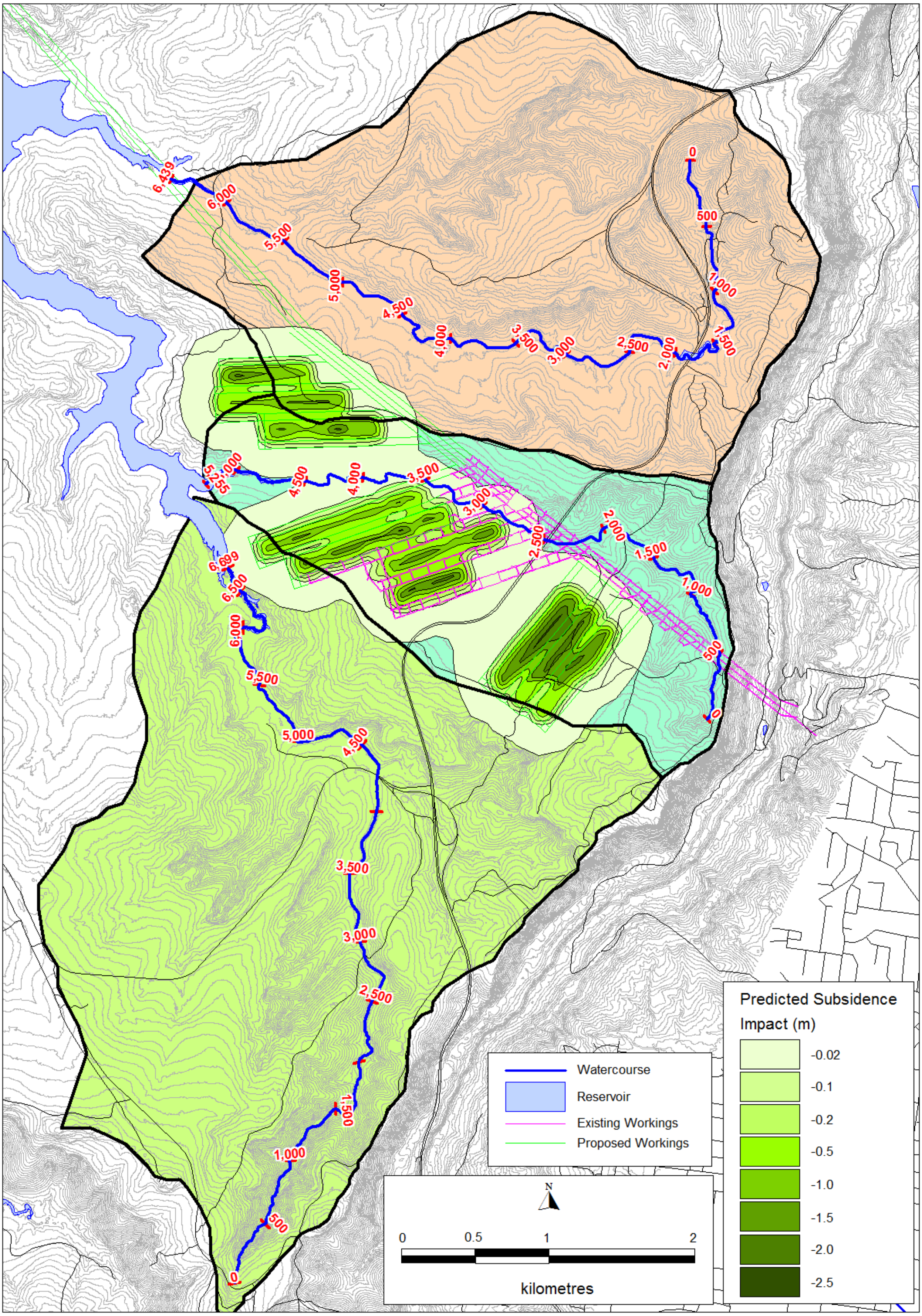


Figure 3.3 Alignments of Longitudinal Profiles of Cataract River, Cataract Creek and Bellambi Creek

3.3 CATARACT RIVER

As shown in Figure 2.2, Cataract River is a 3rd order stream upstream of the Link Road crossing, and 4th order from the confluence near the crossing to the Lake Cataract backwater.

Cataract River is approximately 6.7km long from its headwaters to the upstream reaches of the Lake Cataract storage. Channel invert elevations fall from approximately 430m AHD to 285m AHD. The channel is relatively gently sloping at a gradient of 0.5%, for much of its length - the exception being the steep upstream 0.5km reach, which slopes at around 17%.

The proposed Wonga East workings do not underlie the Cataract River. The mine panels are to be laid out in accordance with SCA requirements for clearance from the reservoir area.

Channel cross-sections at three locations along Cataract River are shown in Figure 3.5.

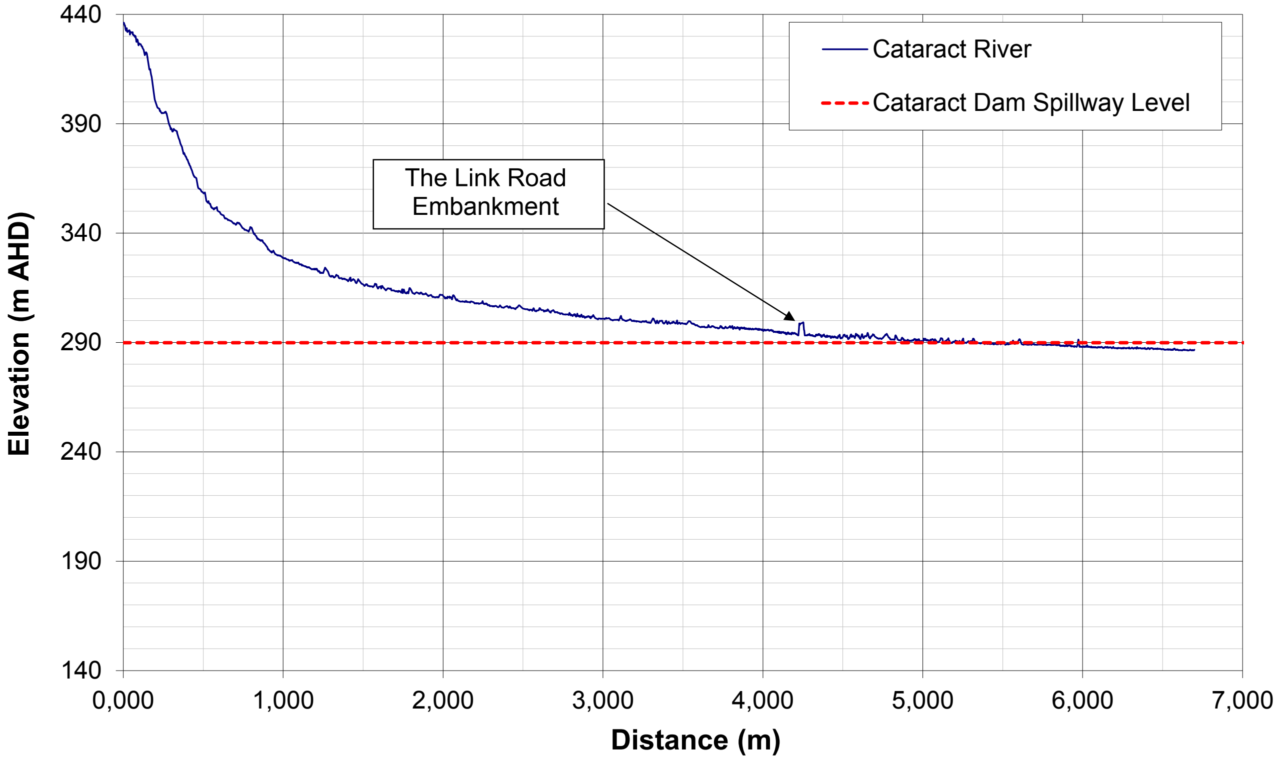


Figure 3.4 Longitudinal Profile Cataract River

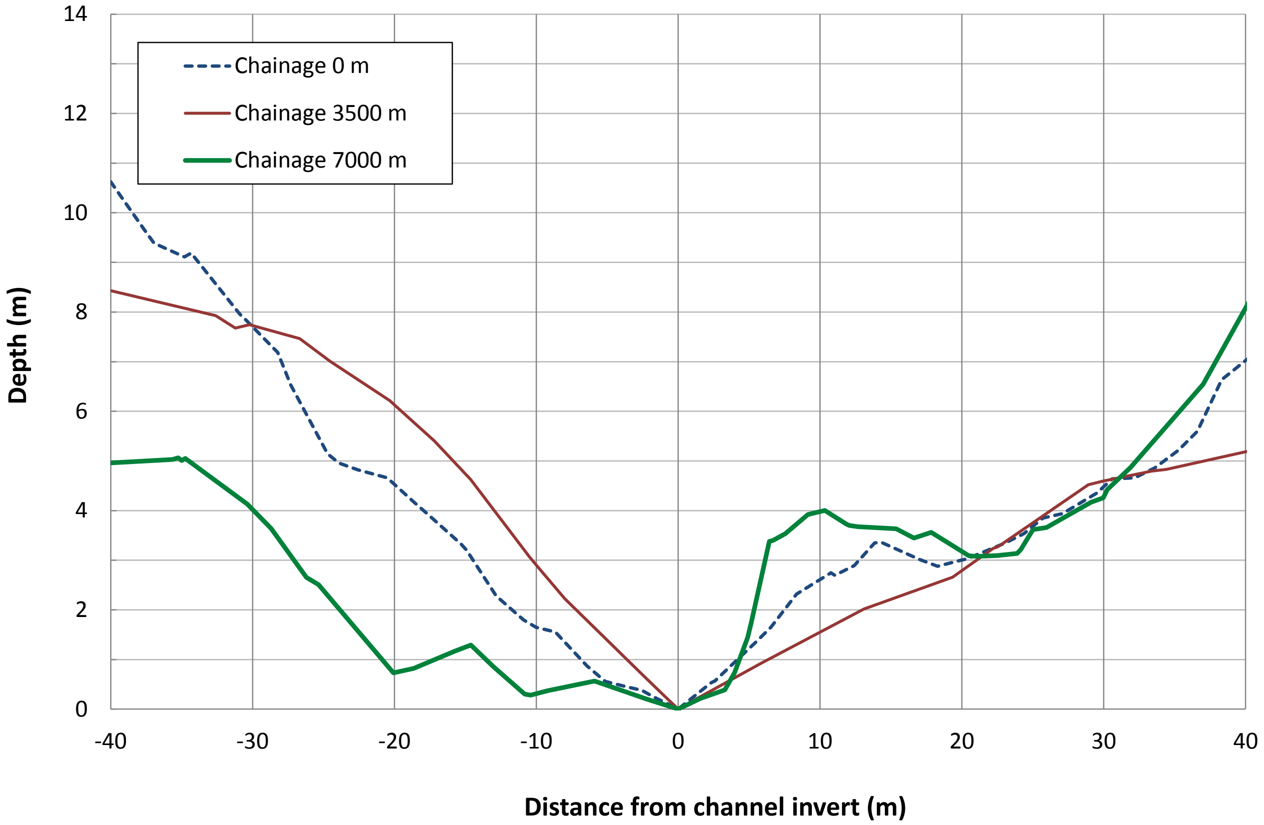


Figure 3.5 Cross-sections of Cataract River

3.4 BELLAMBI CREEK

As shown in Figure 2.2, Bellambi Creek is a 3rd order stream upstream of Chainage 5,500m, and 4th order from Chainage 5,500m to the Lake Cataract backwater.

Bellambi Creek is approximately 6.4km long from its headwaters to the upstream reaches of the Lake Cataract storage. Channel invert elevations fall from approximately 453m AHD to 286m AHD. The channel is relatively gently sloping at a gradient of 0.6%, for much of its length - the exception being the steep upstream 1.0km reach, which slopes at around 2.8%.

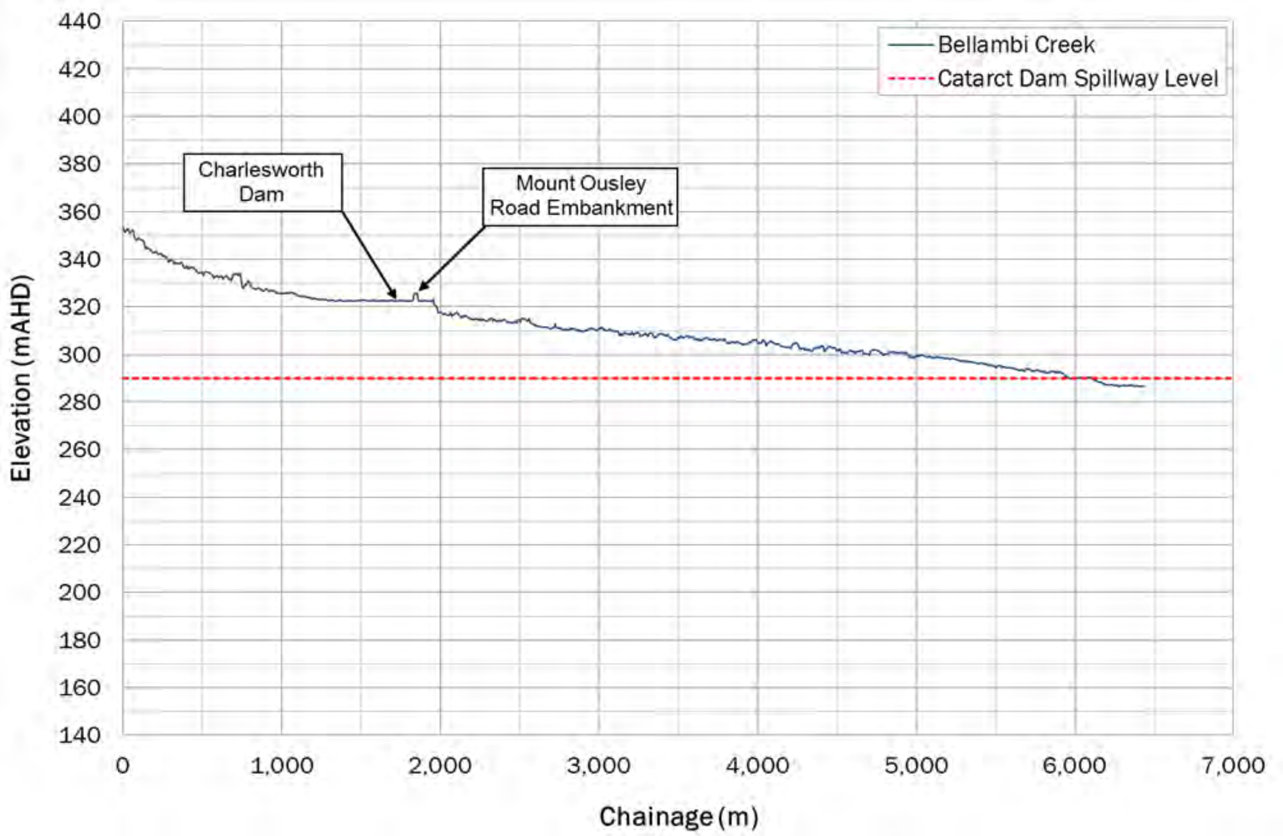


Figure 3.6 Longitudinal Profile Bellambi Creek

4 CLIMATE CHARACTERISTICS

4.1 RAINFALL

4.1.1 Available Data

Daily rainfall has been recorded by the Bureau of Meteorology (BOM) and the SCA and its predecessors. The nearby rainfall stations with the longest records are located at Cataract and Cataract Dam. These stations have good quality records extending from 1883 to 1966 and 1904 to 2014 respectively.

The BOM's SILO data service has prepared Patched Point Datasets (PPDs) from the Cataract and Cataract Dam records. Gaps in the records are infilled with data interpolated from other nearby stations to provide continuous records between 1889 and the present day (Jeffrey et al., 2001).

4.1.2 Temporal Variability

As shown in Figure 4.1, annual rainfall at Cataract Dam for the period 1889 to 2013 has varied from 480mm in 1944, to 2,293 mm in 1950. Mean annual rainfall over this period was 1,085 mm/a.

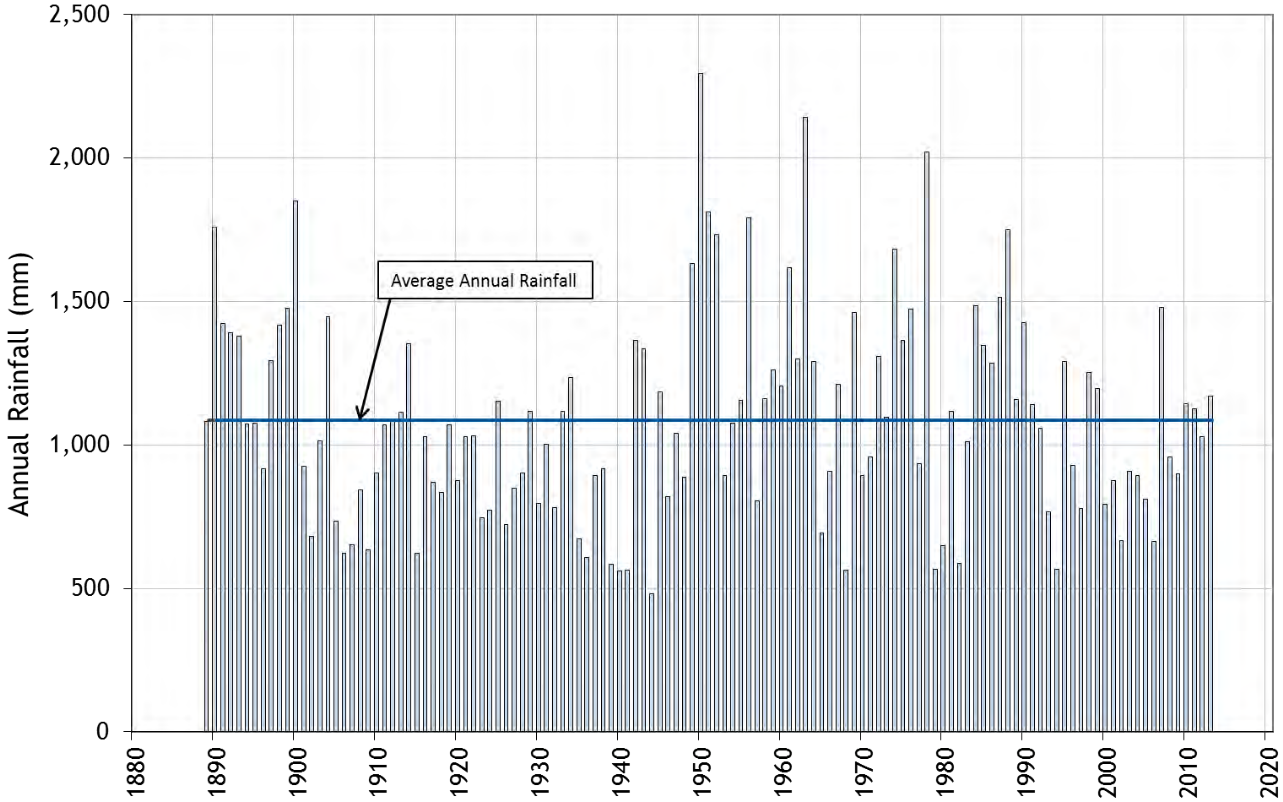


Figure 4.1 Annual Rainfall at Cataract Dam (Patched Point Dataset)

Cataract Dam rainfall is relatively consistent throughout the year. Rainfall is highest between January and June and lowest between July and December. This is illustrated in Figure 4.2, which shows mean monthly rainfall.

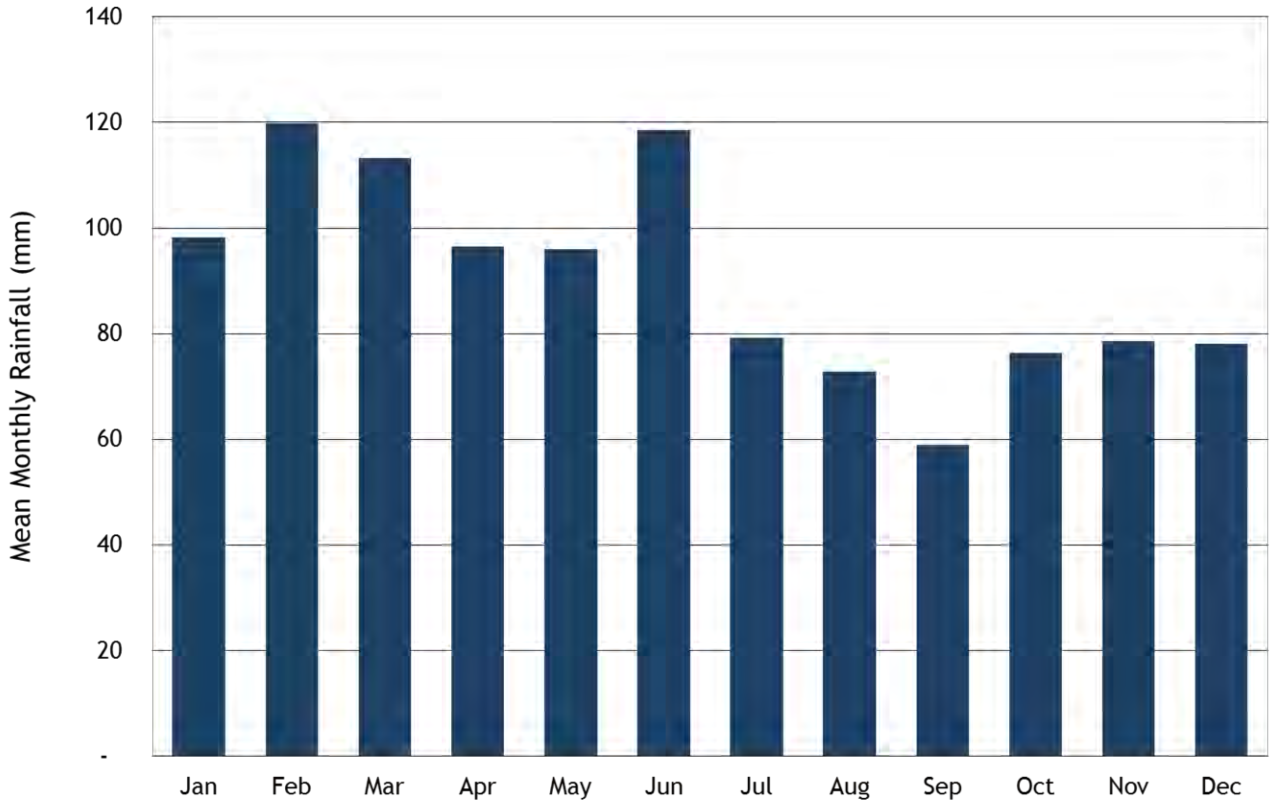


Figure 4.2 Variation in Mean Monthly Rainfall at Cataract Dam

Figure 4.3 shows a plot of rainfall residual at Cataract Dam for the period 1889 to 2013 (prepared using the PPD). The raw data for the station is overlaid on this line for comparison over the available period of record.

The rainfall residual shows departures from the long-term average (i.e. it has not been seasonally adjusted). Upward sloping lines indicate relatively wet periods, and downward sloping lines indicate relatively dry periods.

The figure shows that the period between 1905 and 1942, and the period since 1992 were relatively dry. The period from 1890 to 1900 and between 1950 and 1992 was generally relatively wet (with the exception of the late 1960s and the early 1980s). A plot of the SOI residual has been overlaid on the rainfall residual for comparison.

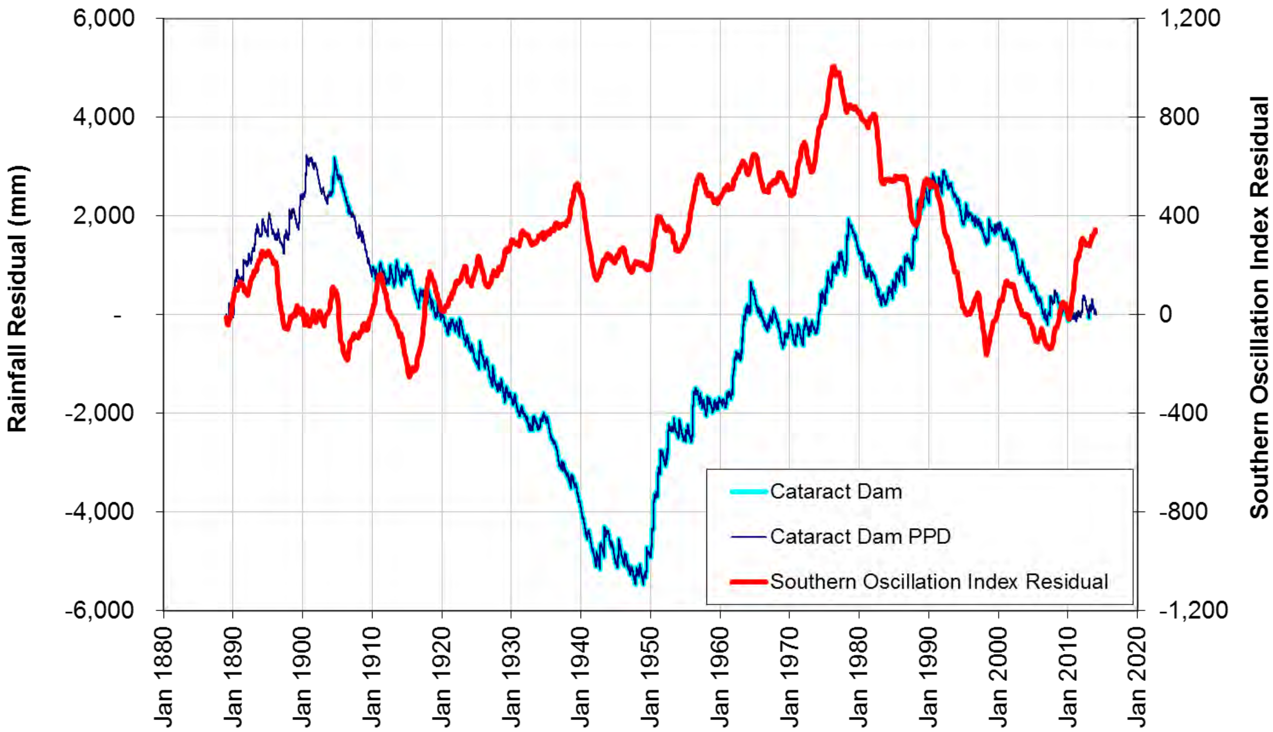


Figure 4.3 Rainfall Residual at Cataract Dam 1889-2013

4.1.3 <u>Spatial Variability</u>

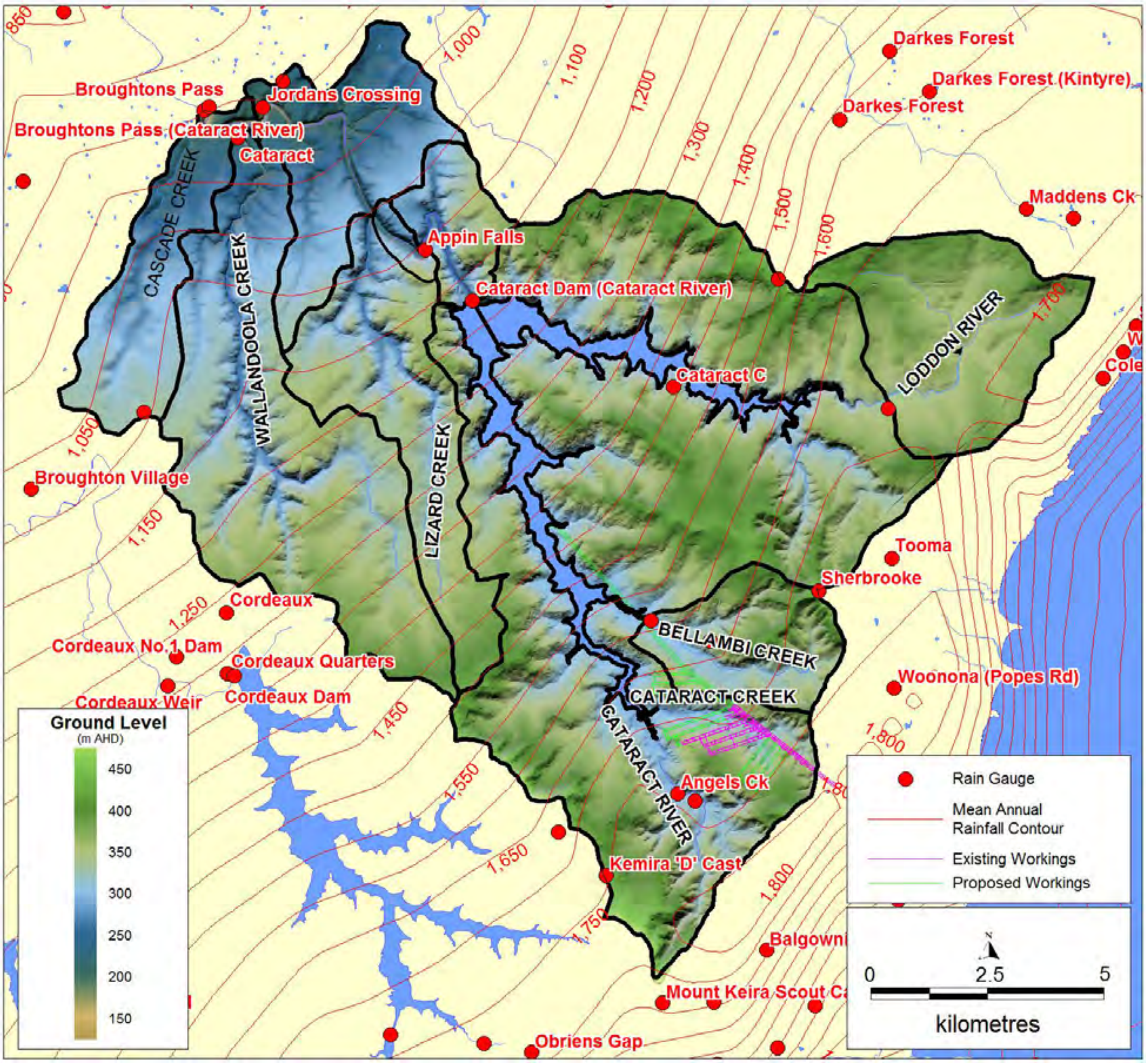
The locations of rainfall stations of interest are shown in Figure 4.4. Few stations have operated in the immediate vicinity of the proposed workings, and most are located near the Study Area boundary. Table 4.1 shows the period over which data was available from each of the gauges.

Table 4.1 Daily Rainfall Recording Stations in the Vicinity of the Study Area

Station Number	Station Name	Period of Record	
		Start	Finish
568004	Cordeaux Airstrip	08-Feb-1964	-
68020	Cordeaux Quarters	01-Jul-1945	-
68017	Cataract	30-Mar-1883	29-Dec-1966
68016	Cataract Dam	01-Jan-1904	-
568065	Letterbox Tower	06-Dec-1964	-
568067	Beth Salem	30-Aug-1966	-
68086	Mount Keira Scout Camp	30-Jan-1944	29-Jul-1992

The length and quality of records from these seven stations is variable. Continuous data from an overlapping data period is only available for the period 1984 to 1991. Figure 4.5 and Figure 4.6 compare mean annual and mean monthly rainfall at the gauges over this common period.

The figures show rainfall increases significantly across the study area from west to east. The eastern stations exhibit relatively high rainfall in February, March, April and June compared to the rest of the Study Area. This spatial variability of rainfall is also illustrated in Figure 4.4, which shows isohyets derived from gridded interpolated rainfall data over the Study Area prepared by BOM for the period 1969 to 1990.



(Source: BOM gridded data 1969-1990)

Figure 4.4 Mean Annual Rainfall Isohyets

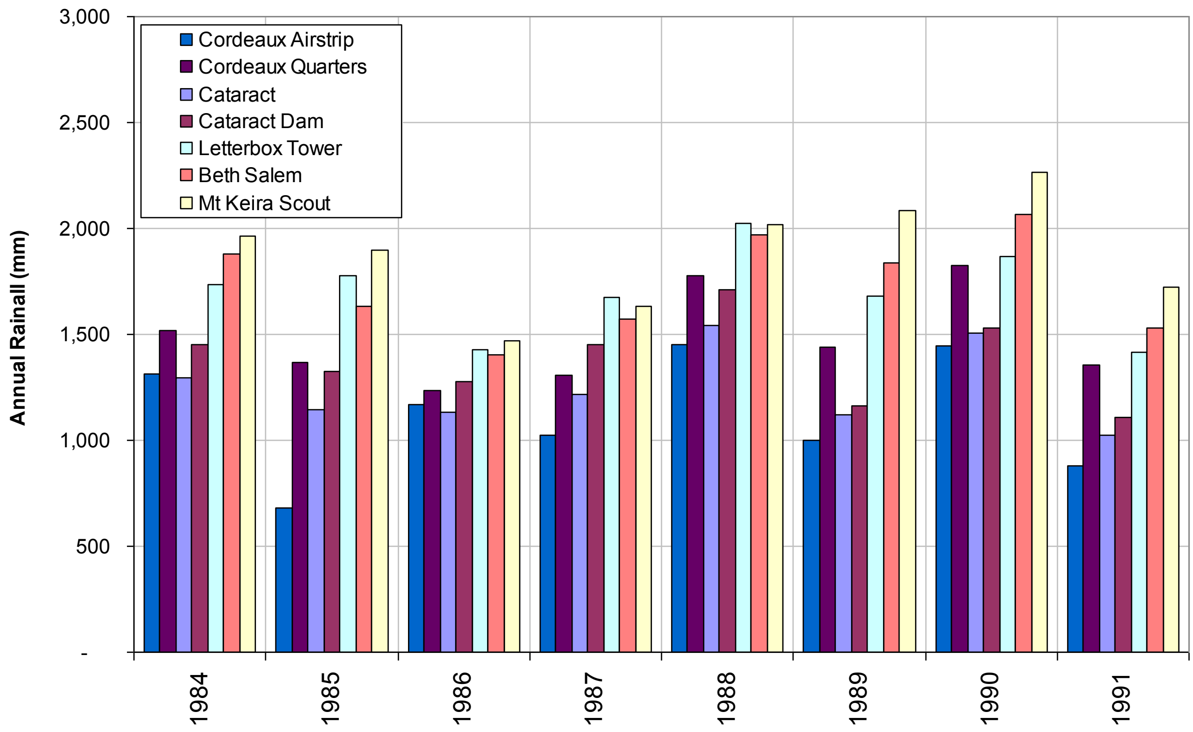


Figure 4.5 Variation in Mean Annual Rainfall across the Catchment (raw data 1984-1991)

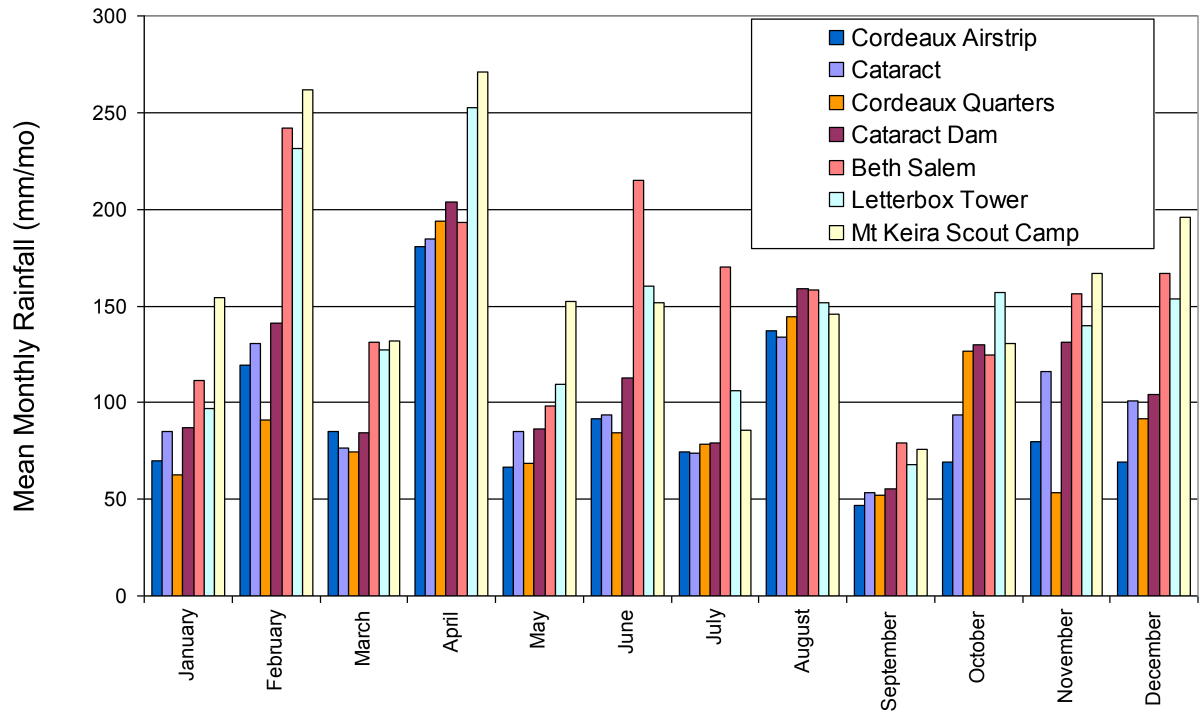


Figure 4.6 Variation in Mean Monthly Rainfall across the Catchment (raw data 1984-1991)

4.2 EVAPORATION

Daily Pan Evaporation has been recorded at the sites shown in Table 4.2 and Figure 4.7.

Table 4.2 Daily Evaporation Recording Stations in the Vicinity of the Study Area

Station	Location	Start	Finish
68017	Cataract		
668048	Cataract Dam	1908	
668049	Cordeaux Quarters	1-Jul-45	
668068	Upper Cordeaux	1973	31-Jul-96

Evaporation is relatively consistent across these gauges. Mean annual pan evaporation at Cataract Dam is approximately 1420 mm/a.

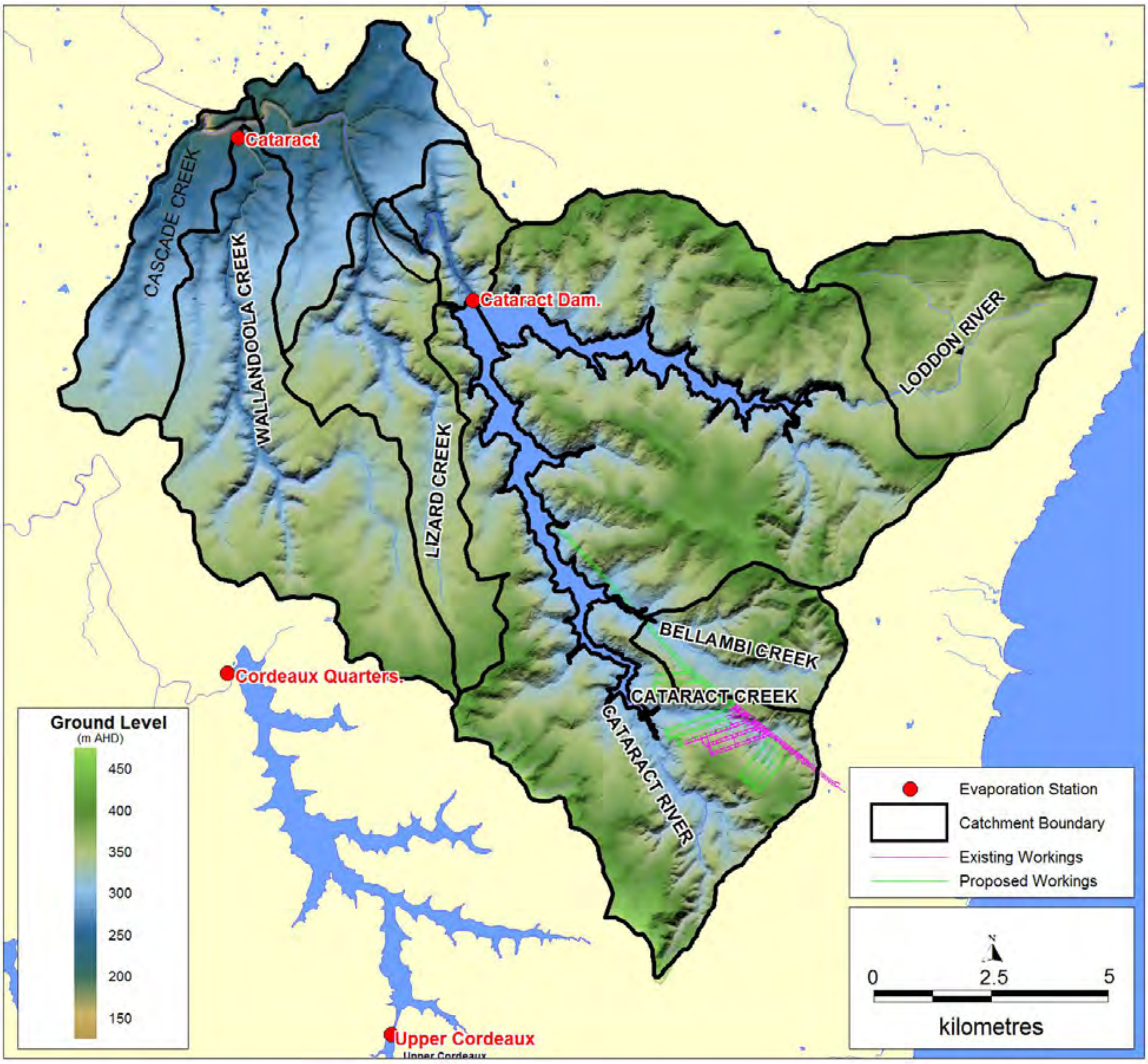


Figure 4.7 Daily Pan Evaporation Recording Stations

The monthly variation in pan evaporation at Cataract Dam is illustrated in Figure 4.8. Evaporation is highest in the summer months.

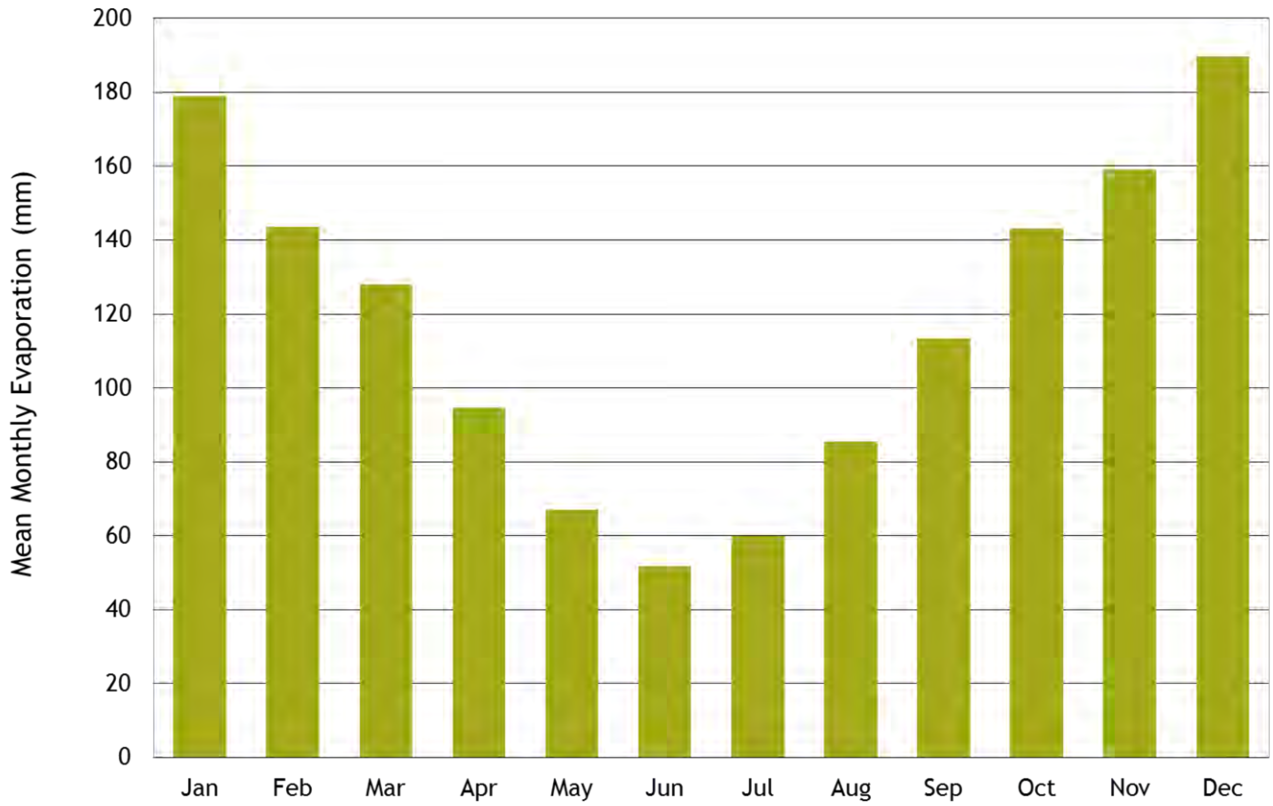


Figure 4.8 Monthly Pan Evaporation at Cataract Dam (PPD)

5 RUNOFF CHARACTERISTCS

5.1 STREAMFLOW DATA

Long term streamflow has been recorded in the Study Area at the gauges shown in Figure 5.1. Gauges in the immediate vicinity of the proposed workings used for this study are listed in Table 5.1. Both are in headwater streams flowing into Lake Cataract, and are not directly impacted by the predicted subsidence from the proposed workings.

The SCA operated a streamflow gauge in the Cataract River at Jordon's Crossing over the period from August 1986 to July 2013. Unfortunately the streamflow at this location is heavily influenced by releases from water storages upstream of the gauge. Therefore, the data from this gauge is unsuitable for the analysis of natural streamflow conditions in the Cataract River.

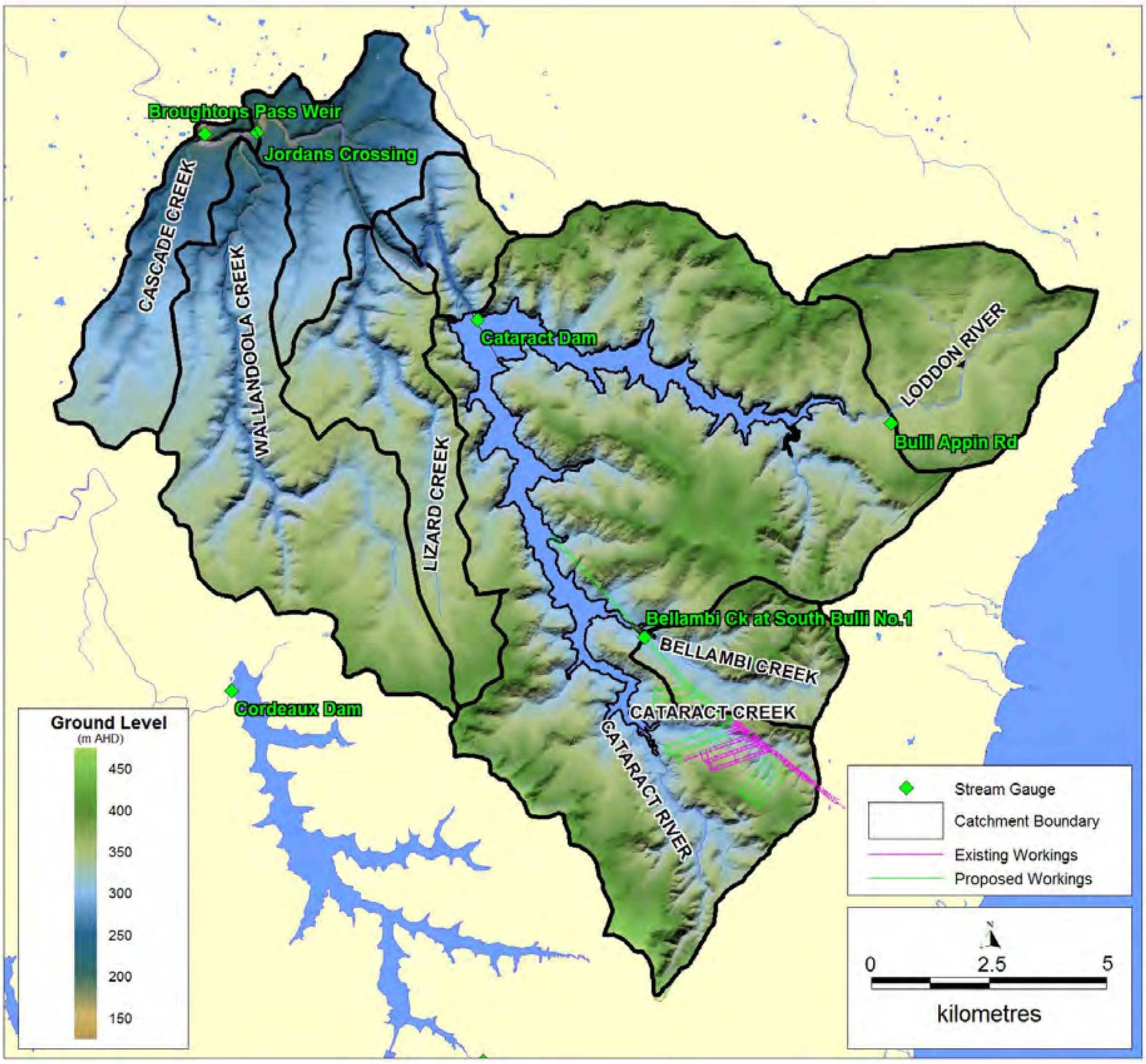


Figure 5.1 Streamflow Recording Stations in the Study Area

Table 5.1 Streamflow Recording Stations in the Study Area

Station Number	Station Name	Catchment Area (km^2)	Mean Flow (ML/a)	Median Flow (ML/a)	Period of Record
2122321	Bellambi Creek at South Bulli No 1	9.3	2,608	1,194	01/01/1991-03/09/1995
2122322	Loddon River at Bulli Appin Rd	17.6	12,810	1,920	01/01/1991-08/11/2009

Streamflow is shown in Figure 5.2 for the overlapping period between 1991 and September 1995. The figure shows the catchments respond similarly, although much higher flows are generated from the Loddon River. Baseflow persists for extended periods after rainfall – and is similar in both streams, even though the Bellambi Creek catchment is much smaller. The flow frequency curves in Figure 5.3 and Figure 5.4 show that flow occurs more than 90% of the time, and flows exceeding 3ML/d occur 50% of the time.

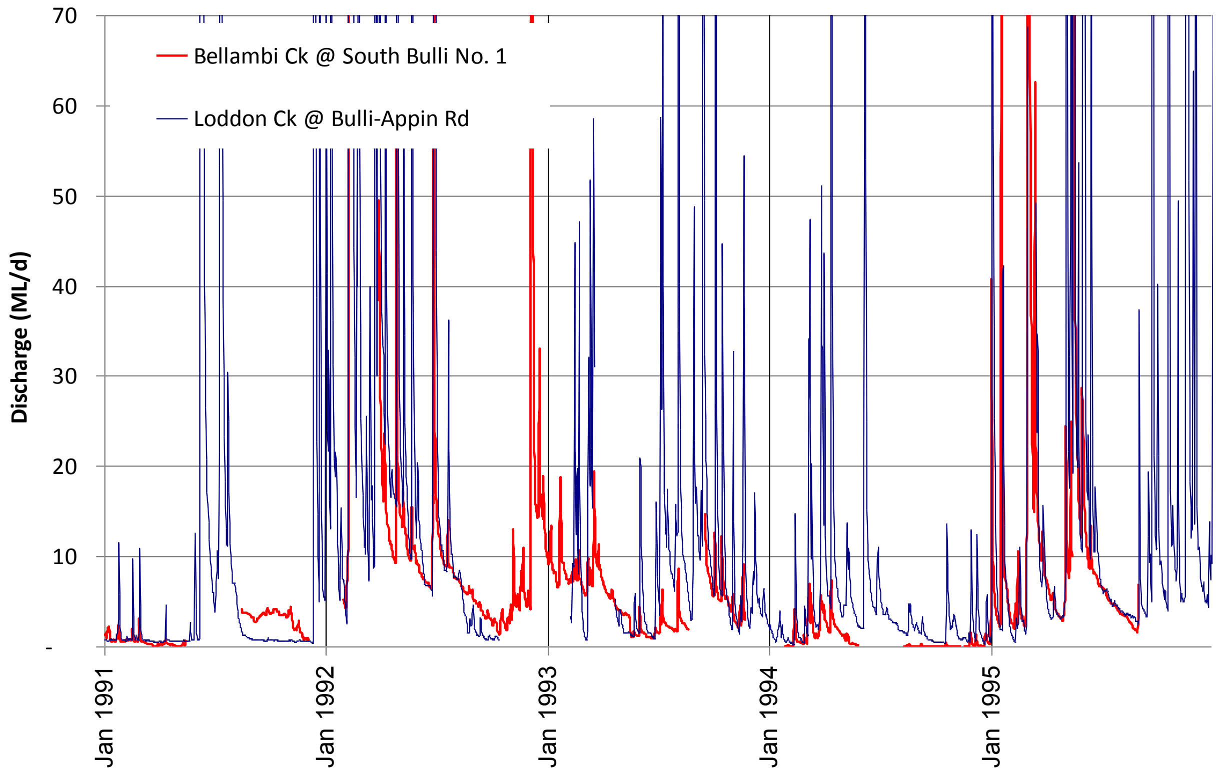


Figure 5.2 Sample Streamflow Record Bellambi Creek and Loddon River (1991-1995)

While persistent baseflow is a notable feature of the streamflow, it contributes a relatively small portion of total streamflow volume. The curves in Figure 5.5 show that over 90% of the total streamflow volume came from the largest 40% of daily flows. Flows of less than 3ML/d made up only 5% of total flow volume from both catchments.

There are however some periods when the flows are dissimilar – due probably to spatially variable rainfall. The Loddon River catchment exhibits a significantly higher runoff to rainfall ratio, as demonstrated in the table below, which compares total runoff (considering days when flow was recorded at both gauges only).

Table 5.2 Runoff Characteristics Loddon River and Bellambi Creek 1991-1995

Station Name	Mean Annual Flow (ML/a)	Runoff Depth (mm/a)
Bellambi Creek at South Bulli No 1	2,608	280
Loddon River at Bulli Appin Rd	9,239	525

Very low flows less than 1 ML/d occurred less frequently in Bellambi Creek. This could be a hydrological characteristic of this catchment. Alternatively, low flows may have been affected by historical streamflow loss through subsidence-induced cracking of Bellambi Creek. However, it is possible this characteristic is an artefact of inaccuracies in the height-discharge relationship of either or both of these streamflow gauges.

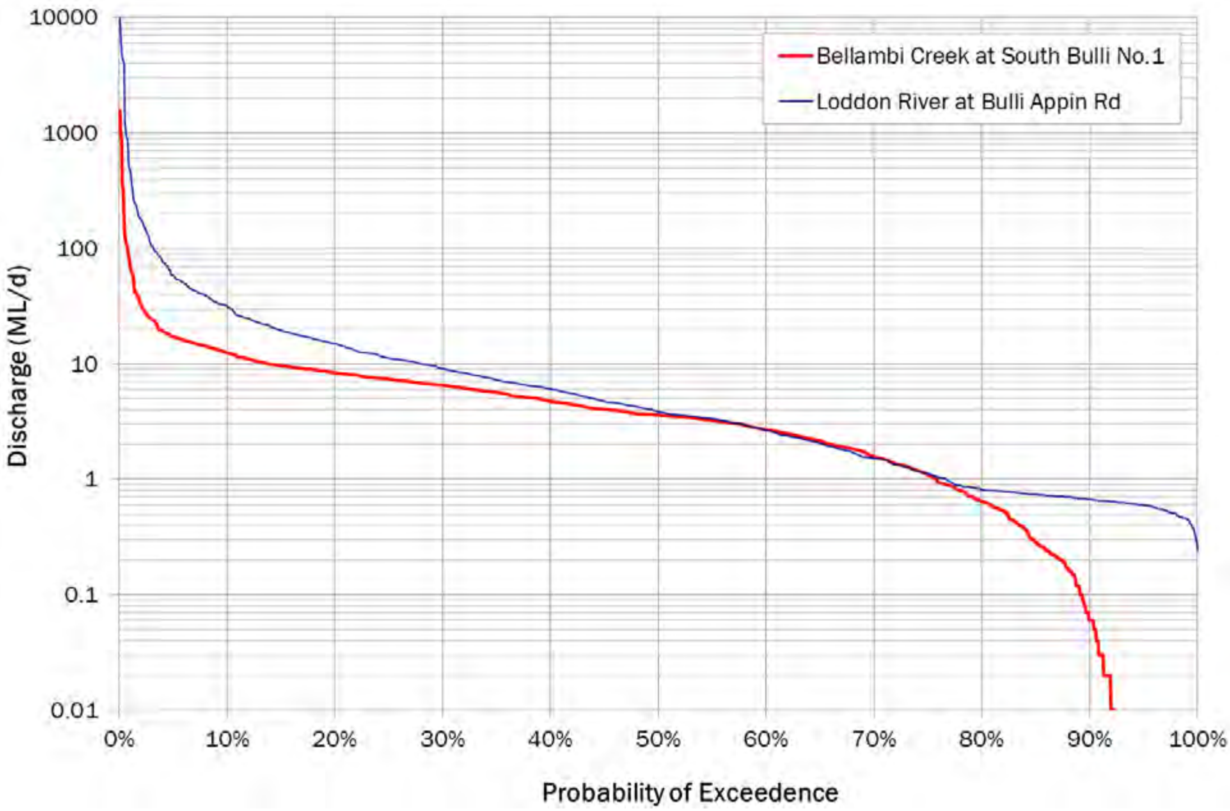


Figure 5.3 Flow Frequency Curves Bellambi Creek and Loddon River (1991-1995) - Discharge

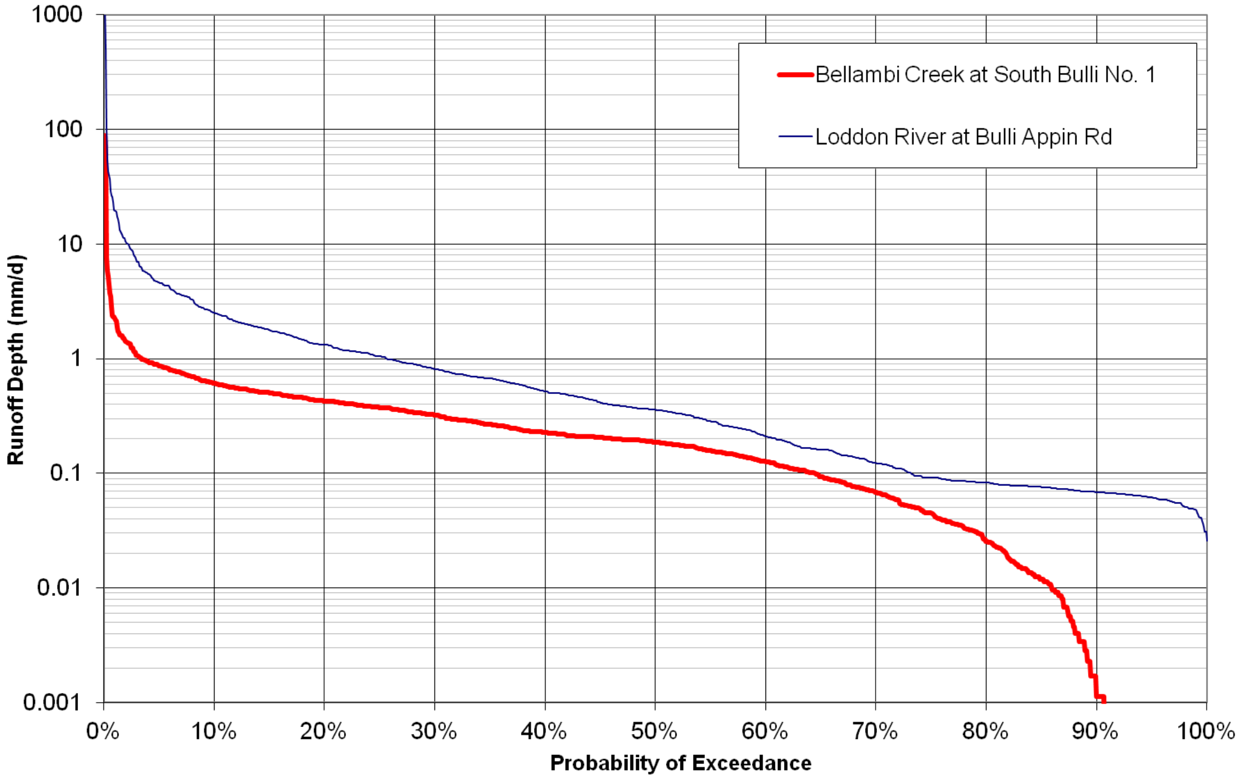


Figure 5.4 Flow Frequency Curves Bellambi Creek and Loddon River (1991-1995) – Runoff Depth

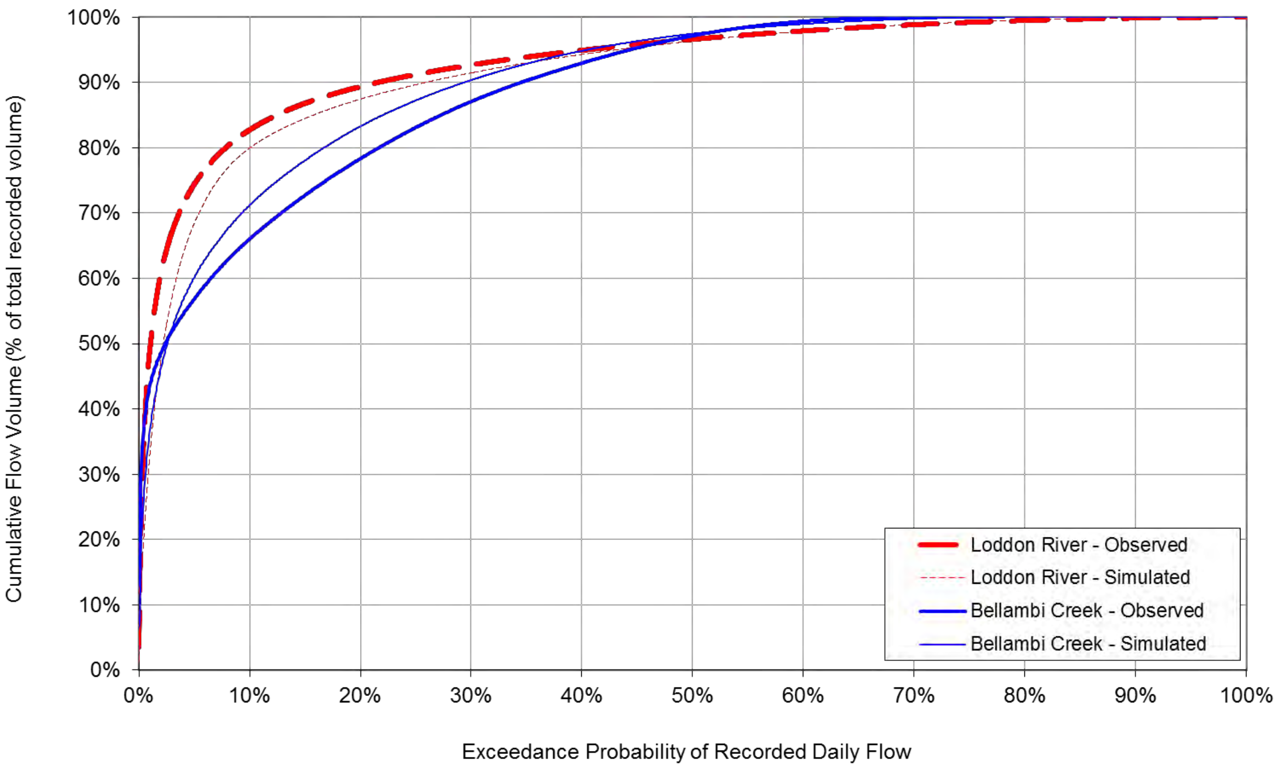


Figure 5.5 Cumulative Flow Volume Bellambi Creek and Loddon River

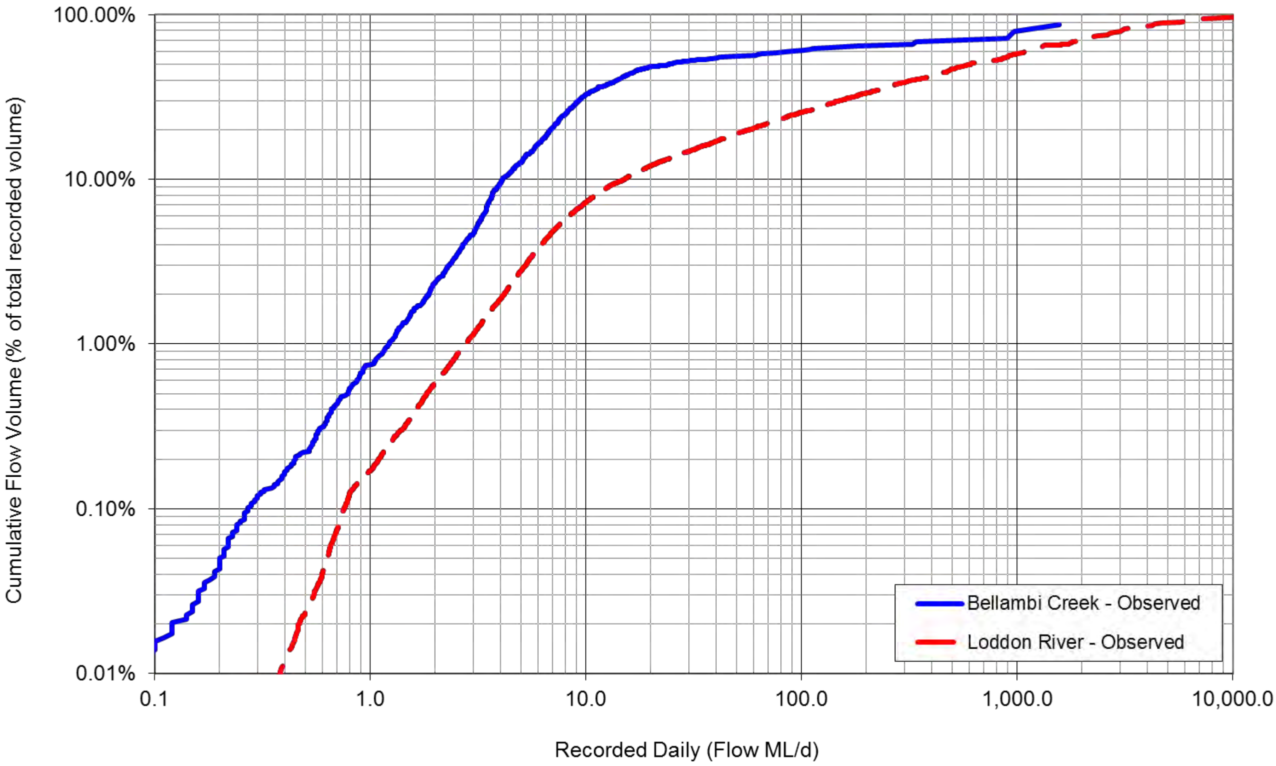


Figure 5.6 Cumulative Flow Volume Bellambi Creek and Loddon River

5.2 POOL LEVEL AND STREAM FLOW MONITORING

Pool water levels have been monitored in the study area since September 2009. Seven sites are located on Cataract Creek and three on the Cataract River as shown in Figure 5.7 below. There also two monitoring points on an upper unnamed, third order tributary of Cataract Creek. The downstream-most monitoring points on both streams are affected by Lake Cataract water levels, when stored volumes are high.

Figure 5.8 to Figure 5.10 show the recorded pool water levels in Cataract Creek and the Cataract River. Note that during the period 3/9/2011 to 2/12/2011 the logger at CC3 did not record any useable data.

Wollongong Coal periodically undertakes measurements of flow velocity across transects at Cataract Creek monitoring points. However, at the time of preparing the present study, insufficient data was available to develop full reliable rating curves, and flow-frequency relationships at the monitoring points.

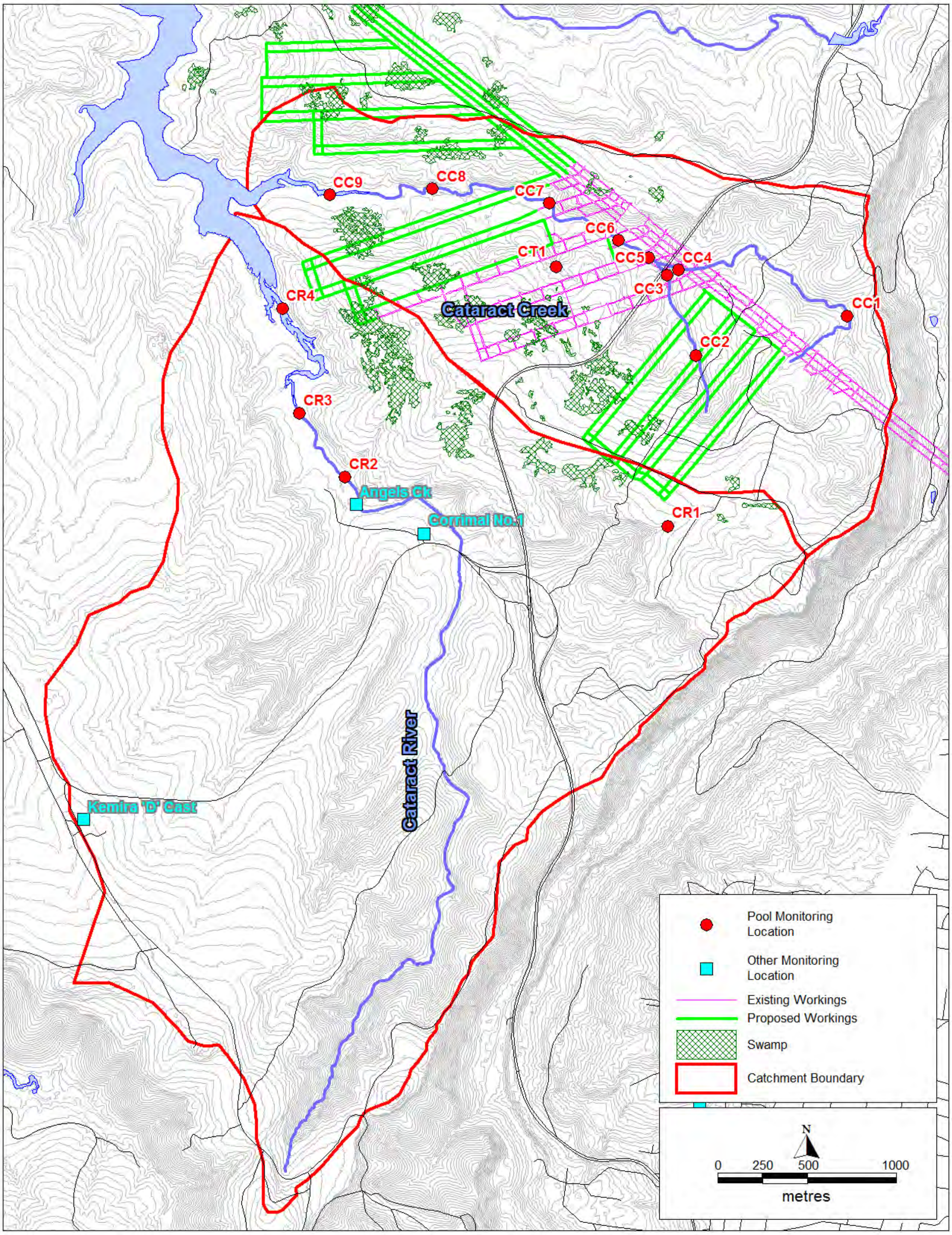


Figure 5.7 Pool Monitoring Locations, Wonga East

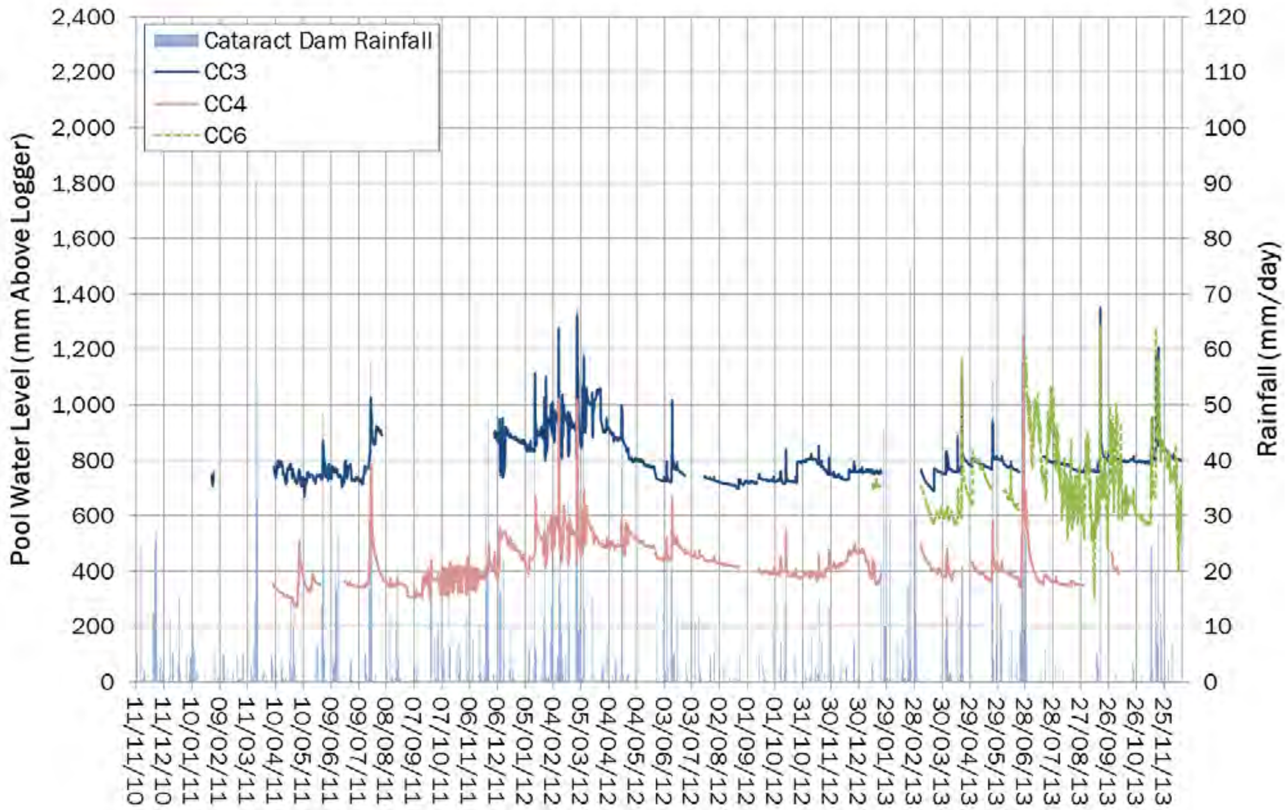


Figure 5.8 Cataract Creek Pool Monitoring Data

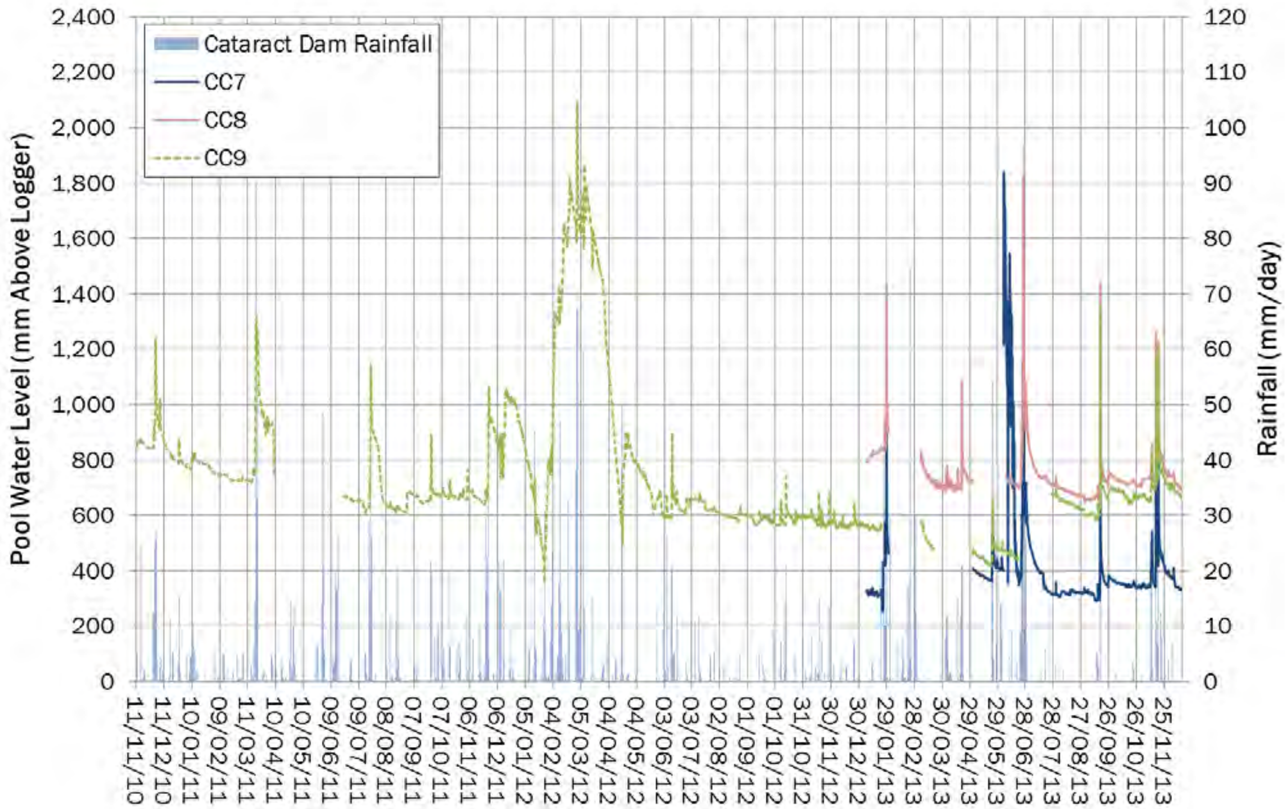


Figure 5.9 Cataract Creek Pool Monitoring Data

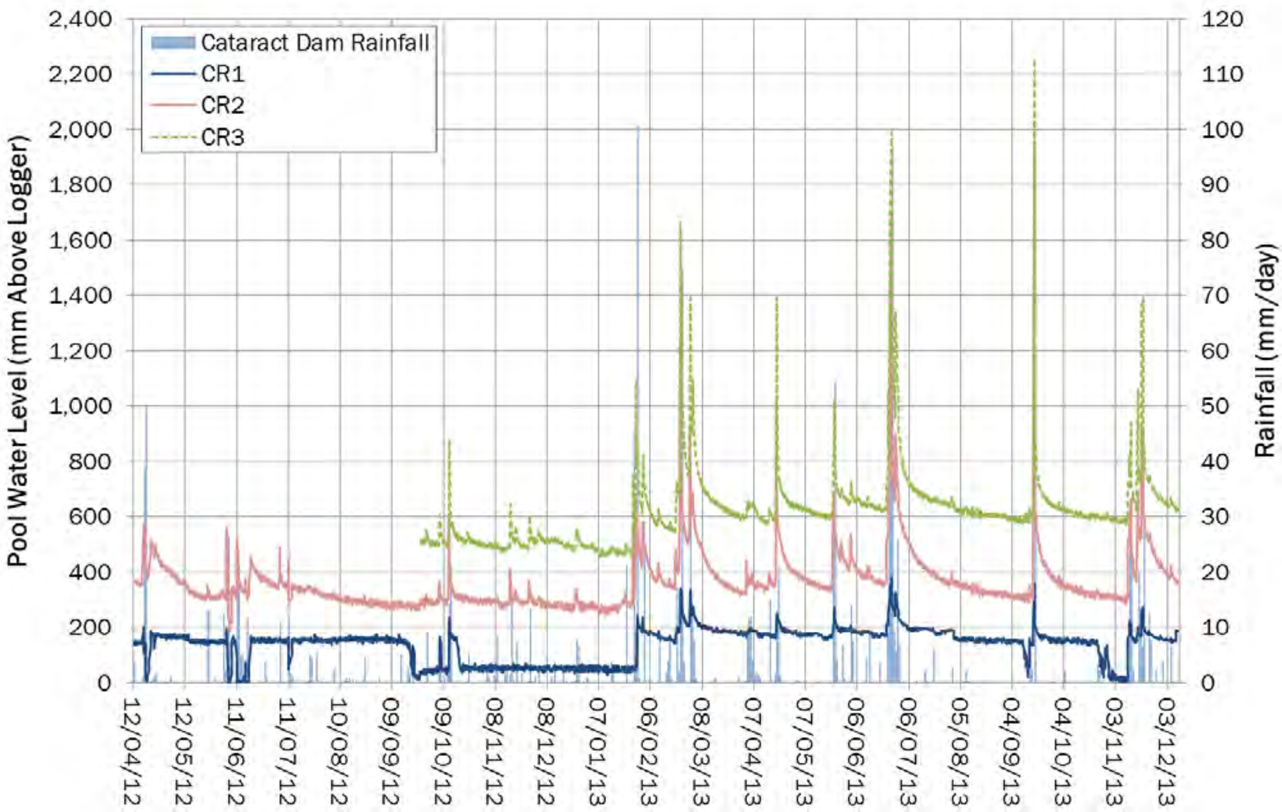


Figure 5.10 Cataract River Pool Monitoring Data

5.2.1 <u>Streamflow Monitoring</u>

Volumetric stream flow monitoring sites have been established on Cataract Creek at the Mount Ousley Road Crossing. Full stage-discharge relationships will be established once sufficient flow measurements have been taken and flow-frequency relationships will be developed. In addition, a number of pool monitoring sites are being investigated for their suitability as flow measurement points, taking into account the potential effects of:

- the presence of subsidence cracking in the creek bed resulting in disconnected stream flow during low flow periods due to mining subsidence over the Bulli Seam and Balgownie Seam workings dating back to the 1970s. The isolated cracked areas can enable transfer of overland stream flow to the shallow groundwater system under the creek bed. This means that not all of the total catchment flow in this reach is present as overland flow, and therefore a surface flow based monitoring system could under-report the actual volume of water flowing down the catchment and into Cataract Reservoir;
- overland flow diversions through natural bedding plane discontinuities which are washed out. It should be noted that this diversion is natural and is not due to subsidence cracking;
- baseflow though the hyporheic zone particularly in sandy channels during dry periods.

6 CATCHMENT MODELLING

6.1 MODELLING APPROACH

Rainfall-runoff models were created for the two gauged headwater catchments in the Study Area; Loddon River and Bellambi Creek. The models were calibrated to the daily streamflow records and used to extend those records to the length of available climate record.

The AWBM was selected for catchment modelling, as it has been successfully used in neighbouring catchments for similar studies. It uses a group of connected conceptual storages (three surface water storages and one ground water storage) to represent a catchment. Water in the conceptual storages is replenished by rainfall and is reduced by evaporation. Simulated surface runoff occurs when the storages fill and overflow. The model parameters define the storage depths, the proportion of the catchment draining to each of the storages, and the rate of flux between them (Boughton, 2003).

Daily runoff from other catchments in the Study Area was estimated using the AWBM, with model parameters transposed from the adjacent calibrated catchments. Climate data specific to each sub-catchment of interest was used to account for the spatial variability described in the previous sections.

6.2 INPUT CLIMATE DATA

Key climate data inputs for the AWBM are daily rainfall and daily evapotranspiration (this is different to most rainfall-runoff models, which use potential evapotranspiration) (Podger, 2004).

Rainfall data for the gauged catchments was obtained from nearby recording stations. The locations of these stations are shown in Figure 6.1 and Figure 6.2 respectively.

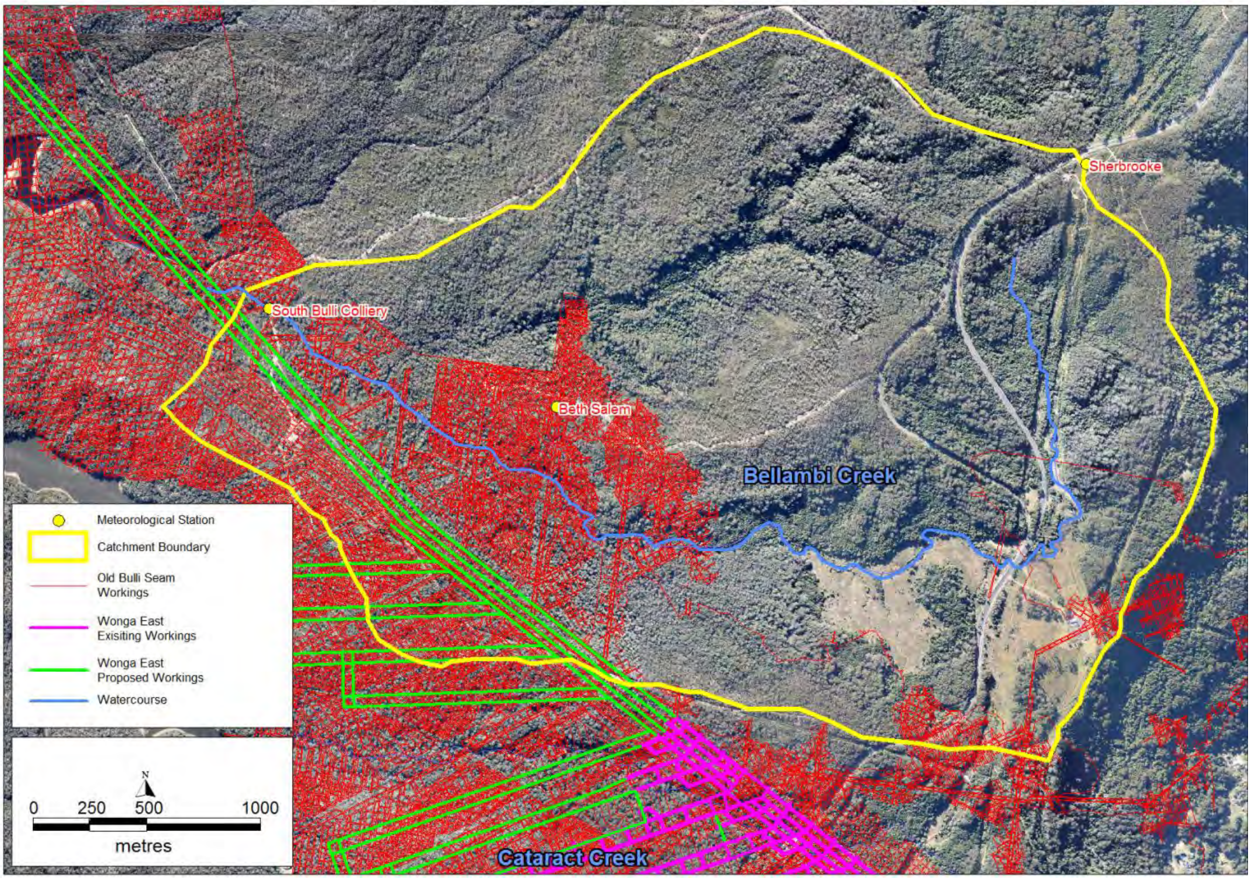


Figure 6.1 Bellambi Creek Catchment

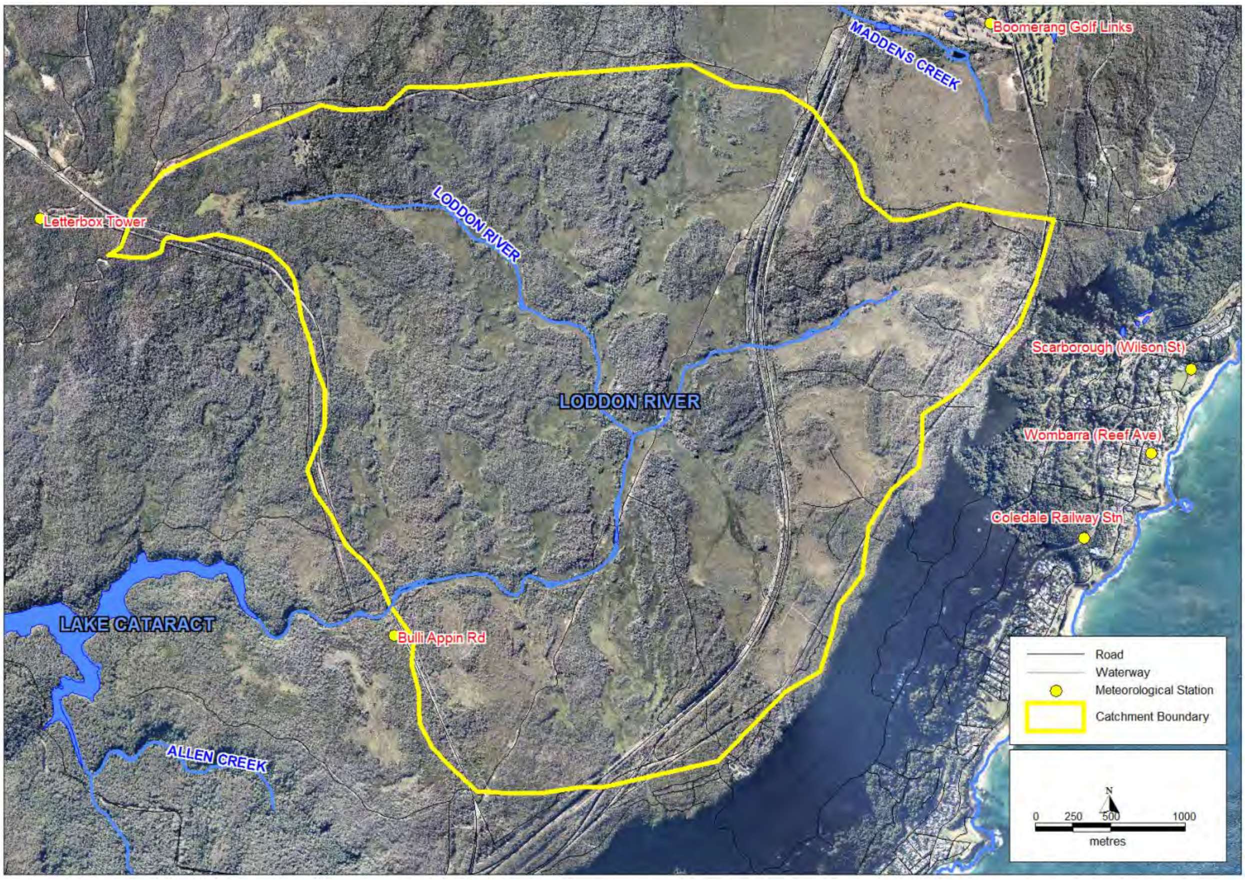


Figure 6.2 Loddon River Catchment

As pan evaporation has not been recorded in the immediate vicinity of the streamflow gauges, the BOM's SILO Data Drill service was used to derive inputs for catchment modelling. The Data Drill *"accesses grids of data derived by interpolating the Bureau of Meteorology's station records. Interpolations are calculated by splining and kriging techniques. The data in the Data Drill are all synthetic; there are no original meteorological station data left in the calculated grid fields. However, the Data Drill does have the advantage of being available for any set of coordinates in Australia"* (Bureau of Meteorology, 2006).

Data Drill data was used to infill and extend the datasets from the nearby recording stations where required. Details of the data used are summarised in Table 6.1. Daily rainfall derived using the Data Drill are compared to rainfall observations in Appendix A for nearby rainfall gauges.

While the Data Drill data is a synthetic dataset, and therefore needs to be used with caution, it can be useful for catchment studies where insufficient site-specific data is available.

Table 6.1 Input Data Sources for Catchment Modelling

Stream Gauge	Rainfall Data Source	Evapotranspiration Data Source
Bellambi Creek at South Bulli No.1	Beth Salem (Raw Data from SCA extend and with gaps in-filled using Data Drill at Beth Salem)	Data Drill at Beth Salem
Loddon River at Bulli-Appin Rd	Letterbox Tower (Raw Data from SCA extend and with gaps in-filled using Data Drill at Beth Salem)	Data Drill at Letterbox Tower

The recorded datasets are shown in the following four figures, which also show the duration and timing of rainfall data gaps that were infilled prior to calibration and the SCA quality codes assigned to the streamflow records. Descriptions of the corresponding quality codes are given in Table 6.2.

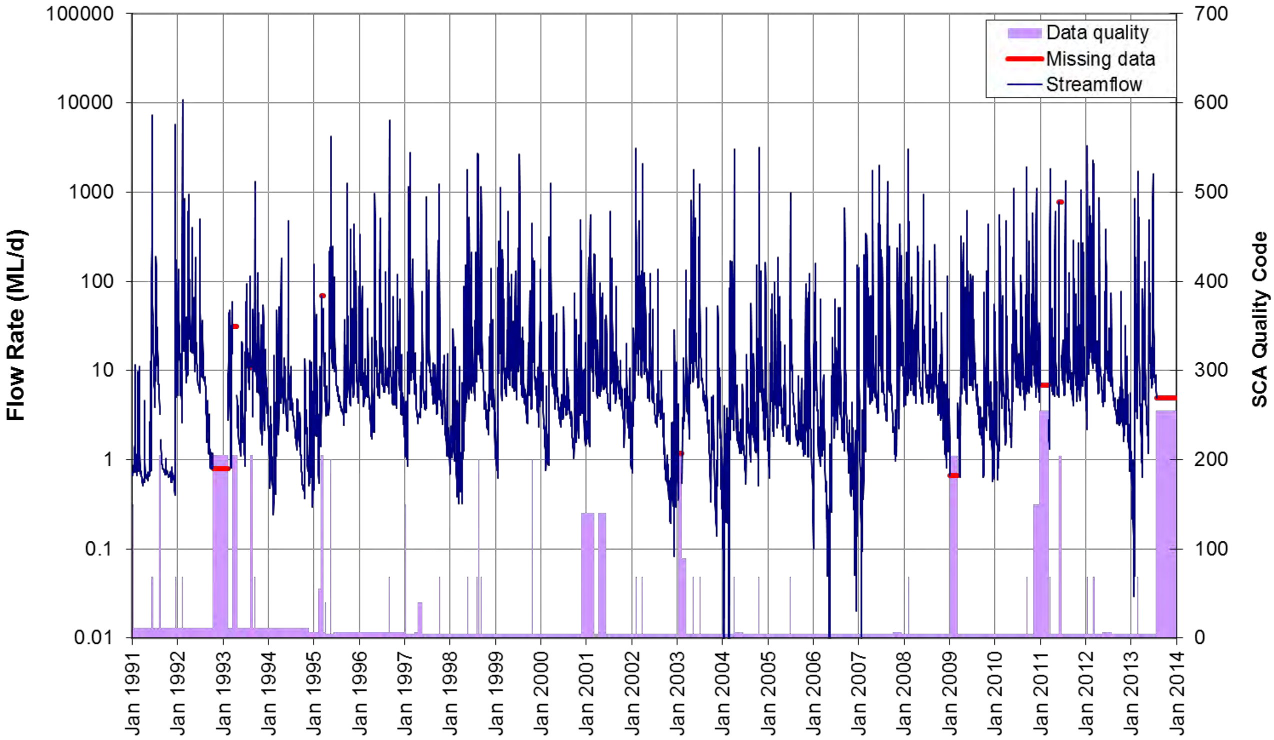


Figure 6.3 Streamflow Measured at Loddon River at Bulli Appin Road

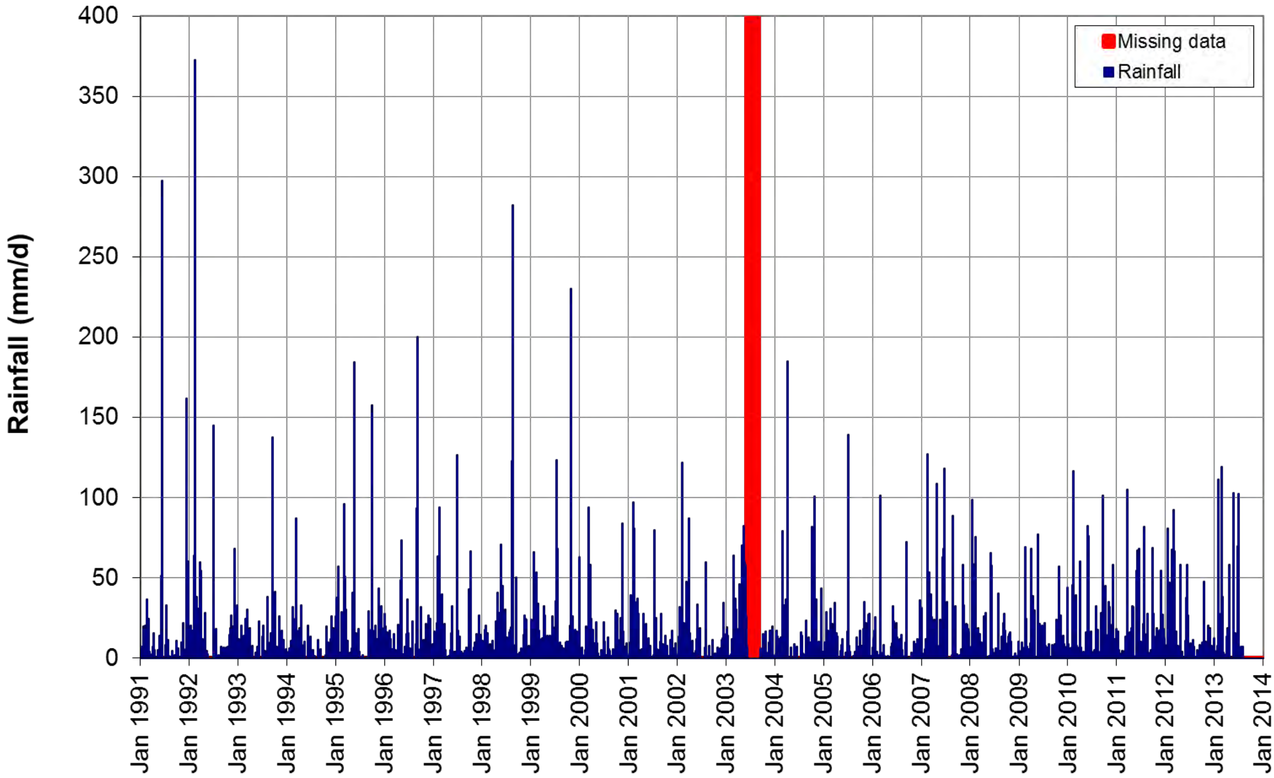


Figure 6.4 Rainfall Measured at Letterbox Tower over Loddon River Gauge Period

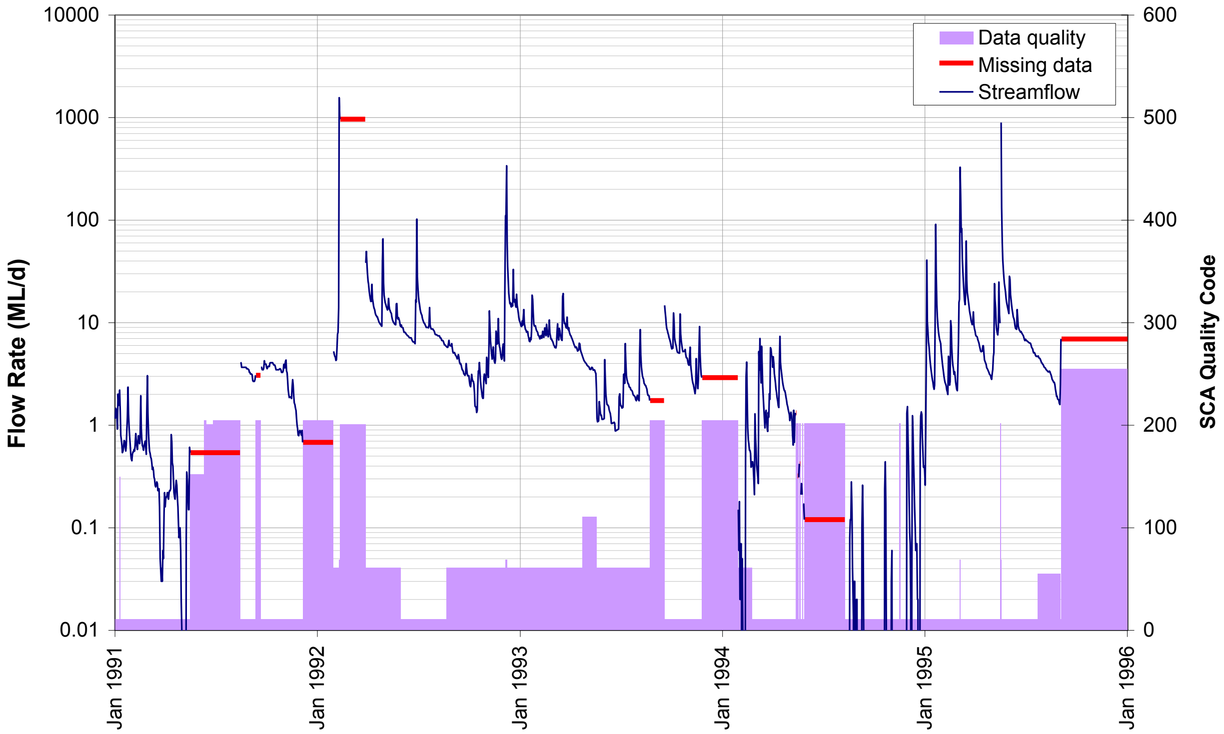


Figure 6.5 Streamflow Measured at Bellambi Creek at South Bulli No. 1

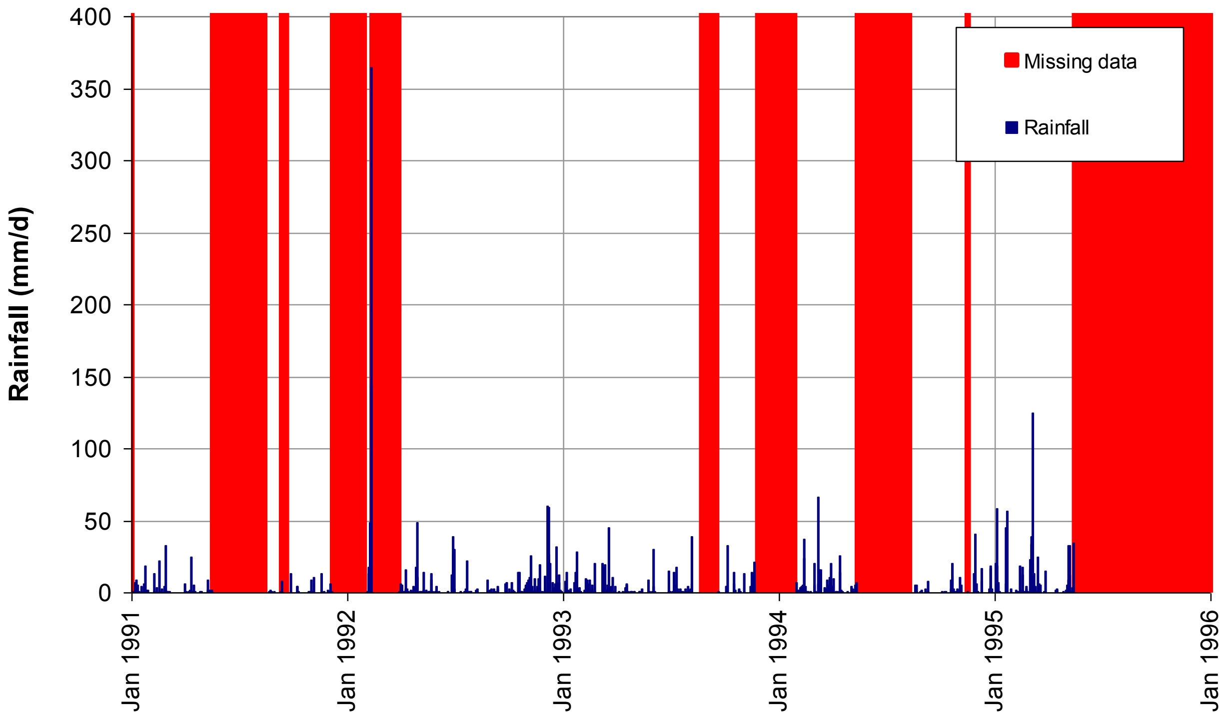


Figure 6.6 Rainfall Measured at Beth Salem Over Bellambi Creek Gauge Period

Table 6.2 SCA Quality Code Descriptions

Quality Code	Description
5	Good quality edited data
6	Reasonably good quality edited data
11	Good quality record processed pre 1995 and coded either 5 or 6
40	Good quality estimate (correlation or other reliable method)
55	Fair quality edited data
57	Fair quality contractor supplied data
61	Fair quality record processed pre 1995 and quality coded 55
69	Fair quality rating extrapolation
90	Fair quality estimation (correlation or other method)
105	Poor quality edited data
111	Poor quality records processed pre 1995 and quality coded 105
119	Poor quality rating extrapolation
140	Estimate that reasonably reflects the actual event with edit comments inserted to explain method of estimation
149	Contractors data supplied without quality codes
150	Data not yet quality coded
151	Backwater affected
152	Data for which quality
162	SENSOR OUT OF WATER WITH NO FLOW
201	Data not recorded - logger/sensor not installed
202	Data not available for release (e.g requires extensive editing)
204	Data lost due to vandalism
205	Data lost
255	Hydsys default - no data

6.3 CALIBRATION OF BELLAMBI CREEK CATCHMENT MODEL

The Bellambi Creek AWBM Model was calibrated over the period between the 1st January 1991 and the 1st September 1995. The adopted AWBM parameters are summarised in Table 6.3 below.

Table 6.3 Adopted AWBM Parameters – Bellambi Ck Catchment

Parameter	Value
A1	0.134
A2	0.433
BFI	0.317
C1	6
C2	94
C3	240
K_{base}	0.976
K_{surf}	0.632

It was not possible to perfectly replicate all streamflow features of interest (e.g. annual flow, flow frequency, monthly flow, daily flow, hydrograph shape, and baseflow) at all temporal scales. The calibration parameters were selected to achieve a compromise between matching the above characteristics.

Observed and simulated streamflow time series are compared in Figure 6.7. During the period from mid-1992 to mid-1993 the model underestimates baseflow, and during mid-1995 it overestimates baseflow. This is probably due to rainfall variability, with the earlier discrepancy due to differences between the rainfall recorded at Beth Salem compared to the rest of the catchment, and the latter due to the limitations of using Data Drill rainfall in areas of high rainfall gradient. The presence of Charlesworth Dam in the upper catchment will also tend to reduce flows during dry periods, and possibly slightly delay flow down the catchment.

Simulated mean annual runoff is 3,644 ML/a, compared to the observed mean annual runoff 3,279ML/a over the same period. The streamflow frequency curves in Figure 6.8 show a reasonable match, but flows between 10ML/d and 100ML/d tend to be overestimated by the model, and flows between 1ML/d and 10ML/d are underestimated. The model fit is reasonable given the limitations of the available data. The most significant discrepancy is that the model tends to underestimate the frequency of no-flow periods.

As mentioned in Section 5, very low flows less than 1 ML/d appear to occur less frequently in Bellambi Creek than in Loddon River. This could be due to rating curve errors, or be a hydrological characteristic of this catchment. Alternatively, low flows may have been affected by historical streamflow loss through subsidence-induced cracking of Bellambi Creek. The observed discrepancy would be consistent with a streamflow loss of 0.3ML/d.

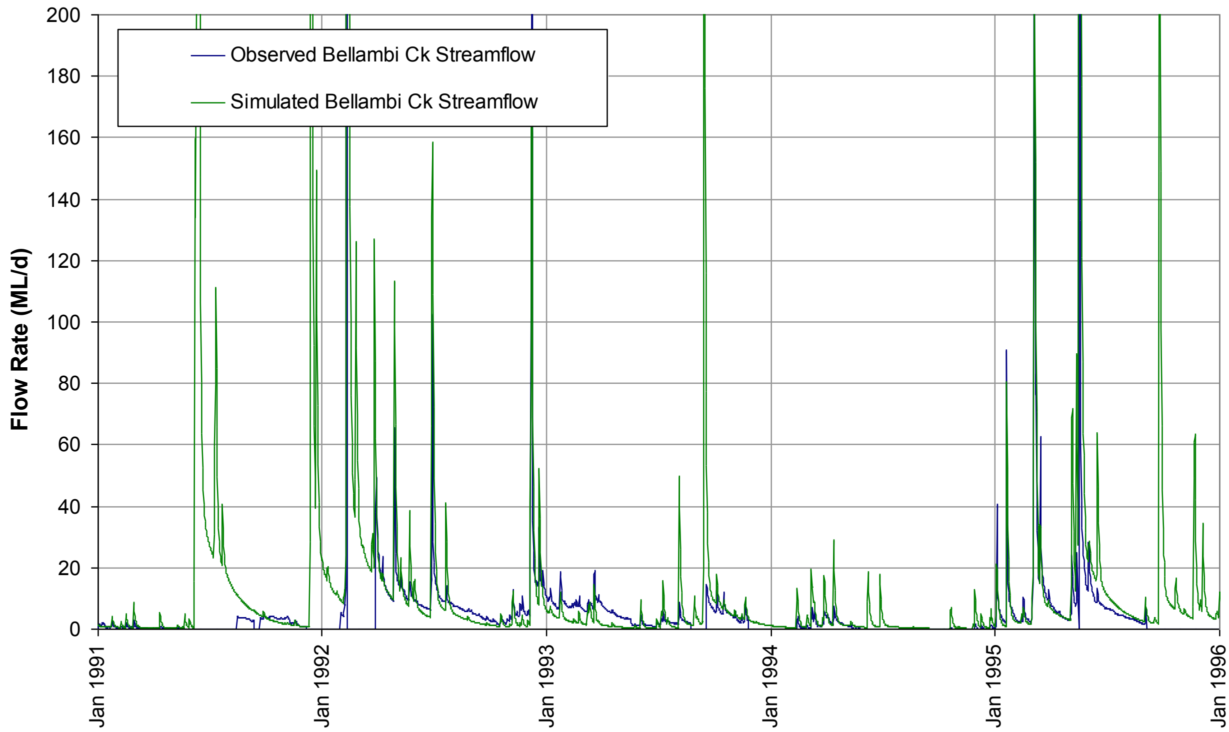


Figure 6.7 Observed and Simulated Streamflow – Bellambi Ck at South Bulli No. 1

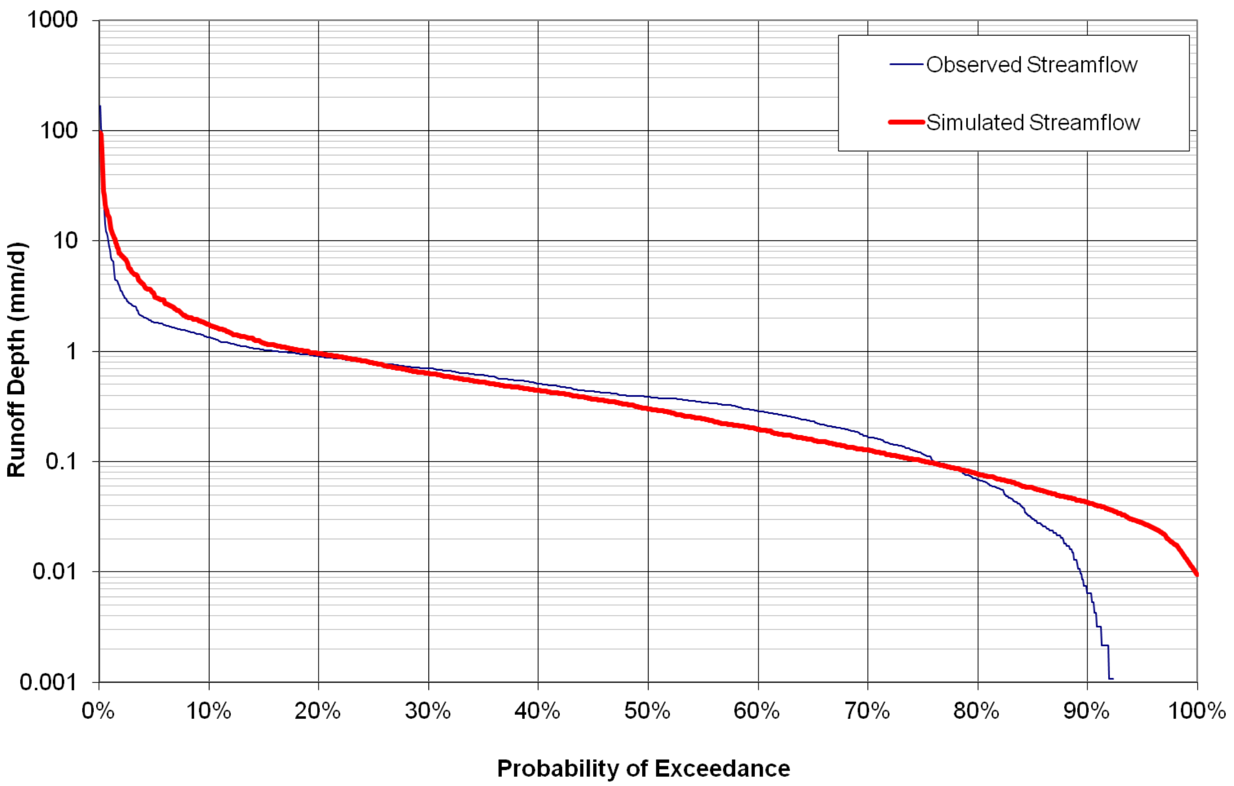


Figure 6.8 Observed and Simulated Streamflow Frequency Curves - Bellambi Ck at South Bulli No.1

6.4 CALIBRATION OF LODDON RIVER CATCHMENT MODEL

The Loddon River AWBM Model was calibrated over the period between the 1st January 1991 and the 8th November 2009. The adopted AWBM parameters are summarised in Table 6.4 below.

It was not possible to perfectly replicate all streamflow features of interest (e.g. annual flow, flow frequency, monthly flow, daily flow, hydrograph shape, and baseflow) at all temporal scales. The calibration parameters were selected to achieve a compromise. The calibration parameters were selected to achieve a compromise between matching the above characteristics, and tend to match the observed frequency of very low flows curve at the expense of matching the full baseflow recession curve for some flow events.

Table 6.4 Adopted AWBM Parameters – Loddon River catchment

Parameter	Value
A1	0.134
A2	0.433
BFI	0.200
C1	12.0
C2	39.4
C3	100.0
K_{base}	0.975
K_{surf}	0.200

Observed and simulated streamflow time series are compared in Figure 6.9 below.

Simulated mean annual runoff is 13,245 ML/a, compared to the observed mean annual runoff of 13,920 ML/a over the same period.

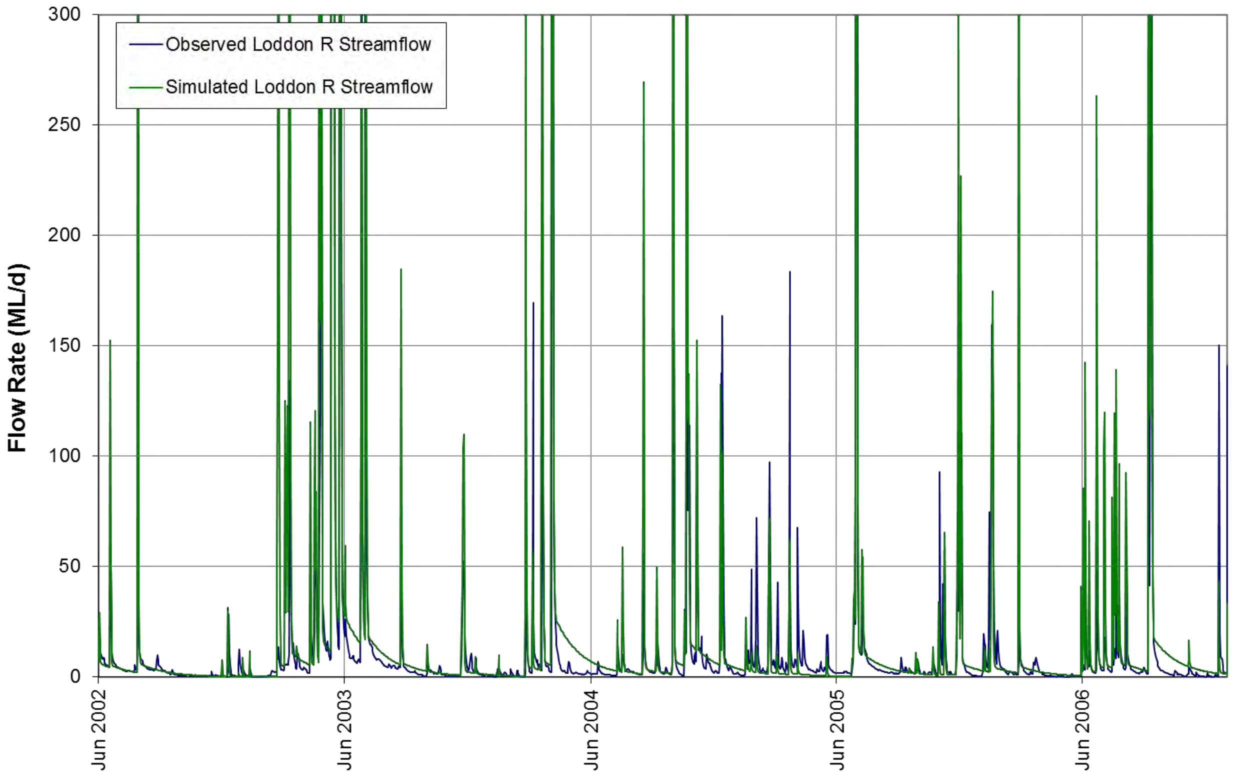


Figure 6.9 Observed and Simulated Streamflow – Loddon River at Bulli Appin Road – Sample of Record from June 2002 to December 2006

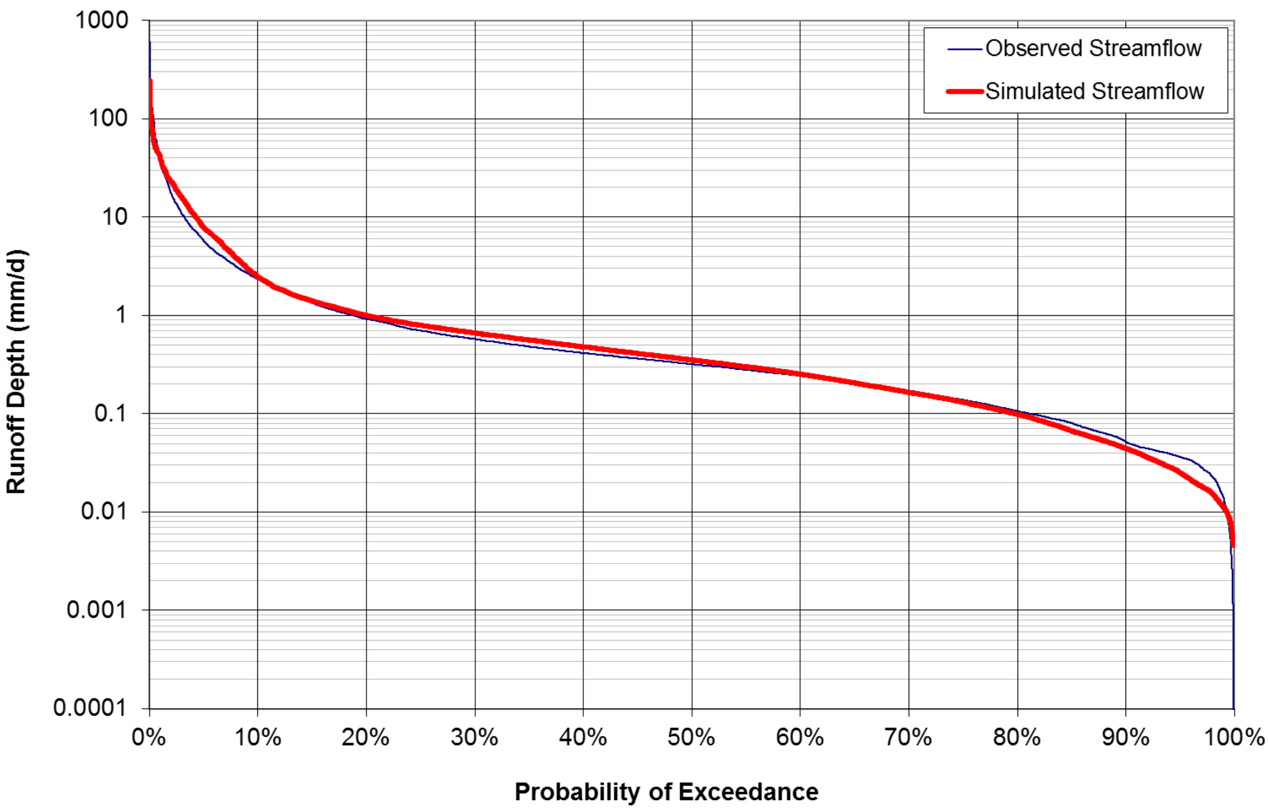


Figure 6.10 Streamflow Frequency Curves for Loddon River at Bulli Appin Road

6.5 STREAMFLOW IN AFFECTED CATCHMENTS

While insufficient information is available to derive accurate rating curves for monitoring sites, the water level observations can be used to verify the ability of the model to reproduce streamflow characteristics in the affected catchments.

Figure 6.11 below compares modelled daily streamflow to water levels observed every 12 hours at monitoring station CC4 between February 2012 and June 2012. The figure shows the model produces runoff at the same times as were observed, and also the persistence of baseflow over similar periods to what was observed.

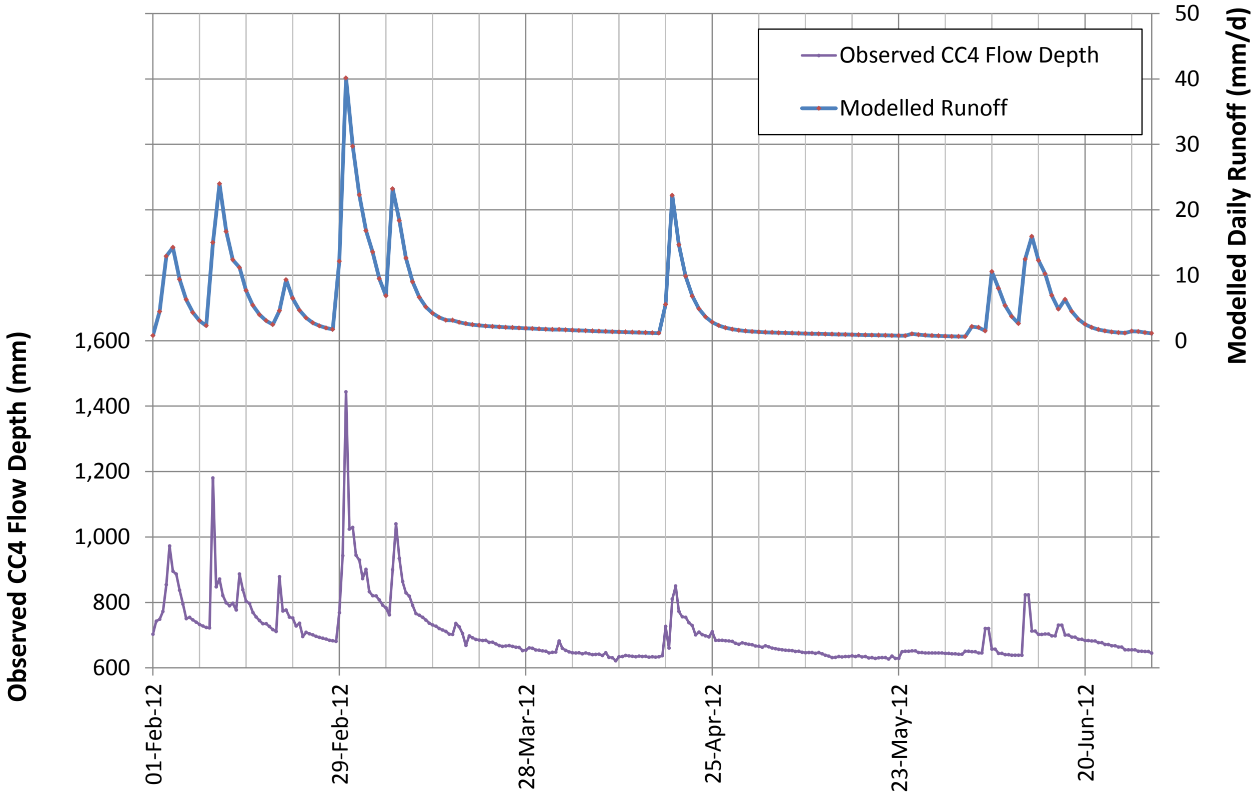


Figure 6.11 Comparison of Modelled Streamflow to Water Level Observations at CC4

Figure 6.12 shows the contribution that baseflow makes to total streamflow over this period. Based on catchment modelling, over the long term, it makes up approximately 32% of total flow. The relative contribution of baseflow to average streamflow varies seasonally, as shown in Figure 6.13.

Table 6.5 summarises the modelled surface runoff and baseflow at each of the monitoring points. The table shows that average daily streamflow is significantly larger than median daily due to the impact of a small number of large surface flow events. Average daily streamflow at CC9 on Cataract Creek is 11.2 ML/d of which 3.5ML/d is baseflow. Median baseflow at this location is 2.2ML/d.

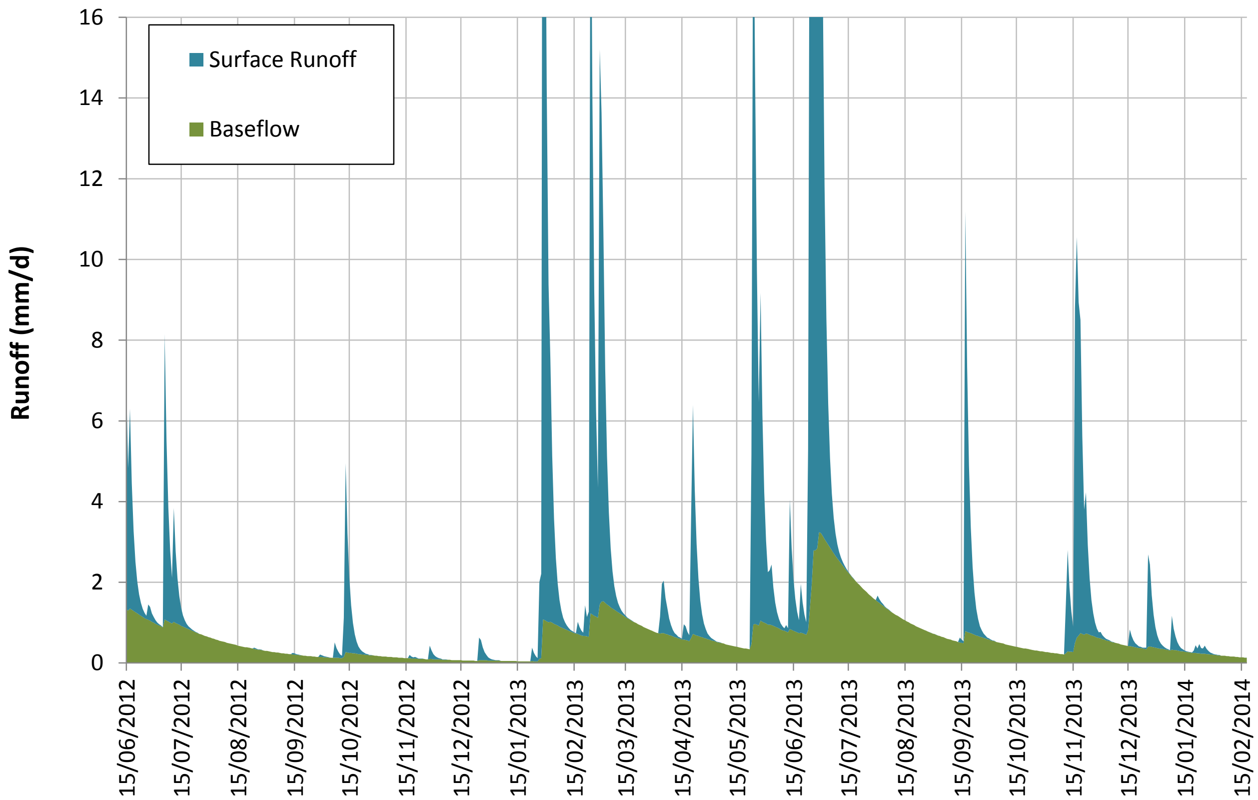


Figure 6.12 Modelled Cataract Creek Baseflow and Surface Flow Hydrographs

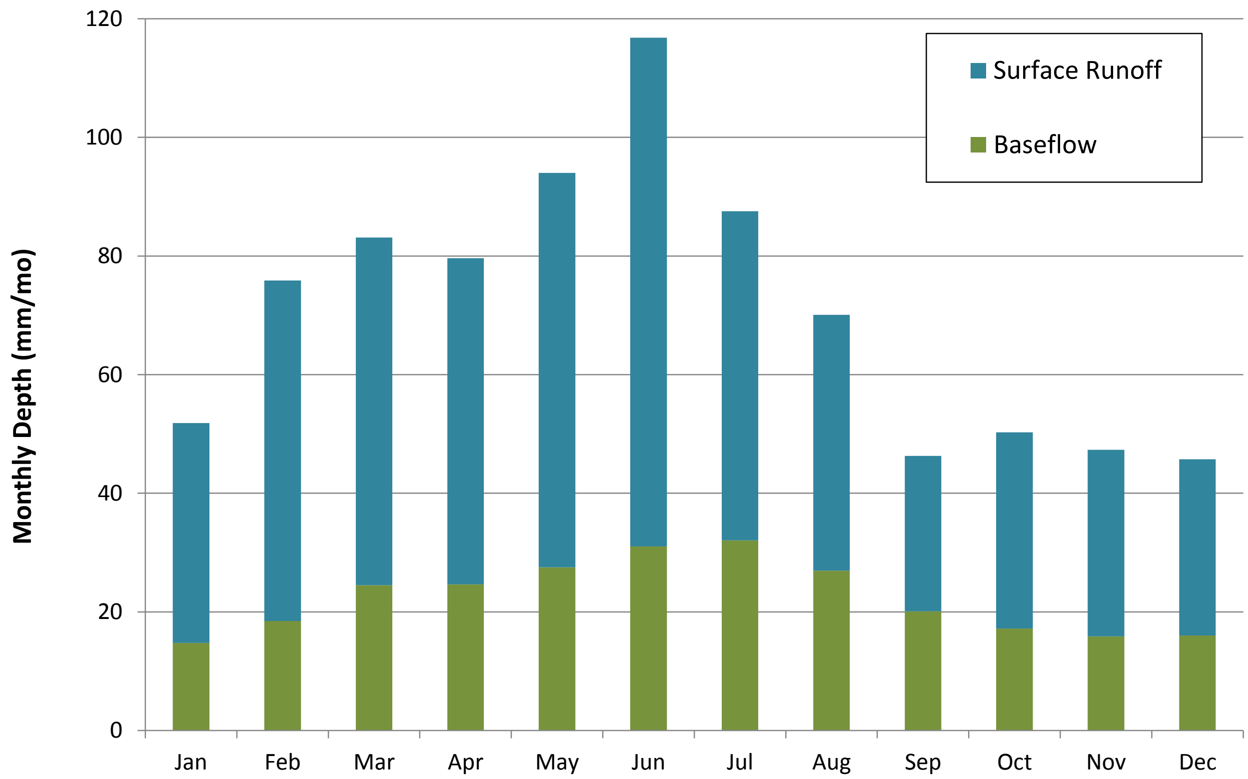


Figure 6.13 Modelled Cataract Creek Mean Monthly Baseflow and Surface Flow

Table 6.5 Contribution of Baseflow to Mean and Median Daily Modelled Flow at Monitoring Points

Catchment	Average Flow (ML/d)			Median Flow (ML/d)		
	Surface Runoff	Baseflow	Total Streamflow	Surface Runoff	Baseflow	Total Streamflow
Cataract Creek						
CC3	1.7	0.8	2.5	0.04	0.49	0.71
CC5	4.2	2.0	6.2	0.11	1.22	1.78
CC6	4.6	2.1	6.8	0.12	1.34	1.95
CC7	5.5	2.6	8.1	0.14	1.60	2.33
CC8	6.6	3.1	9.7	0.17	1.92	2.80
CC9	7.6	3.5	11.2	0.19	2.21	3.22
Cataract River						
CR2	15.4	7.1	22.5	0.39	4.46	6.49
CR4	17.5	8.1	25.6	0.44	5.07	7.39
Bellambi Creek						
BC4000	6.5	3.0	9.5	0.16	1.89	2.75
BC4500	7.7	3.6	11.2	0.19	2.23	3.24
BC5000	8.6	4.0	12.5	0.22	2.48	3.61

7 LAKE CATARACT RESERVOIR YIELD

7.1 OPERATIONAL DATA SUPPLIED BY SCA

The SCA provided data pertaining to the operation of Lake Cataract. The daily stored volume, controlled release (including regulated discharges and environmental releases) and spillway discharge information are shown in Figure 7.1. Releases are made from Cataract Dam for the purposes of meeting water supply requirements and providing environmental flows. Figure 7.2 shows the surface area and water volume characteristics of the lake.

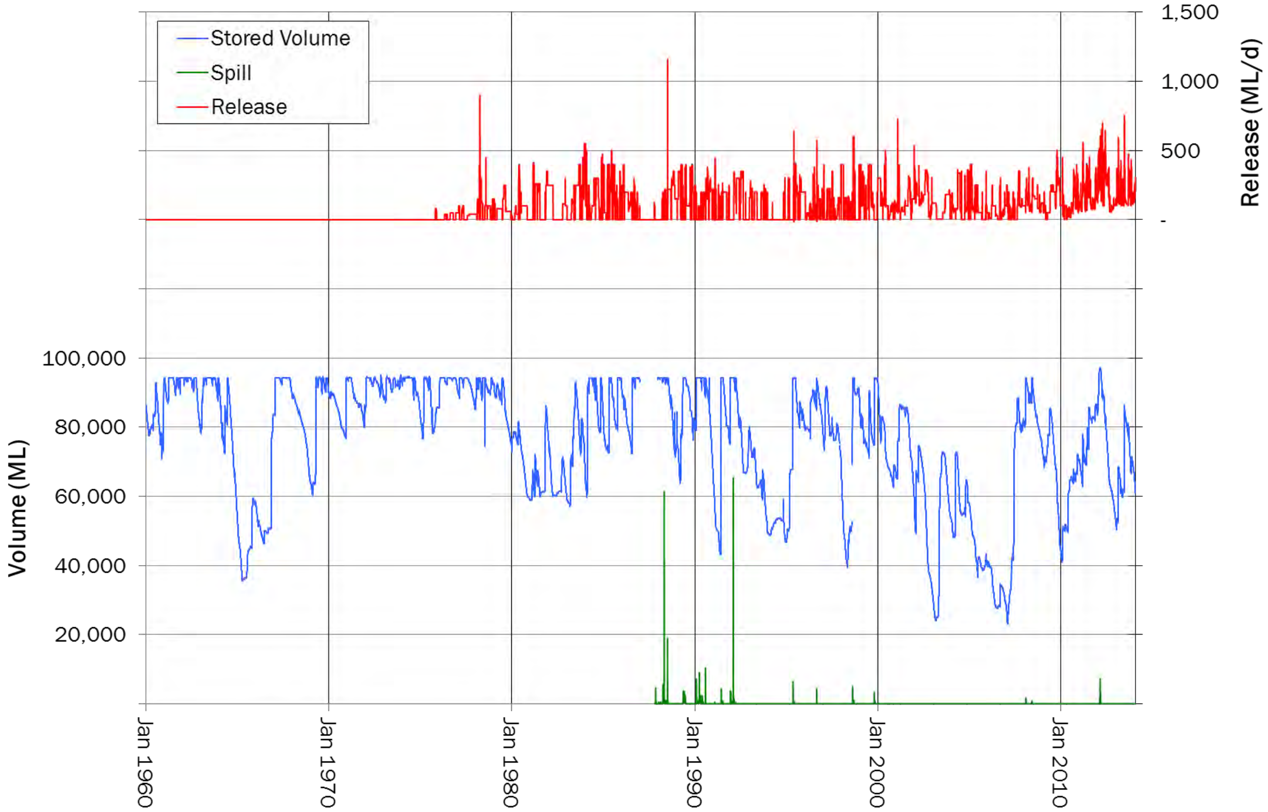


Figure 7.1 Lake Cataract Operational Data

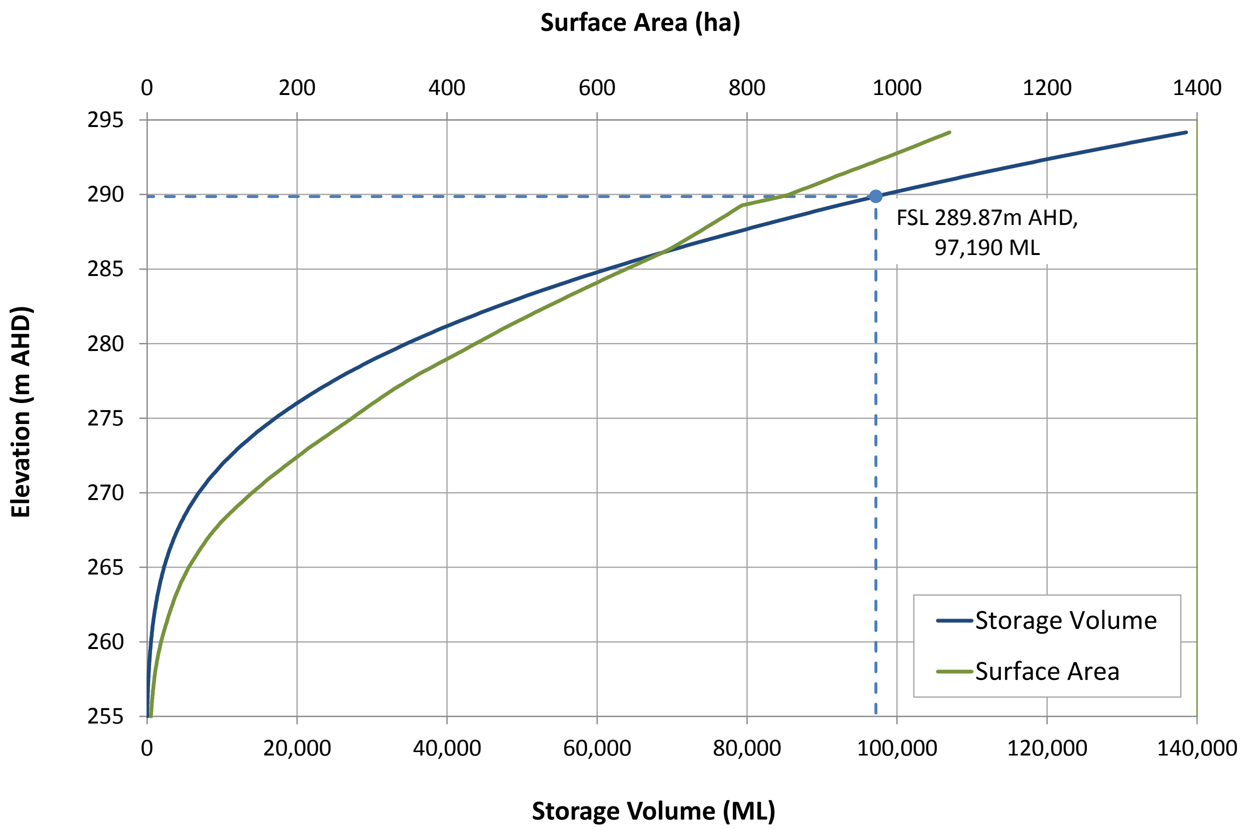


Figure 7.2 Lake Cataract Storage Curves

7.2 PURPOSE OF MODEL

A daily timestep water balance model of the Lake Cataract reservoir was developed with a view to deriving time series of inflows and outflows which replicate the historical behaviour of the reservoir.

These time series could then be used to develop a reservoir model to determine the impact of additional catchment losses on the potential for the storage to be drawn down completely under historical conditions. The focus of the analysis was therefore on reproducing behaviour during the longest dry spell on record, which occurred between 2002 and 2007.

7.2.1 Model Schematisation

The behaviour of Lake Cataract was simulated using a daily time step spreadsheet model comprising the following major components (shown schematically in Figure 7.3):

- Direct rainfall to the lake surface - a daily time series of rainfall depths was obtained from the SILO Patched Point Dataset for Cataract Dam. The rainfall depth was applied to the lake surface area estimated at each time step from the storage curve shown in Figure 7.2.

- Evaporation from the lake surface – a time series of lake evaporation rates was obtained from the SILO Patched Point Dataset for Cataract Dam. The pan evaporation rate (adjusted by a pan factor of 0.9) was applied to the lake surface area estimated at each time step from the storage curve shown in Figure 7.2.

- Releases from the dam – the daily time series of recorded releases provided by SCA were extracted from the storage.

- Spills from the dam – inflows exceeding the remaining water storage were treated as spills.

Each of the above inflows and outflows can be quantified relatively easily and accurately. The most challenging input to estimate is the catchment runoff - due to the lack of long-term streamflow records and the high spatial variability of rainfall in the catchment.

Catchment runoff was estimated using recorded streamflow in contributing tributaries, where available, and the AWBM rainfall/runoff model where it was not. The highly variable rainfall of the area necessitated subdividing the catchment into four subareas with different combinations of AWBM catchment parameters and input daily climate datasets (as summarised in Figure 7.3).

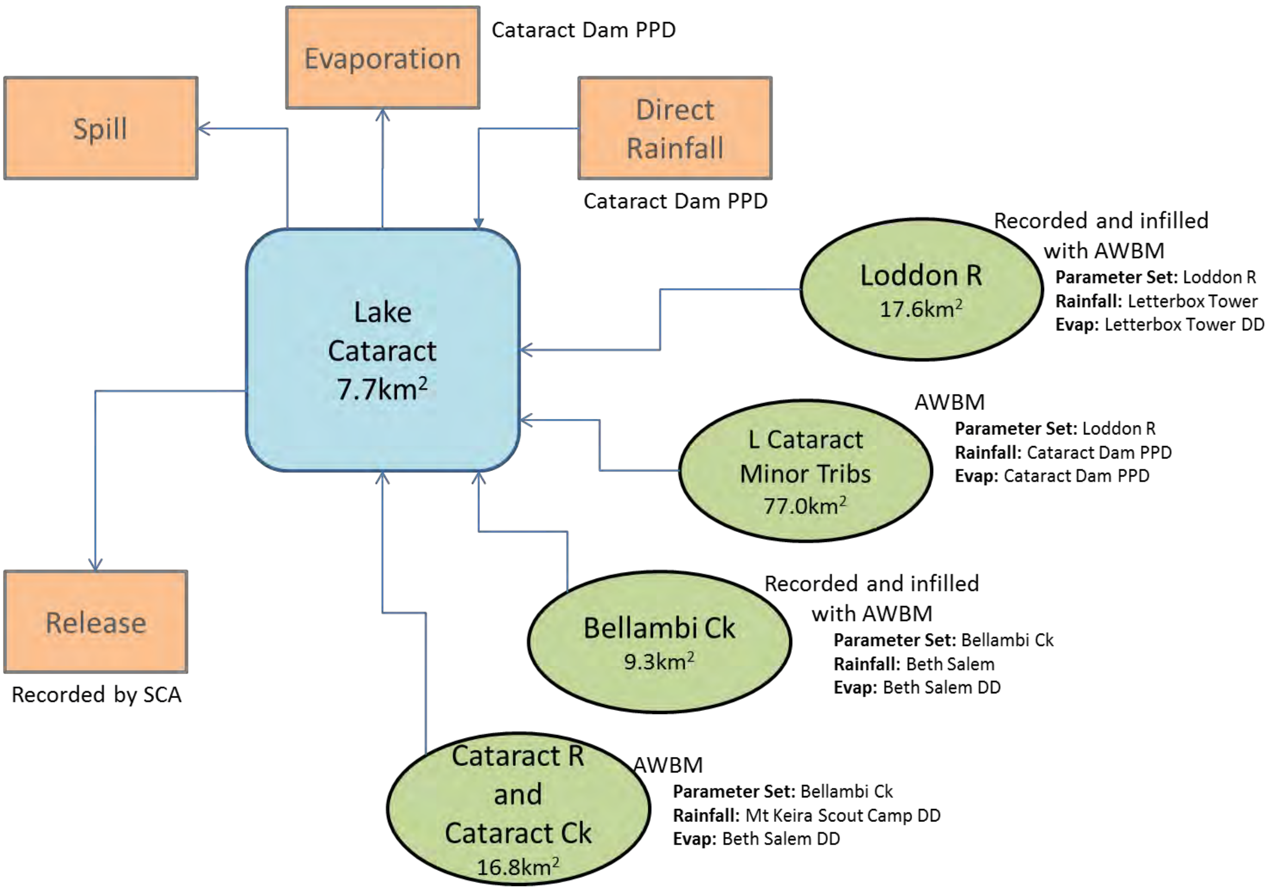


Figure 7.3 Lake Cataract Hydrological Model

Over the period of records since 1977, based on the results of the water balance modelling, the total water balance for the reservoir is estimated to be as follows:

Table 7.1 Lake Cataract – Average Annual Water Balance

Item	Flow (ML/a)
Catchment Runoff (including direct rainfall)	217
Surface Evaporation	25
Seepage to Groundwater	10
Releases (recorded)	120
Overflows	64
Change in Volume	-2

The above estimates should be used with some caution, because while the distribution of rainfall as defined in Figure 7.3, is likely to be generally representative of distributions over the catchment, it is not perfectly representative across all historical events. This is illustrated in Figure 7.4 which shows that over much of the historical record, the model gives a good representation of historical stored volumes, but there are discrepancies in the volume of runoff (and hence also overflows) generated during some inflow events.

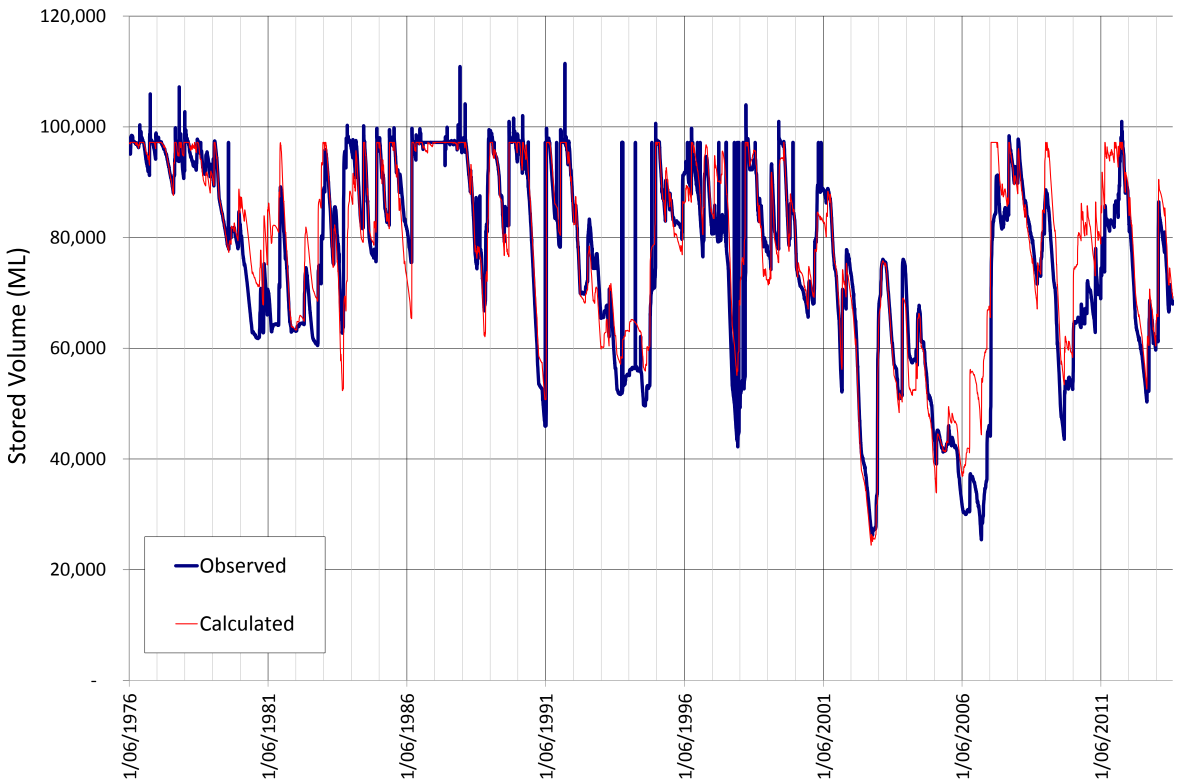


Figure 7.4 Observed and Modelled Volume at Cataract Dam from 1977

For the purpose of the yield impact assessment, a more accurate representation of historical inflows, runoff was estimated from the change in stored volume during wetter periods. The resultant time series of modelled stored volume is a good representation of the observed behaviour - as shown in Figure 7.5.

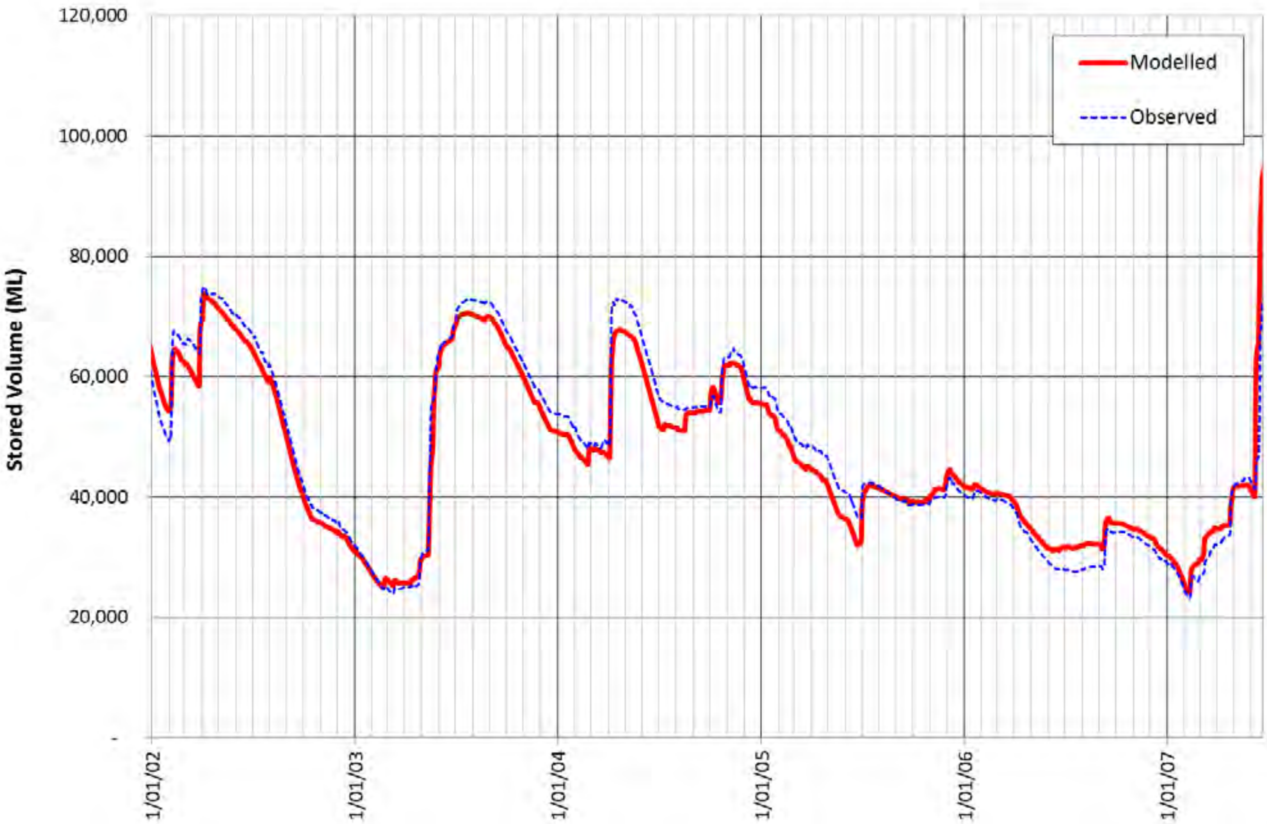


Figure 7.5 Observed and Modelled Dry Period Volume at Cataract Dam 2002-2007

The most rapid drawdown of the reservoir occurred between August 2003 and March 2003. Over this period, the stored volume fell from 88,780 ML to 26,190 ML26191 (62,590 ML) (by June 2003 - the dam stored over 67,000ML again).In 587 days - this equates to a 107ML/d loss – made up of:

- Releases to supply demand - 169ML/d;
- Evaporation - estimated to be approximately - 23.5ML/d;
- Seepage to groundwater of - 10ML/d;
- Runoff inflows - estimated from modelling to be 94.1ML/d

8 CONTRIBUTION OF CATCHMENTS POTENTIALLY AFFECTED BY SUBSIDENCE

8.1 POTENTIAL MECHANISMS FOR HYDROLOGICAL IMPACTS

The following potential hydrological risks have been raised as stakeholder concerns:

- **Reservoir yield** - the possibility that the quantity of water reaching Lake Cataract and Broughtons Pass Weir could be reduced,

- **Stream health** – the possibility that cracking of the stream beds draining into Cataract Dam and Broughtons Pass Weir may induce loss of overland stream flow and adversely affect stream water quality or stream health.

In its review of the Metropolitan Coal Project Environmental Assessment, the Planning Assessment Commission (PAC) Panel cited the following potential mechanisms whereby this may occur (NSW PAC, 2009):

1. Rainfall on the broader catchment, which previously found its way to watercourses by surface or subsurface flow infiltrates through fractures and is permanently lost to the surface water system.
2. Water in streams that are subject to fracturing is lost from the surface water system to the groundwater system and does not reappear.

The above potential risks are addressed in the following sections.

In its submission on the DGR's the Department of Water and Energy required this EA report *demonstrate the project is consistent with the spirit and principle of the NSW State Rivers and Estuaries Policy, Wetland Management Policy, including :*

1. *General description of channel form, river style or other descriptive category of any affected channel, including identification of key geomorphological indicators and conditions within the zone of influence for the proposal.*

2. *Hydrologic and geomorphic character of the riverine system, stream energy and stream power relationships, energy relationships at bankfull stage and at peak flow, and assessment of stream power and critical tractive stress for existing and any modified conditions for any rivers affected by the proposal, which provides details of:*
    - *long profile and cross sectional survey along the channel, and identification of at least the closest upstream and downstream controls on the channel*
    - *assessment of bed and bank material, identification of critical entrainment and destabilisation thresholds*
    - *assessment of the constriction and resultant change in afflux through, past or over the structure, and resultant changes in energy profiles involving the structure*

- *nature of bedload transport, and mechanism(s) to permit bedload transport through the structure*

3. *Procedures to develop stream relocation and reconstruction criteria which utilise best practice management, which must include the principles which underpin any embargoes currently in force under the Water Act, 1912, or operational rules of any Water Sharing Plan in force under the Water Management Act 2000 over the site*

4. *Methodologies by which proposed relocation or reinstatement of watercourses will be undertaken, and whether any proposed ecological offset provisions will provide adequate protection to any instream or groundwater dependent ecosystems which exist on the site*

5. *Mechanism to maintain long profile grade through the structure, or to provide energy dissipation through the structure at the re-entry point design volumes/velocity downstream*

6. *Nature of existing controls along all watercourses on the site, and proposed use of engineered and vegetation to provide long term control to the channel*

7. *Final configuration of any relocation, modification or other impact upon rivers and watercourses on or surrounding the site, including geomorphic character mimicking conditions of undisturbed rivers or watercourses adjacent to the proposal area*

The streams overlying the project area are not being relocated or reinstated, and no instream structures are proposed. The predicted subsidence impacts are expected to result in only small changes to the stream bed profile. As a result, localised reductions in bed gradients are not likely to cause significant additional ponding. Any localised increase in bed gradient is likely to be within the range of those occurring naturally, and as the stream bed material comprises competent rock, the resultant localised increases in stream power and tractive force are unlikely to cause bed scour. As a result, we have not undertaken a detailed assessment of bedload transport mechanisms or afflux.

The proposed workings will potentially disturb the following portions of the catchments in the Study Area.

Table 8.1 Potential Subsidence Areas Compared to Total Catchment Area

Stream	Catchment Area (km^2)						
	Total Catchment to D/S Confluence	Subsided by More Than 20mm	Percentage Subsided	U/S of Disturbance Envelope	% U/S	D/S of Disturbance Envelope	% D/S
Lake Cataract*	127.8	4.4	3.5%	1.9	1.5%	125.9	98.5%
Cataract Creek	5.2	3.2	61.3%	1.9	36.0%	3.3	64.0%
Cataract River	11.6	0.5	4.3%	0.0	0.0%	11.1	95.7%
Bellambi Creek	9.3	0.4	4.8%	0.0	0.0%	8.9	95.2%

*Lake Cataract disturbance includes disturbance area in Cataract Creek, Cataract River and Bellambi Creek.

8.2 ASSESSMENT METHODOLOGY

The PAC has previously noted that without special techniques and extensive quality control and checking, the normal accuracy of stream gauging measurements combined with staged measurements and the derivation of rating curves, precludes reliable detection of small absolute changes in stream flows from one location to the next (NSW PAC, 2009). This is further affected by the likelihood that in Hawkesbury Sandstone based waterways with natural (and potentially induced) bedding plane as well as jointing washouts and fractures, subsurface flow is present that can not be accurately measured, especially during low flow regimes.

In its review of the Metropolitan Coal Project Environmental Assessment, the PAC was of the view that because fracturing is likely to only occur in the surficial groundwater system, and that any increase in initial rainfall runoff losses would be temporary, any surface water losses would therefore be undetectable unless the surficial groundwater system intercepted a permeable subsurface stratum that bypassed the reservoir (NSW PAC, 2009).

The Southern Coalfield Inquiry was also of the view that there was no evidence that *"subsidence impacts have resulted in any measurable reduction in runoff to the water supply system operated by the Sydney Catchment Authority or to otherwise represent a threat to the water supply of Sydney or the Illawarra Region."* (DECC, 2007)

However, the PAC did make the case that the issue was not beyond doubt and recommended further investigation of catchment yield impacts.

The rate of water loss from pools affected by subsidence induced cracking has been measured in waterways overlying other projects in the Southern Coalfield (Gilbert, 2008). However, due to the lack and distribution of suitable overland stream flow monitoring sites within the Study Area, it is not possible to accurately determine the loss, if any of stream flow reporting into Cataract Dam.

The Wonga East area is different to others in the Southern Coalfields, as the main lithology in the creek bed is the Bald Hill Claystone/Newport/Garie Formations and Bulgo Sandstone. The Hawkesbury Sandstone is mainly only present in the upper headwaters. The significance of this is that the non-Hawkesbury Sandstone creek beds respond differently to subsidence. The uplifted sandstone sheets fractured sandstone diversions observed in Hawkesbury Sandstone based channels are not expected in this area (GeoTerra, 2012).

Given these uncertainties, it is not currently feasible to definitively quantify any overland stream flow losses that may, or may not, result from the potential loss mechanisms.

The catchment models developed for the study area have been used to describe how a range of modelled loss rates could impact on streamflow downstream of potentially affected subsidence areas. The Lake Cataract reservoir model has been used to estimate the impact on historical reservoir yield.

8.2.1 Potential Impact on Reservoir Yield

The Lake Cataract model was used to investigate the impact that various loss rates from the upstream catchment would have on reservoir yield.

Catchment and in-stream losses were applied by reducing the Cataract Creek/Cataract River inflow rate by a daily loss rate in ML/d (up to the daily flow rate). Loss rates of 0.5ML/d, 1ML/d, 5ML/d and 10ML/d were applied.

8.2.2 Potential Impact on Streamflow

Based on pool water level reduction rates, overland stream flow loss in the order of 0.5 ML/d have been estimated at other similar projects in the Southern Coalfields (Gilbert, 2008). Based on observations of groundwater inflows and piezometer behaviour in the area, the credible range of subsidence induced streamflow loss from Cataract Creek due to Wonga East operations is of the range 0.1-0.5ML/d (SCT, 2014), (Geoterra, 2012).

Daily flow rates at the reporting locations shown in Figure 5.7 were reduced by 0.1ML/d, 0.3ML/d and 0.5ML/d to indicate the effect on the hydrograph shape and the flow frequency curves.

8.2.3 Potential Additional Loss of Cataract Creek Streamflow due to Tributary Losses

A potential mechanism for the loss of streamflow in Cataract Creek is the loss of flow to the underground workings via cracking in the tributary catchments overlying the subsidence area.

Several unnamed tributaries of Cataract Creek will be impacted by subsidence cracking. Figure 8.1 shows the contributing catchment areas of the 10 mapped tributaries that will be affected by subsidence. The potential impact on Cataract Creek of losing subsidence affected tributary streamflow within, and upstream of, the extent of the underground workings was assessed by removing these areas from the catchment model and examining the effect on key streamflow characteristics at CC9 (which is located upstream of the Lake Cataract free surface level). Catchment areas downstream of the underground workings were left in the model to continue to contribute to streamflow in Cataract Creek. The impact of loss of streamflow in Tributary 10 was examined separately as the confluence with Cataract Creek is located well downstream of CC9.

The likelihood of losing all tributary streamflow to the underground workings via subsidence cracking is very improbable. The purpose of this modelling is to show the contribution of the tributaries to streamflow in Cataract Creek.

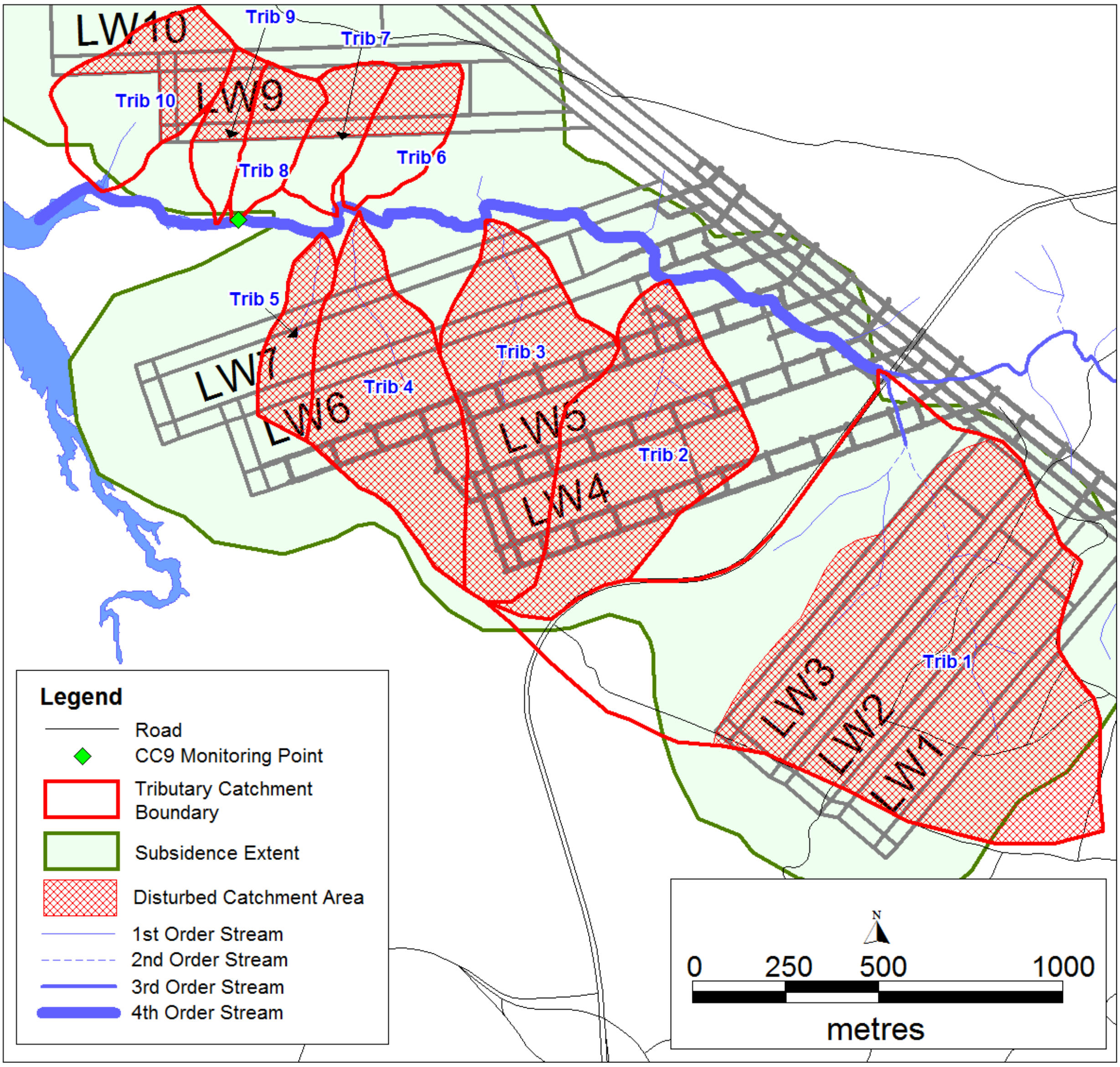


Figure 8.1 Cataract Creek Tributary Catchment Areas

8.3 MODEL RESULTS

8.3.1 Potential Impact on Reservoir Yield

Figure 8.2 below compares the simulated stored water volume with no subsidence losses to those simulated with catchment losses of increasing magnitude.

The overland stream flow loss rates were applied to the total Cataract River (including Cataract Creek) inflow. The results show that under historical water use and climate conditions recorded since 1976, losses of 1ML/d would have had very little impact on Lake Cataract water levels.

The maximum reduction in stored volume occurs in mid-2007 and ranges from 550ML for a loss of 0.5ML/d to 10,890ML for a loss of 10ML/d. Losses of 10ML/d would not have caused the Lake Cataract Reservoir water volume to fall below 10% of capacity. Such loss rates are very large, and based on previous experience and observations at similar coal mines in the Southern Coalfields (Gilbert, 2008) they are unlikely to eventuate given the anticipated and observed response of the stream bed to the predicted subsidence along with the proposed panel layout.

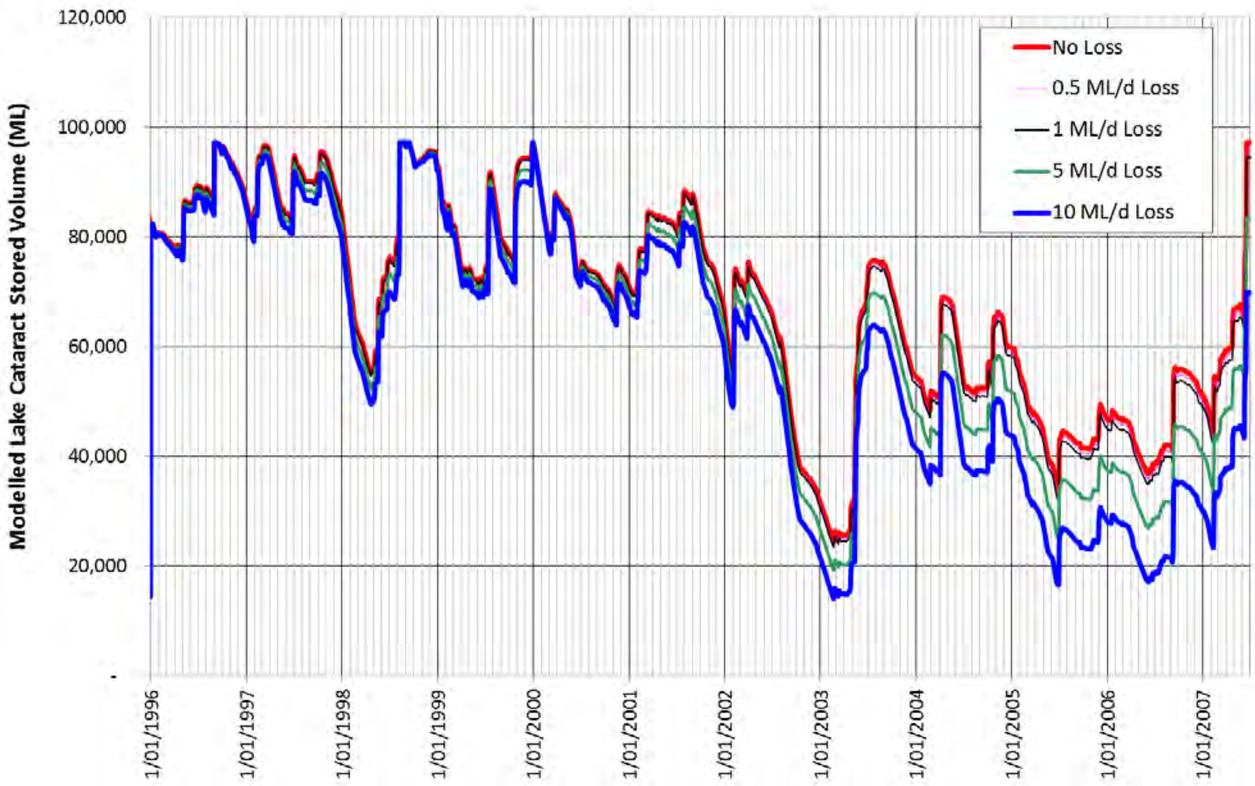


Figure 8.2 Impact of catchment loss on Lake Cataract dry period stored water volume

During a more significant drought which was severe enough to empty the reservoir (i.e. more server than in the reservoir historical record), additional loss created by the project would increase the period of time that water would be unavailable. The worst case scenario (in terms of size of the impact) would be where the reservoir was full at the start of a drought which was long enough to empty it (the length of the drought is not otherwise relevant because the drought-breaking inflow would be much greater than the losses – so supply would restart at the same time after rainfall regardless of the loss).

The table below illustrates the potential impact on supplies from the reservoir in terms of how much longer the dam would be empty because of the extra loss of water. The period of time is dependent on the rate of supply from the dam, as well as the loss rate. The table shows that over the range of likely release rates and loss rates, the impact is likely to be of the order of no more than a few days of no supply.

Table 8.2 Additional Days of No Supply During Reservoir-Emptying Drought

Loss Rate	SCA Release Rate (ML/d)						
ML/d	**20**	**50**	**100**	**200**	**300**	**400**	**500**
0.1	3.9	1.5	0.6	0.2	0.1	0.1	0.0
0.3	11.6	4.5	1.7	0.6	0.3	0.2	0.1
0.5	19.2	7.5	2.9	0.9	0.4	0.3	0.2
1	38.1	15.0	5.7	1.8	0.9	0.5	0.3
5	176.7	71.5	27.7	9.0	4.4	2.6	1.7
10	324.0	135.0	53.4	17.6	8.7	5.1	3.4

8.3.2 Potential Impact on Streamflow

The results of the analysis over the period January 1986 to January 1988 are illustrated in Figure 8.3 and Figure 8.4, which show modelled flow rates at the Cataract Creek pool monitoring stations CC5 and CC9 using the Bellambi Creek AWBM parameters. It should be emphasised that the model overestimates recorded low flows and there are no cease to flow periods in the modelled streamflow dataset.

The effect of losses of the magnitude considered would have a proportionally smaller impact on large flows. However, they could constitute a higher portion of baseflow under low flow conditions at the localised affected areas.

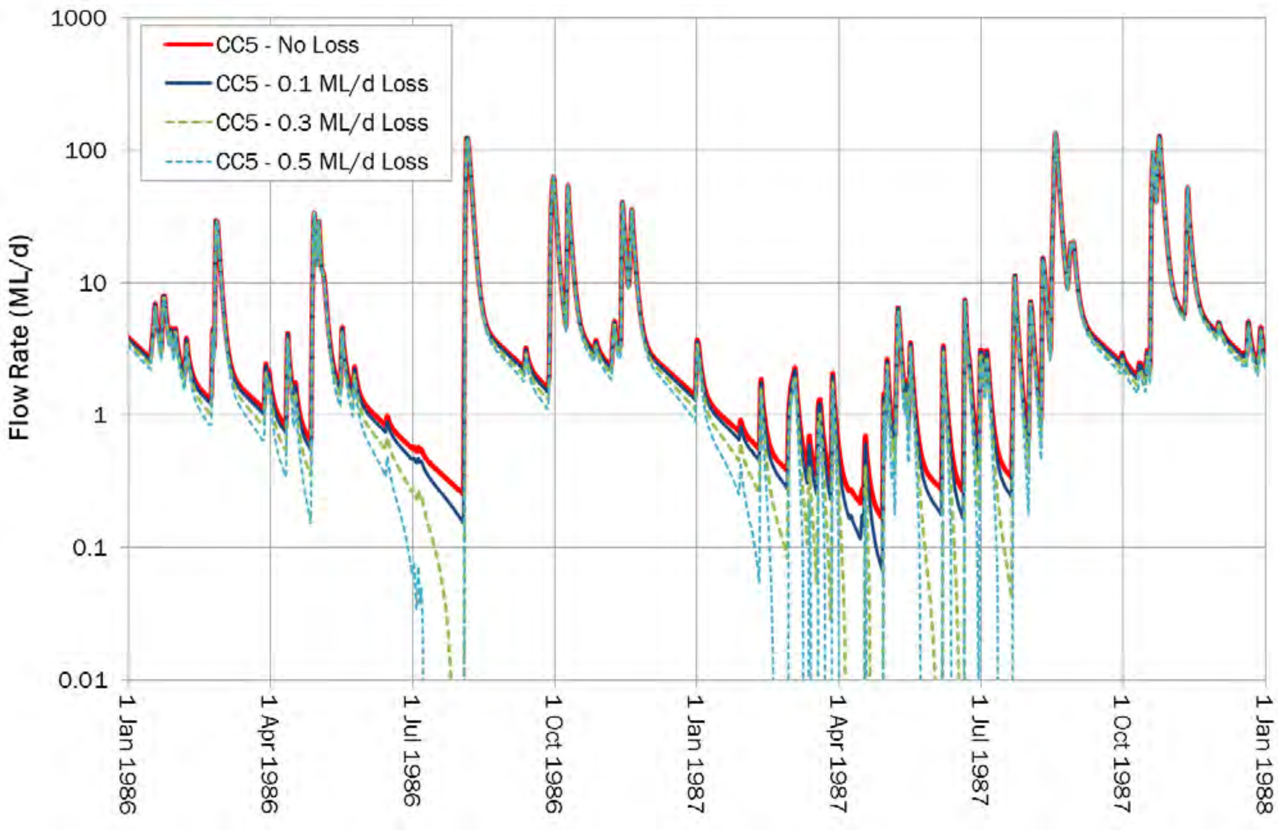


Figure 8.3 Example impact of flow loss on modelled hydrograph shape Cataract Ck at CC5

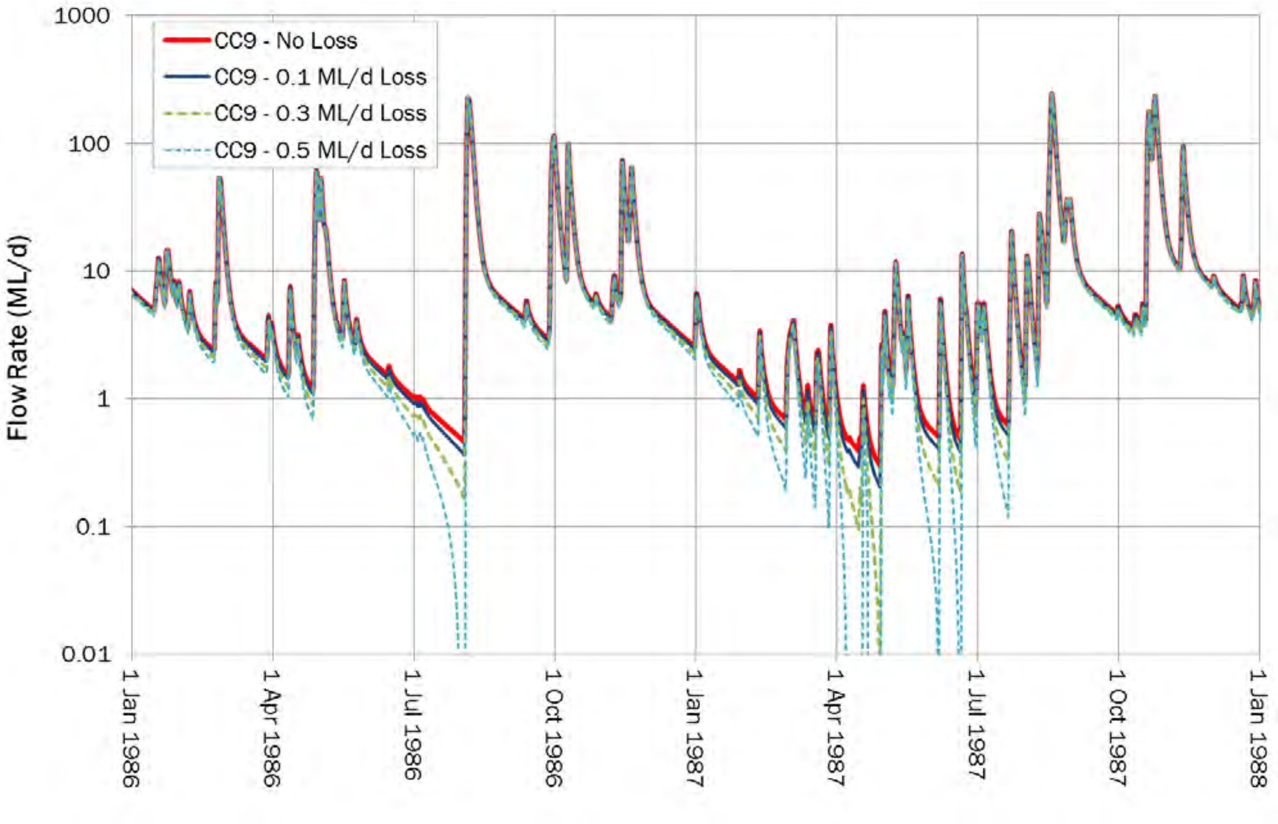


Figure 8.4 Example impact of flow loss on hydrograph shape Cataract Creek at CC9

The impact of the losses over the entire model period, between 1889 and 2014, is illustrated in Figure 8.5 and Figure 8.6. The following observations can be drawn from these results:

- At CC5, a loss of 0.3ML/d would reduce the frequency of flows greater than 1.0ML/d from around 65% to 58%. A loss of 0.5ML/d would reduce the frequency of flows greater than 1.0ML/d to 54%. The median duration of cease to flow periods would increase from 0 to 10 days, and the maximum cease to flow period length would increase from 0 to 78 days.

- At CC9, a loss of 0.3ML/d would reduce the frequency of flows greater than 0.1ML/d from around 78% to 73%. A loss of 0.5ML/d would reduce the frequency of flows greater than 0.1ML/d to 69%. The median duration of cease to flow periods would increase from 0 to 9 days, and the maximum cease to flow period length would increase from 0 to 69 days.

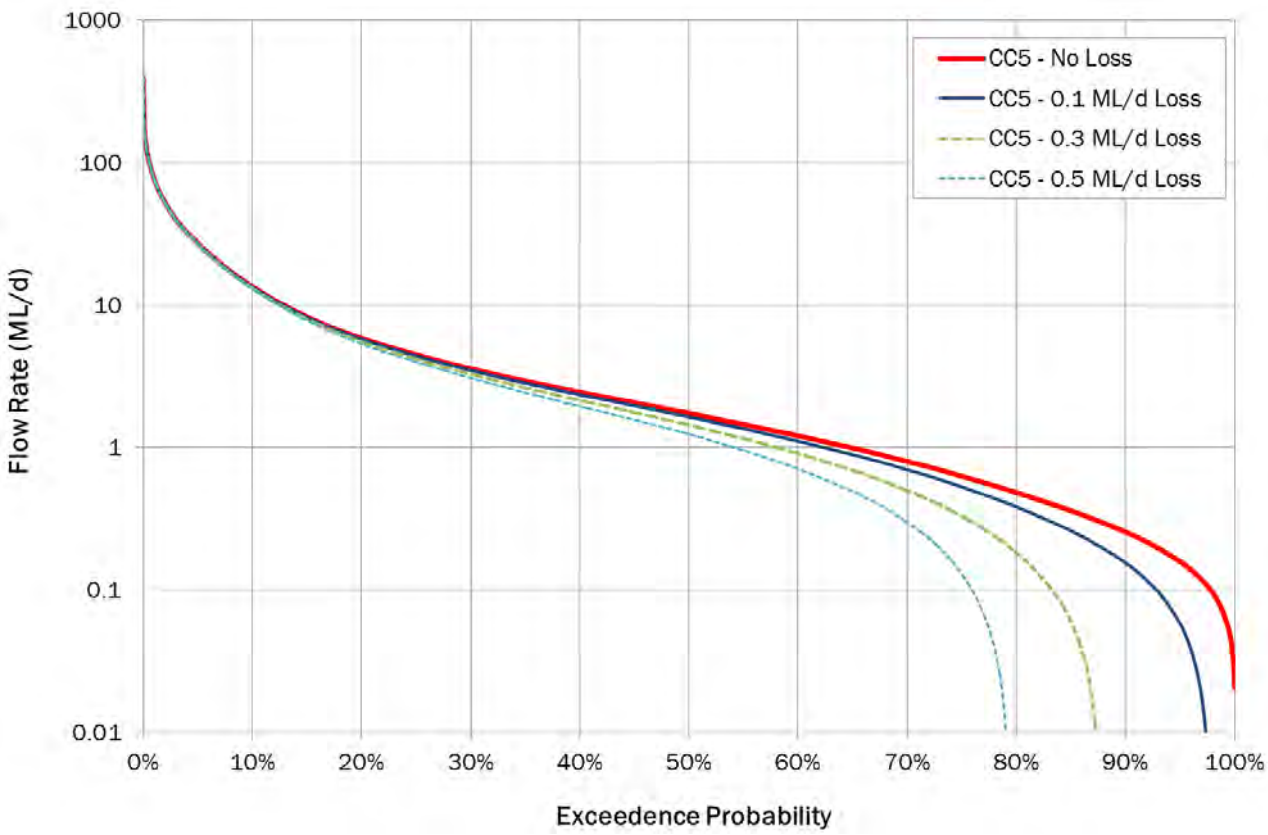


Figure 8.5 Impact of losses on Cataract Creek flow frequency curve at CC5

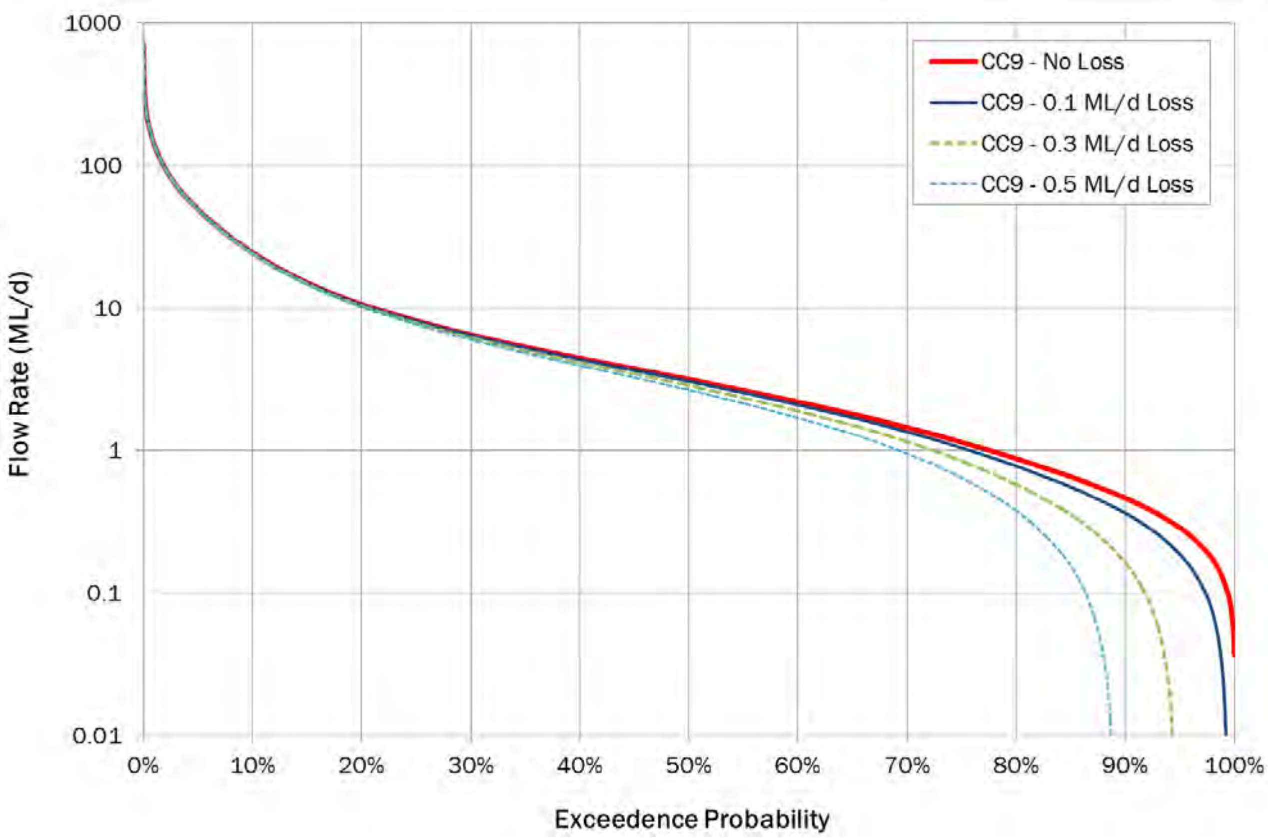


Figure 8.6 Impact of losses on Cataract Creek flow frequency curve at CC9

The AWBM model tends to underestimate the number of cease to flow periods in the Bellambi Creek dataset. While the modelled results appear to be consistent with a lack of no-flow periods observed in Cataract Creek, a sensitivity analysis was undertaken to determine the impact assuming Cataract Creek cease to flow periods were similar to Bellambi Creek. Appendix B shows the impact of streamflow losses on Cataract Creek using historical streamflow data at Bellambi Creek factored by the catchment areas upstream of CC5 and CC9. The following observations can be drawn from the results using historical streamflow data:

- At CC5, a loss of 0.3ML/d would reduce the frequency of flows greater than 1.0ML/d from around 67% to 61%. A loss of 0.5ML/d would reduce the frequency of flows greater than 1.0ML/d to 58%.

- At CC9, a loss of 0.3ML/d would reduce the frequency of flows greater than 0.1ML/d from around 88% to 78%. A loss of 0.5ML/d would reduce the frequency of flows greater than 0.1ML/d to 74%.

It should be noted that if flow losses occurred from a reach of the affected streams, it is thought that the flow would return to the channel further downstream. The impacts described above are therefore likely to affect only limited portions of the affected streams.

8.3.3 Potential Additional Loss of Cataract Creek Streamflow due to Tributary Losses

The results of the analysis over the period January 1986 to January 1988 are illustrated in Figure 8.7 and Figure 8.8, which show modelled flow rates at the Cataract Creek pool monitoring station CC9 using the Bellambi Creek AWBM parameters. Figure 8.10 shows the results of the analysis in Tributary 10.

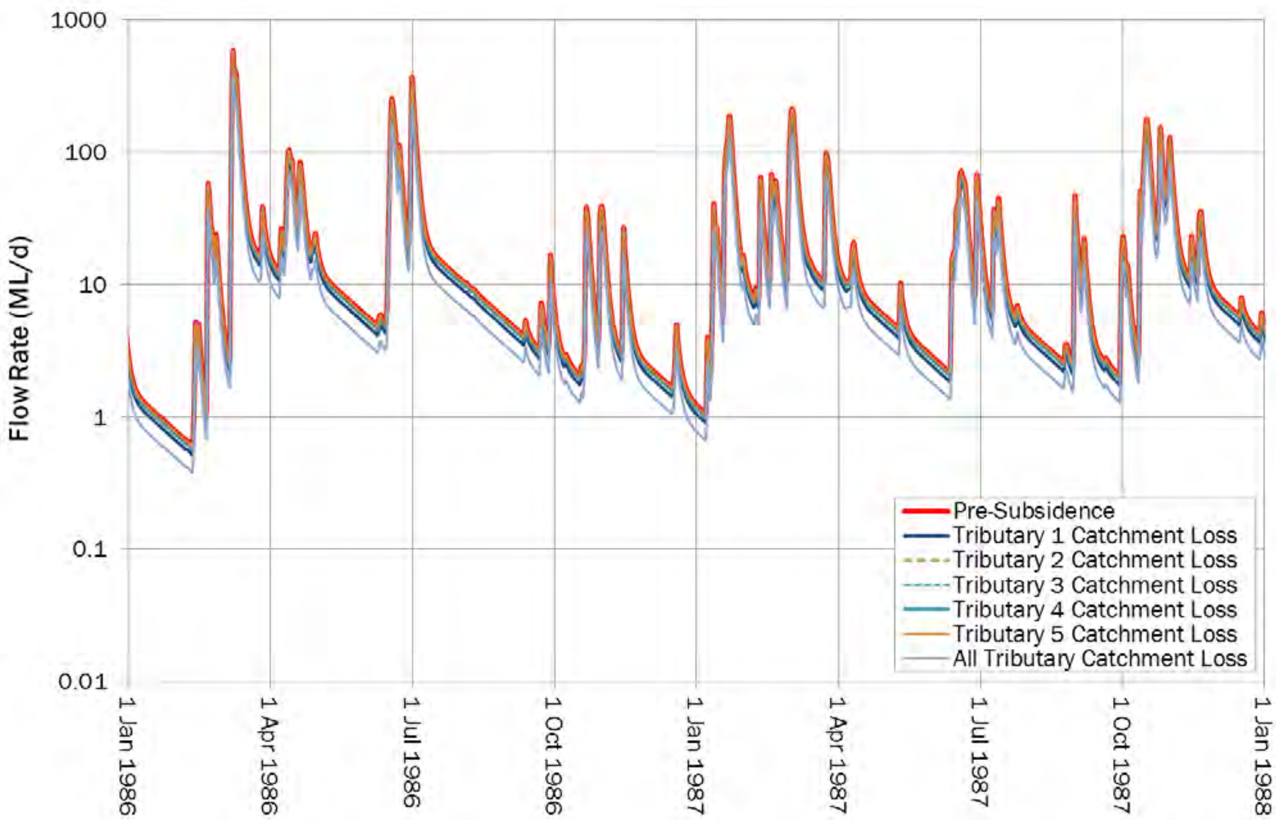


Figure 8.7 Example impact of tributary flow loss on hydrograph shape of Cataract Creek at CC9, Tributary 1-5.

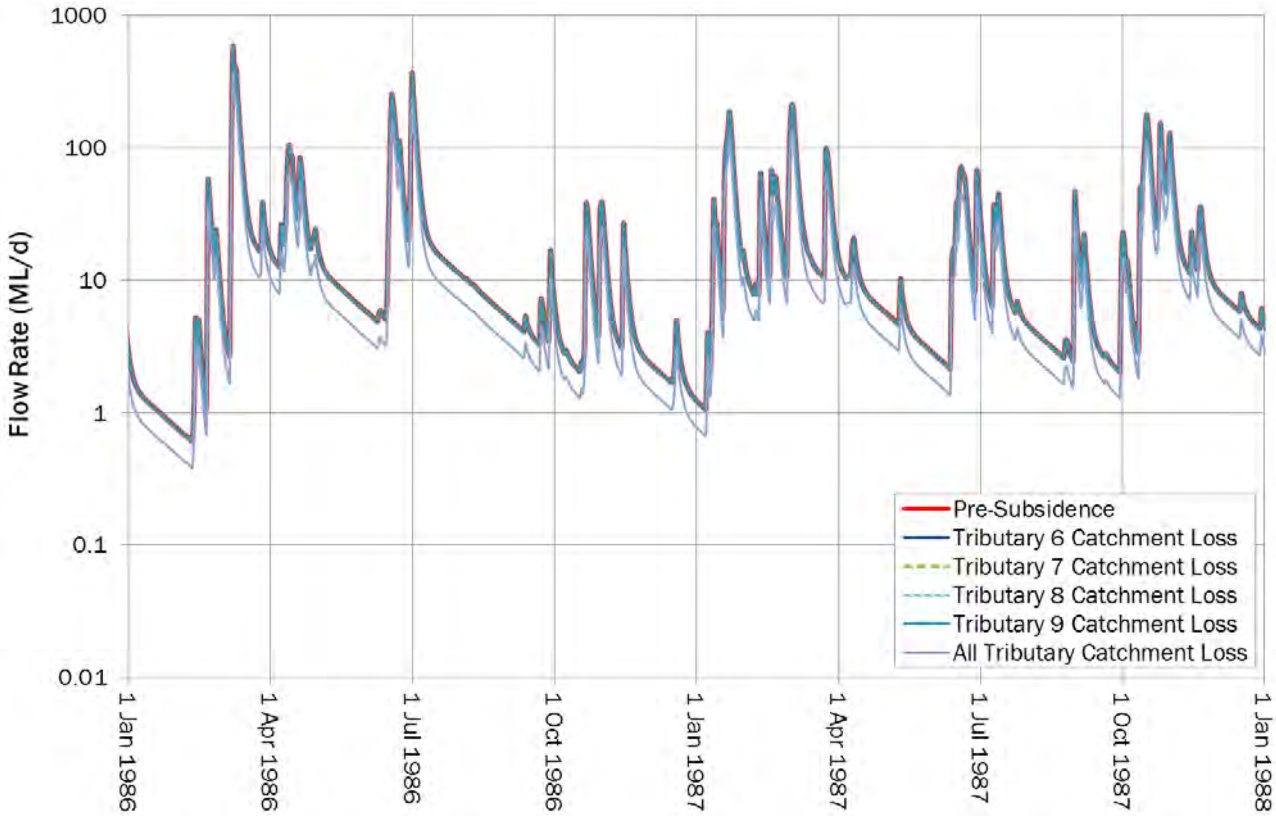


Figure 8.8 Example impact of tributary flow loss on hydrograph shape of Cataract Creek at CC9, Tributary 6-9.

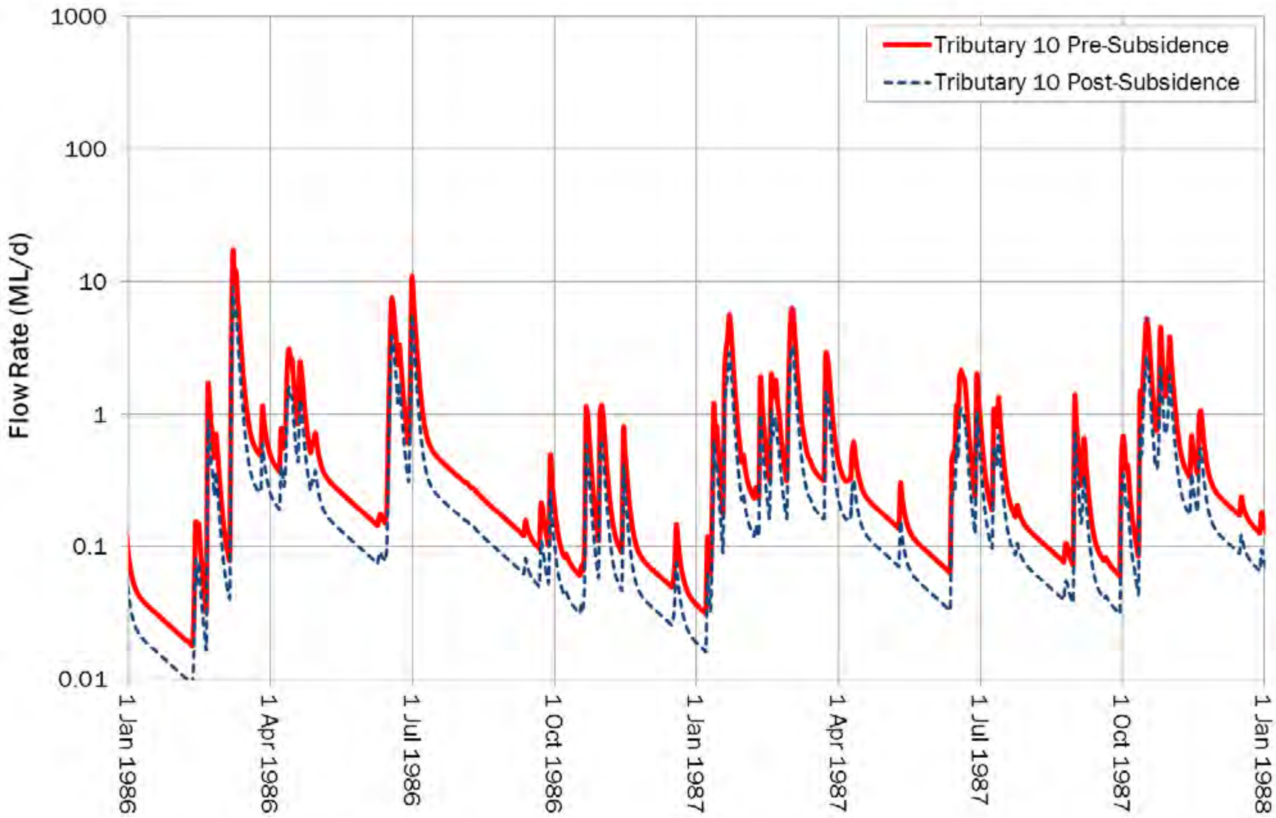


Figure 8.9 Example impact of tributary flow loss on hydrograph shape of Tributary 10.

The additional effect of catchment losses was assumed to be proportionally the same for all flows – with the magnitude of losses being higher during the large flow events. Table 8.3 shows the impact of catchment losses over a range of flows upstream of CC9 and in Tributary 10. The impact of the losses (in the absence of other in-stream losses) over the entire modelled period, between 1889 and 2014, for tributaries upstream of CC9 is illustrated in Figure 8.10 and Figure 8.11. Figure 8.12 shows the impact of catchment loss in Tributary 10.

The following observations can be drawn from these results:

- Loss of streamflow from the catchment areas of all tributaries upstream of CC9 would reduce the median total flow rate by 0.9ML/d (from 2.54ML/d to 1.64ML/d). Median baseflow would reduce by 0.61ML/d (from 1.71ML/d to 1.10ML/d);
- The loss of streamflow from the catchment area of Tributary 1 makes up the bulk of this loss – with the median total flow rate reducing by 0.37ML/d (from 2.54ML/d to 2.17ML/d). Median baseflow would reduce by 0.25ML/d (from 1.71ML/d to 1.46ML/d);
- Loss of streamflow from the catchment areas of the individual tributaries 2-9 would be minimal as each of these tributaries make up less than 6.1% of the total catchment to CC9;
- The loss of streamflow from the catchment area of Tributary 10 would reduce the median total flow rate from this tributary by 0.04ML/d (from 0.08ML/d to 0.04ML/d). Median baseflow would reduce by 0.02ML/d (from 0.05ML/d to 0.03ML/d).

Table 8.3 Impact of tributary losses on streamflow at CC9 and in Tributary 10

Scenario	Disturbed Area (km2)	Unaffected Area (km2)	Total Flow (ML/d)		Baseflow (ML/d)	
			Average	Median	Average	Median
Pre-Subsidence (to CC9)	0.00	4.75	9.71	2.54	3.08	1.71
Loss of:						
Tributary 1	0.70	4.05	8.28	2.17	2.62	1.46
Tributary 2	0.29	4.46	9.12	2.39	2.89	1.61
Tributary 3	0.27	4.48	9.16	2.40	2.90	1.61
Tributary 4	0.24	4.51	9.22	2.41	2.92	1.62
Tributary 5	0.06	4.69	9.58	2.51	3.04	1.69
Tributary 6	0.04	4.71	9.64	2.52	3.05	1.70
Tributary 7	0.03	4.72	9.65	2.53	3.06	1.70
Tributary 8	0.03	4.72	9.65	2.53	3.06	1.70
Tributary 9	0.03	4.72	9.66	2.53	3.06	1.70
All Tributaries (to CC9)	**1.69**	**3.06**	**6.26**	**1.64**	**1.98**	**1.10**
Tributary 10 Pre-Subsidence	0.00	0.14	0.29	0.08	0.09	0.05
Tributary 10 Post-Subsidence	0.07	0.07	0.15	0.04	0.05	0.03

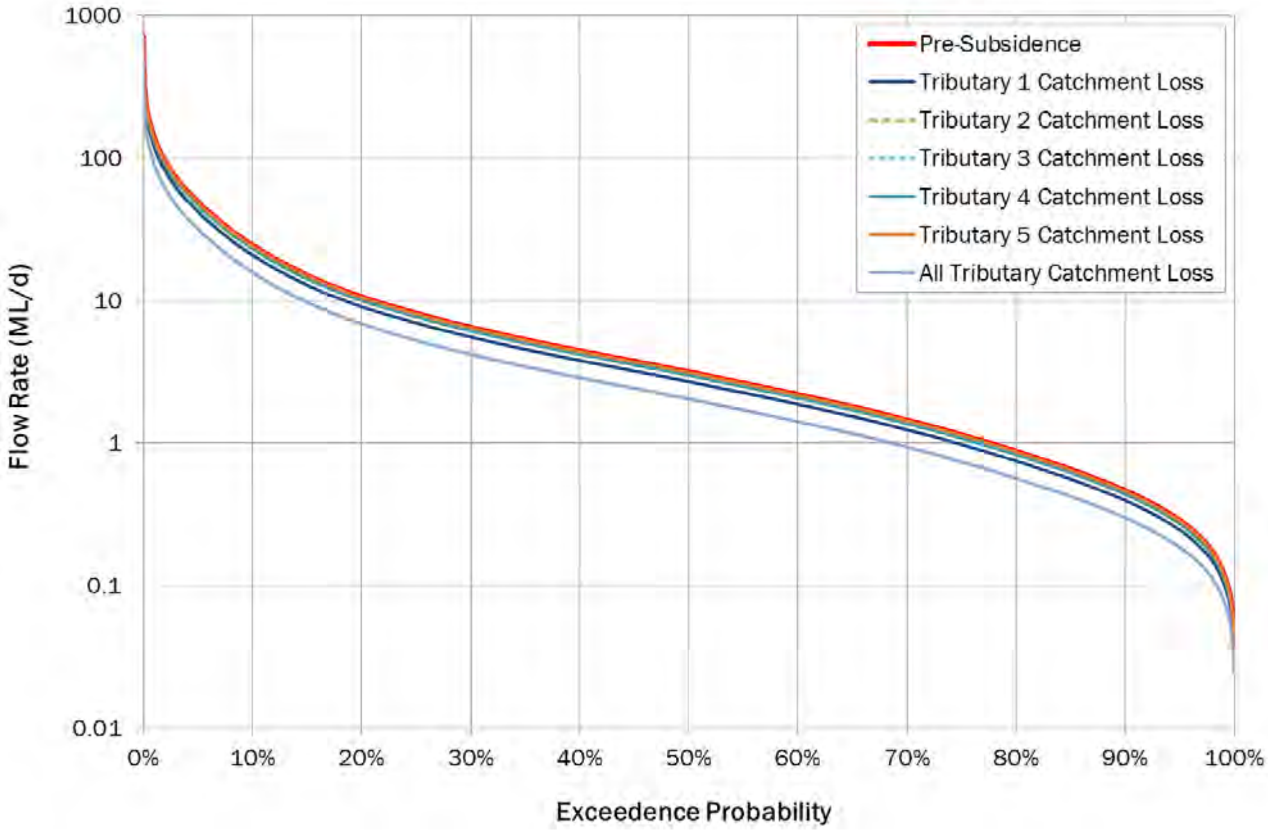


Figure 8.10 Impact of tributary losses on Cataract Creek flow frequency curve at CC9, Tributary 1-5.

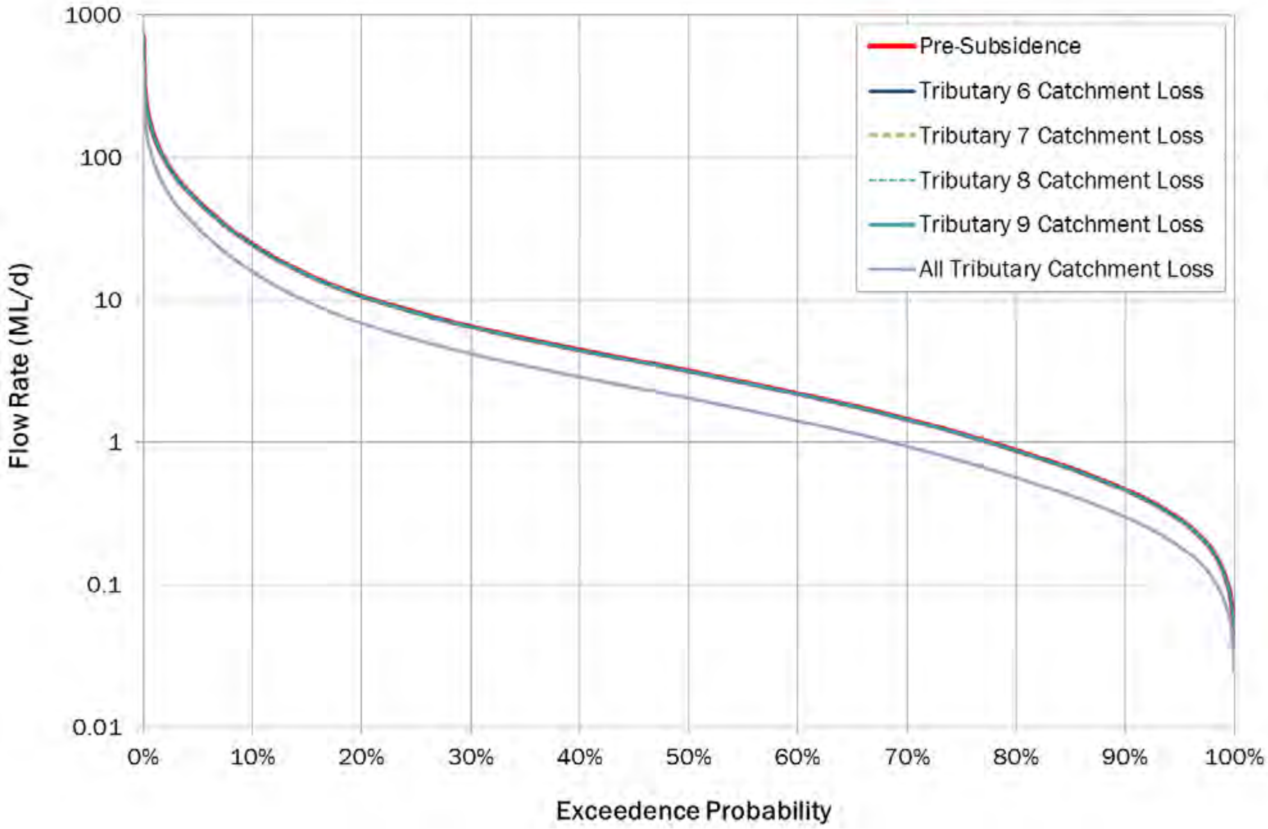


Figure 8.11 Impact of tributary losses on Cataract Creek flow frequency curve at CC9, Tributary 6-10.

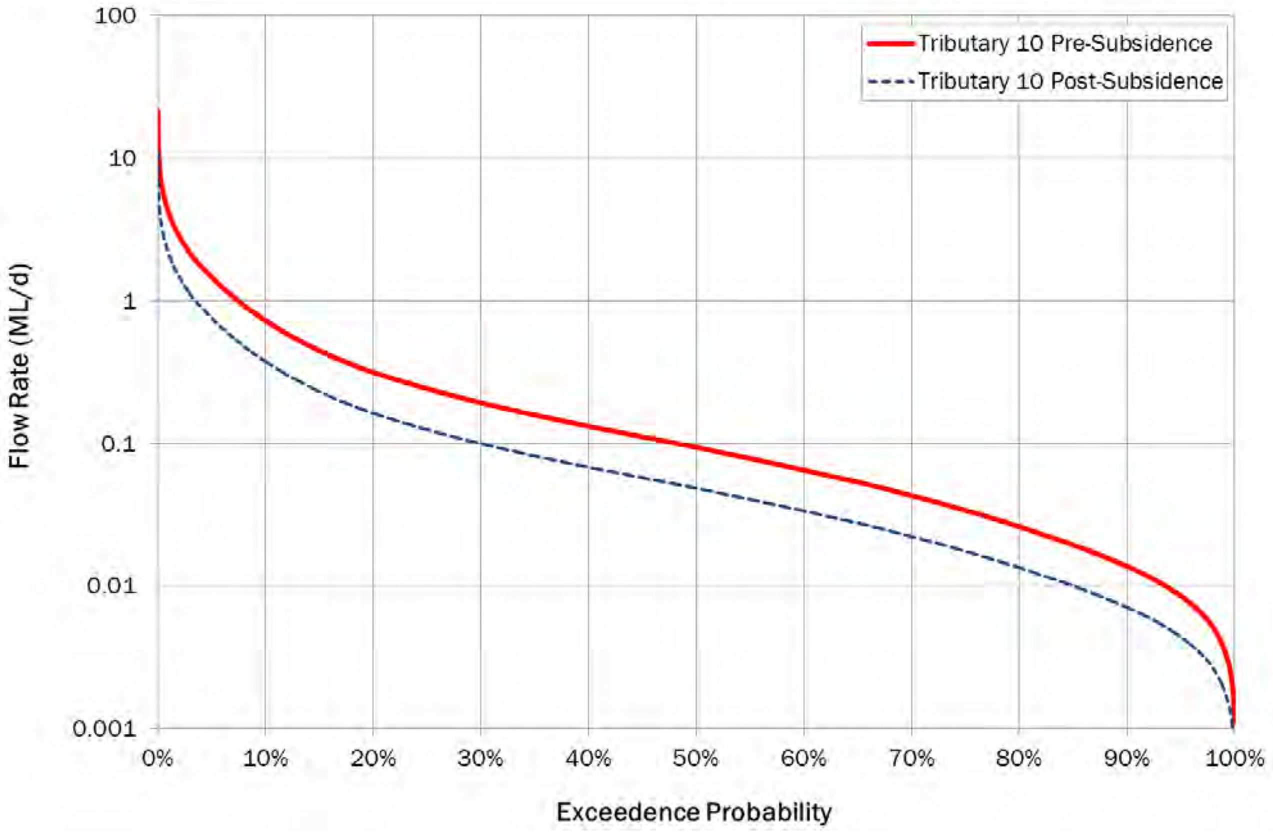


Figure 8.12 Impact of catchment losses on Tributary 10 flow frequency curve.

9 SUBSIDENCE IMPACT ON SWAMPS

9.1 LOCATION OF SWAMPS

The locations of potentially affected swamps in relation to catchments crossing the project area are shown in Figure 9.1 and Table 9.1. Swamps make up around 1.1% of the Cataract Creek catchment.

Table 9.1 Areas of Swamps in the Project Catchment Areas

Catchment	Total Catchment Area	Total Swamp Area	Proportion which is swamp
	ha	ha	%
Cataract River	2,088	16.5	0.8
Cataract Creek	1,928	21.4	1.1
Bellambi Creek	1,441	7.6	0.5
Lake Cataract		3.0	
Total Lake Cataract	**5,463**	**48.5**	**0.9**

Table 9.2 and Figure 9.1 show the proportions of these swamps within the 20mm subsidence zone. Approximately 64% of the potentially affected swamps in the project area are within the proposed subsidence zone.

Table 9.2 Proportions of Swamps Within Subsidence Zone

	Swamp Area Within Subsidence Zone	Unaffected Swamp Area	Total Swamp Area	Proportion Within Subsidence Zone
	ha	ha	ha	%
Cataract River	5.9	10.6	16.5	36
Cataract Creek	19.1	2.4	21.4	89
Bellambi Creek	4.4	3.3	7.6	58
Lake Cataract	0.5	1.2	3.0	29
Total Lake Cataract	**31.1**	**17.4**	**48.5**	**64**

Table 9.3 shows the contribution that swamps, and swamps within the proposed subsidence zone make to the catchment areas to each monitoring station. The table also shows the contribution of swamps to the catchment at key locations along Bellambi Creek.

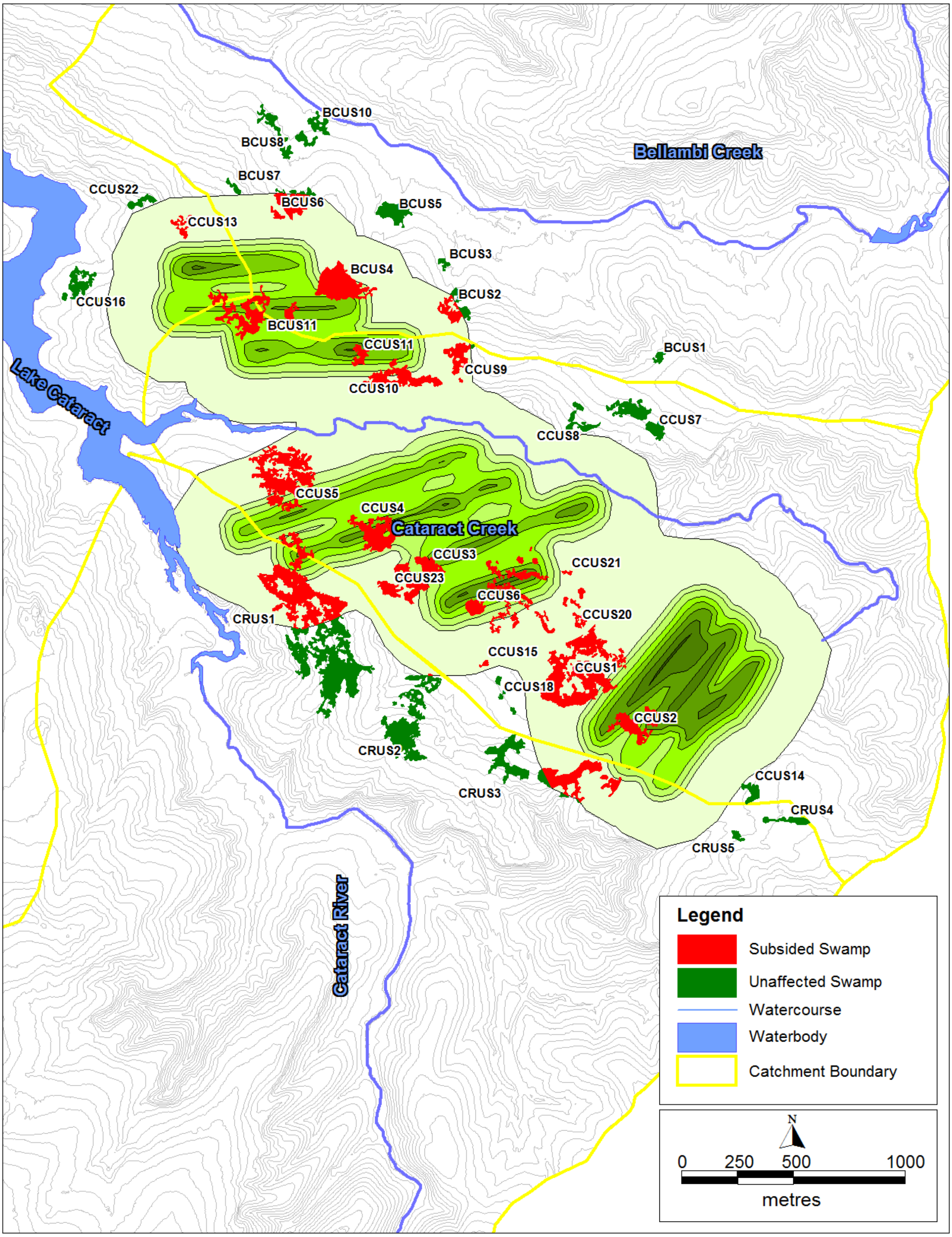


Figure 9.1 Locations of Potentially Subsided Swamps in the Vicinity of the Project Area

Table 9.3 Contribution of Swamps to Catchment Area at Monitoring Points (ha)

Catchment	Swamp Area			Non-Swamp Area	Total Catchment Area
	Undisturbed	Subsided	Total		
Cataract Creek					
CC3	0.5	6.1	6.6	99.5	106.1
CC5	0.5	6.6	7.2	257.8	265.0
CC6	0.9	6.6	7.5	283.5	291.1
CC7	2.3	8.7	11.0	336.4	347.5
CC8	2.3	11.3	13.6	403.8	417.4
CC9	2.3	19.1	21.4	458.5	479.9
Cataract River					
CR2	7.3	1.8	9.1	960.0	969.1
CR4	10.6	5.9	16.5	1085.8	1102.3
Bellambi Creek					
BC4000	0.2	0.0	0.2	410.1	410.2
BC4500	1.6	3.3	4.9	479.0	483.9
BC5000	3.3	4.4	7.6	531.5	539.1

10 CONCLUSIONS

The catchments of Cataract Creek, Bellambi Creek and Cataract River overlie areas anticipated to experience subsidence associated with the proposed expansion of the Wonga East underground workings. However, the proposed mine panel layout has been designed to limit the adverse effects on the potentially affected channels.

As a result, the Bellambi Creek channel will not be affected by subsidence induced by the proposed expansion. The predicted subsidence along the channels of Cataract Creek and Cataract River (including the reaches inundated by Lake Cataract) will be less than 20mm, as detailed below:

1. Cataract Creek. The proposed Wonga East workings are located between Chainage 2,500m and Chainage 4,500m. Of the total Cataract Creek catchment area of 5.2km^2, 3.2km^2 has been identified as potentially subsided by the proposed workings.

2. Cataract River. The proposed Wonga East workings do not underlie the Cataract River. The predicted 20mm subsidence zone runs adjacent to the Lake Cataract backwater for a distance of about 350m. Of the total Cataract River catchment area of 11.6km^2, 0.5km^2 has been identified as potentially subsided by the proposed workings. The western end of Panel 10 in the Wonga East workings extends under the high water extent of the northern bank of the Lake Cataract backwater in the Cataract River.

3. Bellambi Creek. Of the total Bellambi Creek catchment area of 9.3 km^2, 0.4 km^2 has been identified as potentially subsided by the proposed workings.

Subsidence- induced cracking could potentially reduce overland streamflow in reaches overlying the proposed workings.

Based on a catchment yield model calibrated to historical records since 1976, overland flow losses of 1ML/d would have very little impact on Lake Cataract water levels. The maximum reduction in stored volume occurs in mid-2007 and ranges from 940ML for a loss of 0.5ML/d to 1,385ML for a loss of 10ML/d. Losses of 10ML/d would not have caused the Lake Cataract Reservoir water volume to fall below 10% of capacity. Such a loss rate is very large, and unlikely to eventuate given the underlying geology and proposed mining method.

In the absence of long-term streamflow records on Cataract Creek, the impact of losses from the affected reaches on the persistence of baseflow has been estimated by extracting a constant daily loss rate from a simulated streamflow record. The model parameters were transposed from AWBM models calibrated to the adjacent Bellambi Creek catchment runoff records. The loss of low flows in Cataract Creek at the reporting locations just downstream of the proposed 20mm subsidence zone resulted in the following modelled changes to low flow characteristics:

A loss of 0.3ML/d would:

- reduce the frequency of flows greater than 1.0ML/d from around 78% to 72%.
- reduce the frequency of flows greater than 0.1ML/d from around 99% to 91%.
- increase the maximum cease to flow period length from 0 to 83 days.
- increase the median duration of cease to flow periods from 0 to 12 days.

A loss of 0.5ML/d would

- reduce the frequency of 1.0ML/d flows to 69%.
- reduce the frequency of 0.1ML/d flows to 86%.
- increase the maximum cease to flow period length from 0 to 101 days.
- increase the median duration of cease to flow periods from 0 to 9.5 days.

The additional effect of catchment losses from the unnamed tributaries of Cataract Creek was assumed to be proportionally the same for all flows - with the magnitude of losses being higher during the large flow events. The following observations can be drawn from the results of modelling the loss of tributary inflows (in the absence of other in-stream losses):

- Loss of streamflow from the catchment areas of all tributaries upstream of CC9 would reduce the median total flow rate by 0.9ML/d (from 2.54ML/d to 1.64ML/d). Median baseflow would reduce by 0.61ML/d (from 1.71ML/d to 1.10ML/d);
- The loss of streamflow from the catchment area of Tributary 1 makes up the bulk of this loss – with the median total flow rate reducing by 0.37ML/d (from 2.54ML/d to 2.17ML/d). Median baseflow would reduce by 0.25ML/d (from 1.71ML/d to 1.46ML/d);
- Loss of streamflow from the catchment areas of the individual tributaries 2-9 would be minimal as each of these tributaries make up less than 6.1% of the total catchment to CC9;
- The loss of streamflow from the catchment area of Tributary 10 would reduce the median total flow rate from this tributary by 0.04ML/d (from 0.08ML/d to 0.04ML/d). Median baseflow would reduce by 0.02ML/d (from 0.05ML/d to 0.03ML/d).

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Hall & Nash, 2010	Hall, K. and Nash, B., *Sydney's Disappearing Water Supply, BHP Billiton's Subsidence Management Plan Application for Appin Colliery Longwalls 301A to 302*, Submission to Minister for Primary Industries NSW, 20/02/2010.
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Jeffrey et al., 2001	Jeffrey, S.J., Carter, J.O., Moodie, K.M. and Beswick, A.R., 'Using Spatial Interpolation to Construct a Comprehensive Archive of Australian Climate Data', *Environmental Modelling and Software*, Vol 16/4, pp 309-330, 2001.
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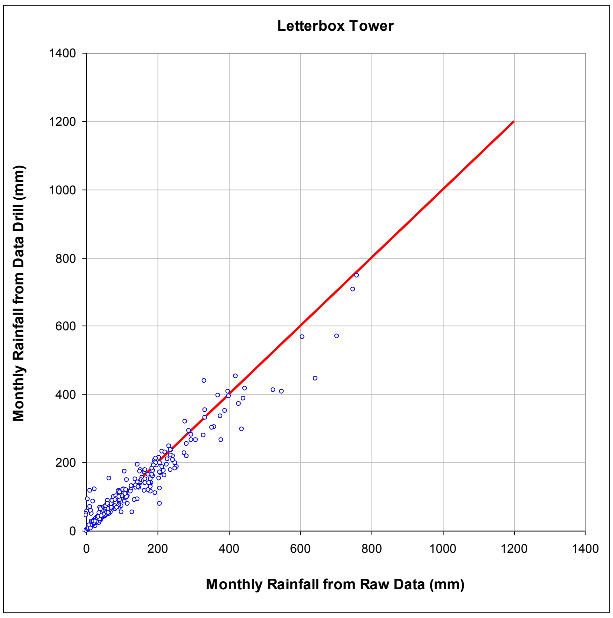
APPENDIX A

COMPARISON OF RAW RAINFALL DATA AND

SILO DATA DRILL RAINFALL DATA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Monthly Rainfall from Raw Data (mm)
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200
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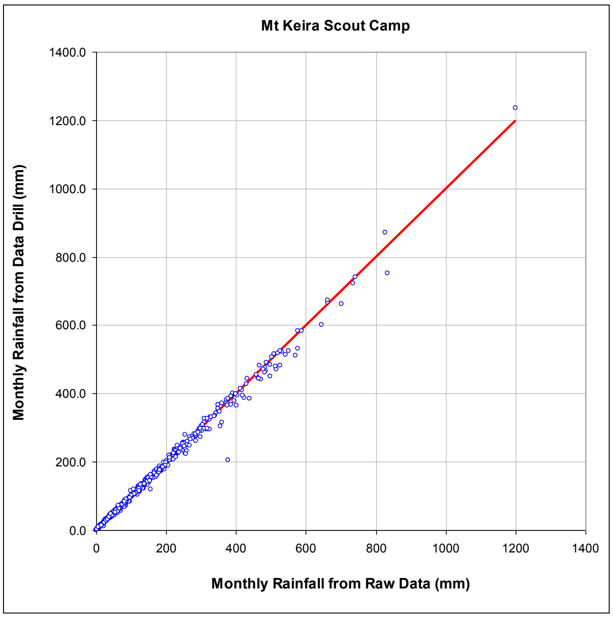
1000
1200
1400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Monthly Rainfall from Raw Data (mm)
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200
400
600
800
1000
1200
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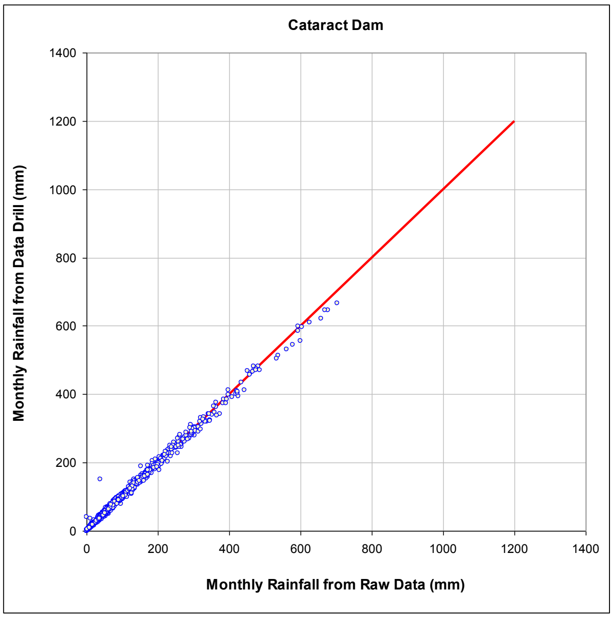
Cataract Dam
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Monthly Rainfall from Raw Data (mm)
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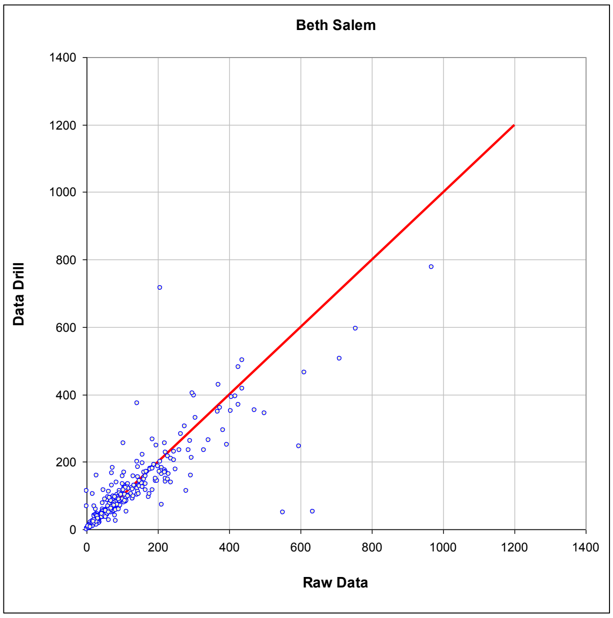
200
400
600
800
1000
1200
1400


Beth Salem
Data Drill
Raw Data
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200
400
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800
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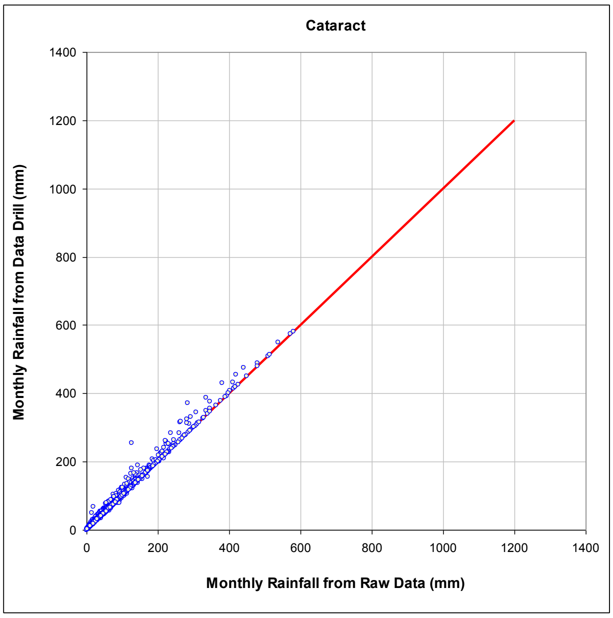
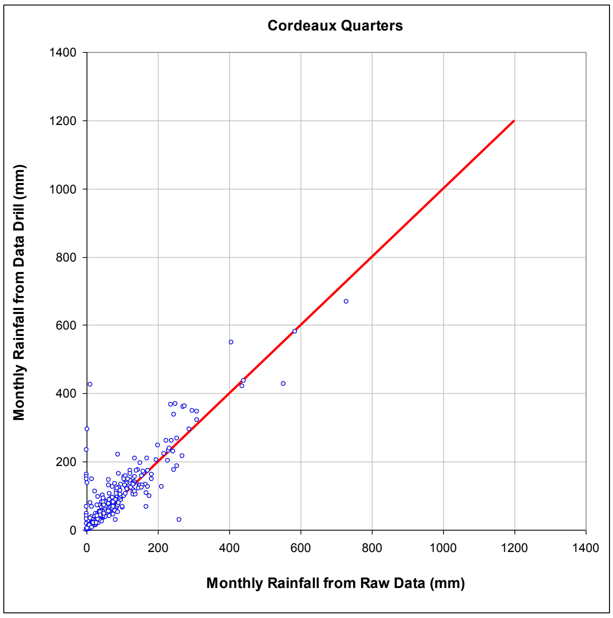

Cataract
Monthly Rainfall from Data Drill (mm)
Monthly Rainfall from Raw Data (mm)
0
200
400
600
800
1000
1200
1400


Cordeaux Quarters
Monthly Rainfall from Data Drill (mm)
Monthly Rainfall from Raw Data (mm)
0
200
400
600
800
1000
1200
1400

APPENDIX B

IMPACTS ON CATARACT CK STREAMFLOW

CALCULATED USING

OBSERVED BELLAMBI CREEK STREAMFLOW DATA

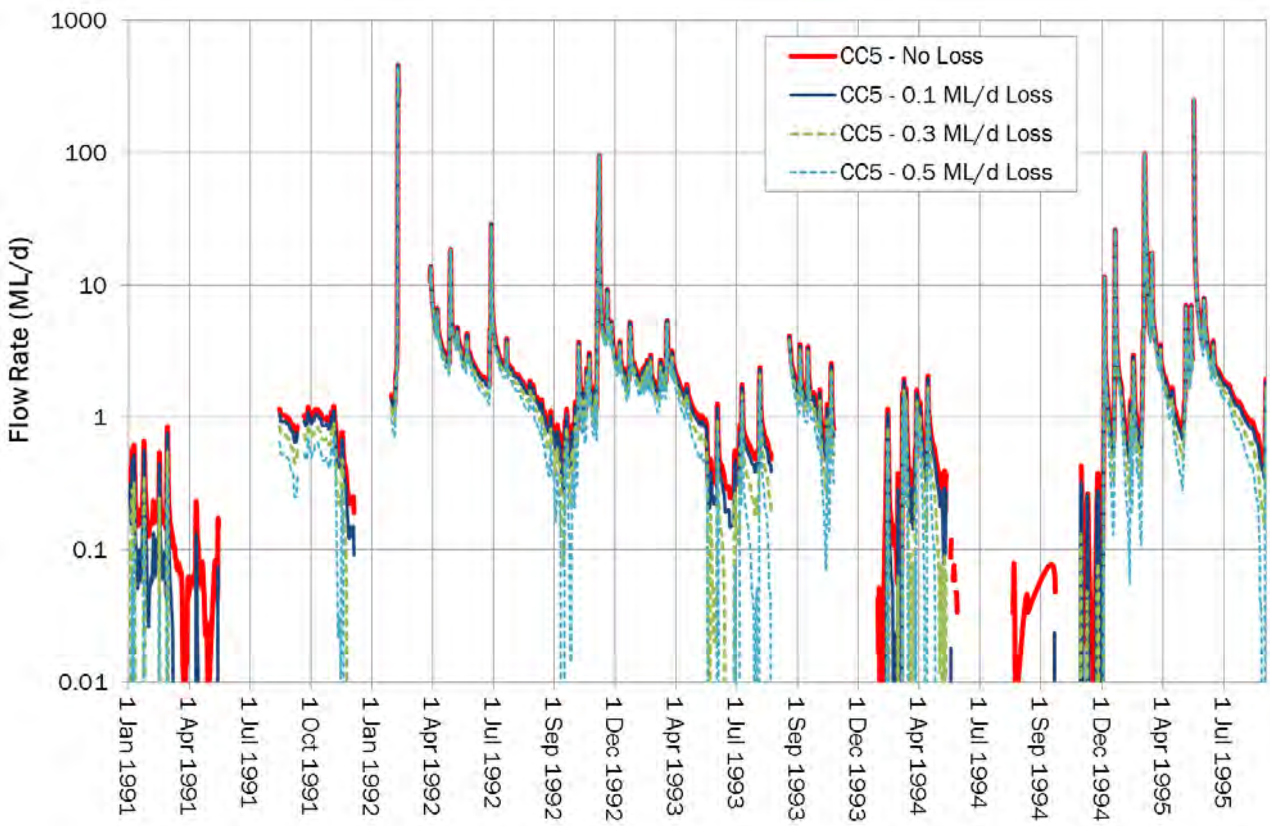


Figure 11.1 Example impact of flow loss on modelled hydrograph shape Cataract Ck at CC5 – Observed Data

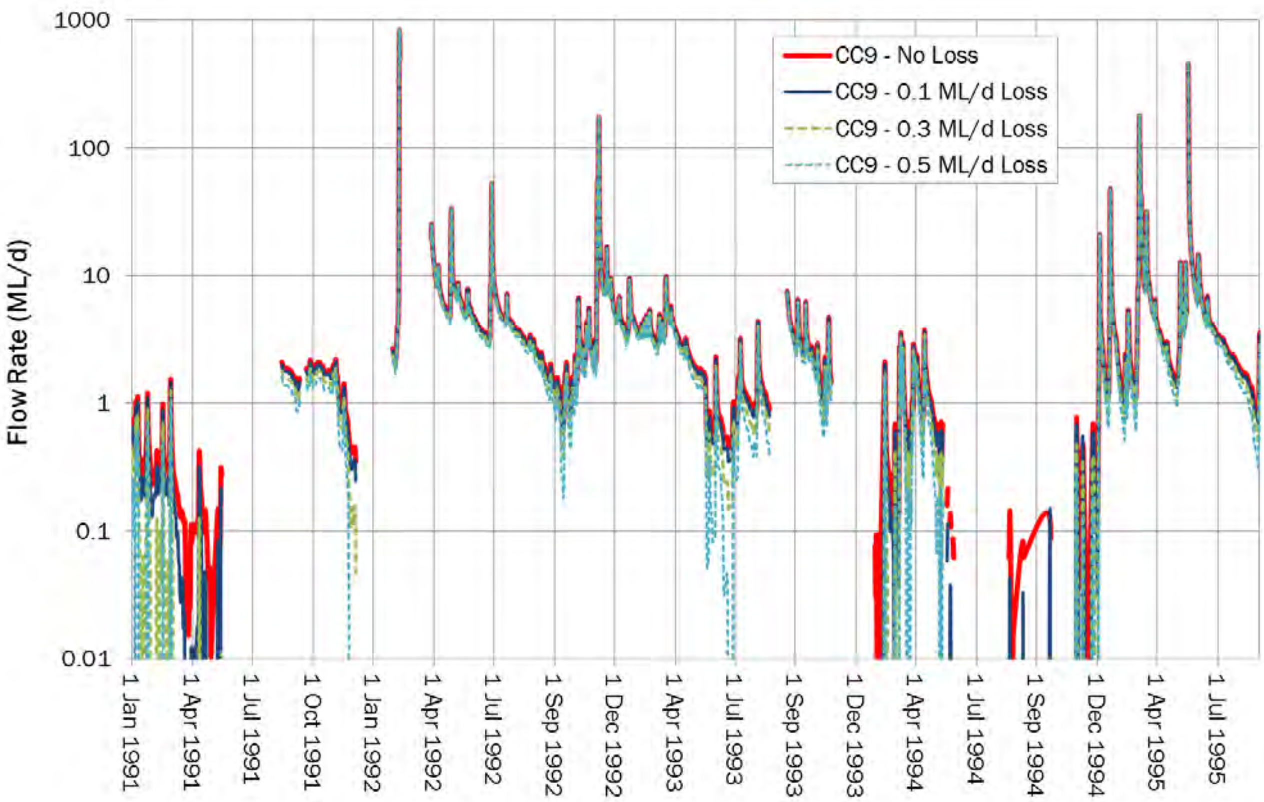


Figure 11.2 Example impact of flow loss on hydrograph shape Cataract Creek at CC9 – Observed Data

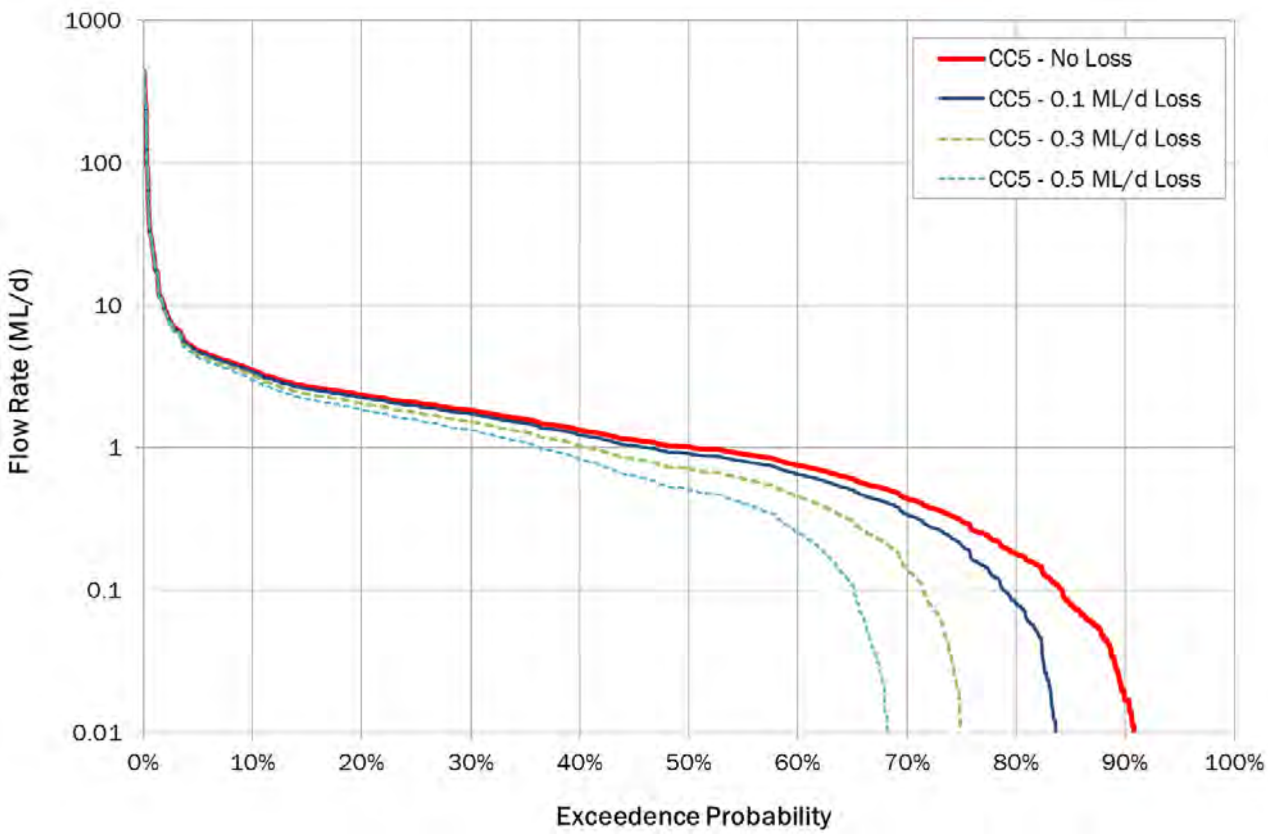


Figure 11.3 Impact of losses on Cataract Creek flow frequency curve at CC5 – Observed Data

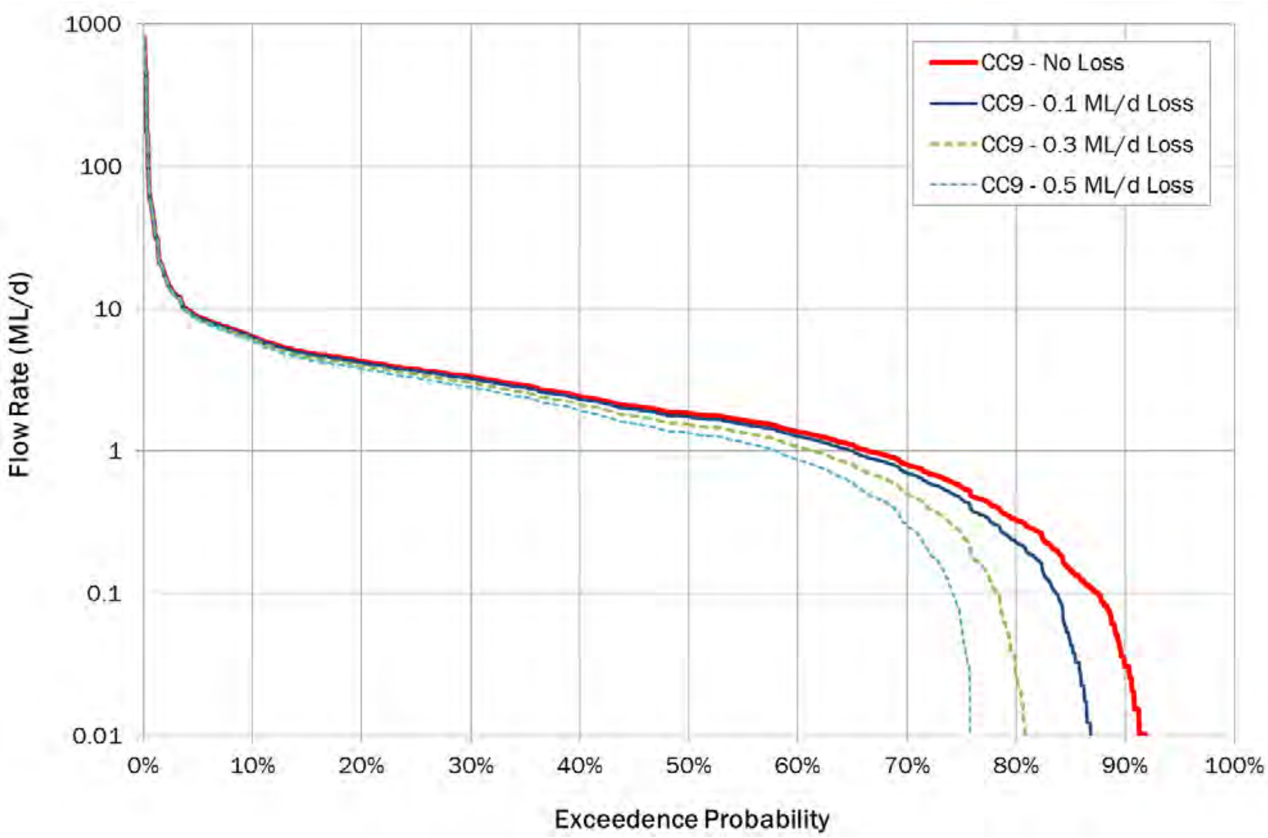


Figure 11.4 Impact of losses on Cataract Creek flow frequency curve at CC9 – Observed Data

Appendix G

RUSSELL VALE COLLIERY – UNDERGROUND EXPANSION PROJECT: PREFERRED PROJECT REPORT – BIODIVERSITY

Russell Vale Colliery – Underground Expansion Project:

Preferred Project Report – Biodiversity

FINAL REPORT

Prepared for Wollongong Coal Ltd

20 June 2014

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Summary

Wollongong Coal previously submitted an Environmental Assessment (EA) for the Russell Vale Colliery Underground Expansion Part 3A project to the NSW Department of Planning and Environment (DPE) in February 2013.

As a result of the submissions received, Wollongong Coal has made the decision to substantially modify the project application, including:

- Removal of Wonga West from the project application.
- Shortening of the Wonga Main drivage to not extend under the south arm of Cataract Reservoir through the known geological feature (in the Bulli Seam).
- Modification of the longwall layout in Wonga East.

Due to the substantive changes made DPE has requested Wollongong Coal prepare a Preferred Project Report (PPR) dated October 2013. This report has been updated to incorporate the final Groundwater Impact Assessment (Geoterra and GES 2014) and replaces the October 2013 report.

This report provides revised impact assessments for significant natural features previously recorded within the study area, based on the revised mine plan and associated revised subsidence predictions, as well as additional surveys and information that have been undertaken or has become available since the EA was submitted. This report also includes an assessment of likely historic impacts to these natural features based on past mining of the Bulli and Balgownie Seams.

The revised impact assessment concluded that there was a reduced risk of impact for many species and ecological communities due to the removal of Wonga West from the project application, the removal of longwalls from beneath Cataract Creek and a reduction in the number and extent of upland swamps being undermined.

The Preferred Project has significantly reduced potential impacts to biodiversity when compared to the original application. However, there remains a high risk of impact to upland swamp of 'special significance' CCUS4, including Giant Dragonfly habitat in this upland swamp, as well as a moderate risk of impact to upland swamp BCUS4.

A detailed Biodiversity Management Plan will be prepared for the Russell Vale Colliery which shall incorporate detailed mitigation and management measures in consultation with relevant regulators for these residual impacts.

1. Introduction

1.1 Project background

The Russell Vale Colliery is located at Russell Vale, to the west of Bellambi, in the Illawarra region of New South Wales (NSW). Wollongong Coal purchased the Colliery in December 2004, but extensive underground mining has been undertaken within the Colliery holdings dating from the late nineteenth century. However, a substantial volume of high quality coking coal resources remain, along with some potential thermal coal resources.

The Colliery holding includes a number of sub leases between Wollongong Coal and surrounding mine operators, including Consolidated Coal Lease (CCL) 745, Mining Purposes Lease (MPL) 271 and Mining Lease (ML) 1575, and covers a total area of approximately 6,973 hectares (ha).

Originally, Wollongong Coal intended to expand its operations in two stages. Stage 1 plans were included in the Preliminary Works Part 3A project application that was approved on 13 October 2011, allowing some first workings coal extraction and surface facility upgrades. On 24 December 2012, the Preliminary Works Part 3A project was modified to allow the extraction of Longwalls 4 and 5 and the establishment of Maingate 6.

The original Stage 2 application, known as the Underground Expansion Project Part 3A, was lodged with the NSW Department of Planning and Environment (DPE) on 12 August 2009 and contained an application to extract 11 longwalls in the Wonga East area and seven longwalls in the Wonga West area along with surface facilities upgrades to allow production up to 3 million tonnes per annum (Mtpa) for up to 20 years. Since that time it has been progressing through the Major Project approvals process and was placed on Public Exhibition on 18 February 2013. As a result of the submissions received on the application, Wollongong Coal has made the decision to substantially revise the application to facilitate the approval process and allow continuity in operations. Due to the scope of the changes, the DPE request Wollongong Coal prepare a Preferred Project Report (PPR) for the revised Underground Expansion Project Part 3A.

The Preferred Project Report (NRE 2013) outlines the revised Underground Expansion Project which has been reduced to a five year interim, staged project, with extraction of eight longwalls in the Wonga East area and upgrading of surface facilities to manage an extraction rate of up to 3 Mtpa run of mine (ROM) coal per annum. The original Wonga West longwall extraction will be resubmitted to DPE as a separate application.

This report produced in October 2013 to support the PPR has been updated in May 2014 and provides revised impact assessments for terrestrial ecology, aquatic ecology and upland swamps (Section 3). Measures to manage and mitigate impacts are discussed in Section 4. A response to submissions received is provided in Section 5. This report entirely replaces the October 2013 PPR ecology report.

1.2 Scope of assessment

The objectives of this report are to:

- Provide details of changes to the original project relevant to terrestrial ecology, aquatic ecology and upland swamps.
- Prepare revised impact assessments and management and mitigation measures based on these changes, including revised subsidence predictions and groundwater modelling results.
- Provide a response to submissions received on the 2013 Preferred Project Report for Biodiversity based on the changes outlined above.

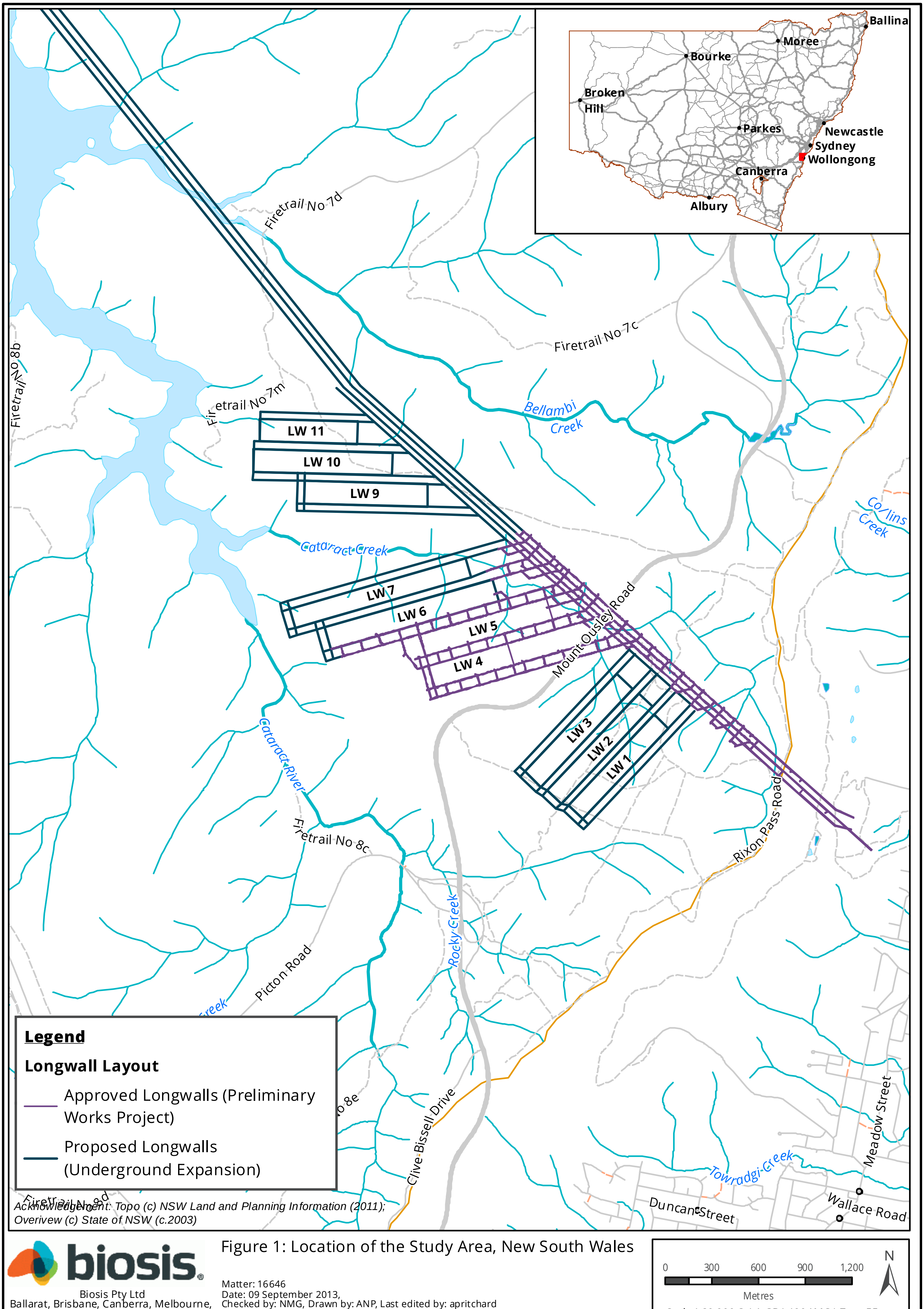

Figure 1: Location of the Study Area, New South Wales

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Ballarat, Brisbane, Canberra, Melbourne, Sydney, Wangaratta & Wollongong

2. Preferred Project Changes

After serious consideration of the community and agency submissions, Wollongong Coal has decided to modify its Underground Expansion Project Part 3A application in the following manner:

1. The Wonga East longwall layout will be modified to minimise impacts to identified significant features while recovering the maximum volume of coal reserves possible.
2. The Wonga Mains driveage will not be extended northwards under the south arm of Cataract Reservoir through the known geological feature (in the Bulli Seam).
3. The Wonga West longwalls will be removed from the application.
4. No change to the Pit Top from the original proposal.

A more detailed summary comparing the original proposal presented in the Environmental Assessment with the Preferred Project is presented in Table 1 and Figure 2.

Table 1: Detailed Summary of Project Changes

Project Area	Original Project	PPR
Project Application Area	• As per Figure 1.2 of Underground Expansion Project Environmental Assessment	• No changes proposed
Production Limit	• 3 Mtpa	• No changes proposed
Pit Top	• Two new stockpiles of 140,000 tonnes capacity each (SP2 & SP3) with associated reclaim facilities • New truck loading facilities • Designated coal dispatch road • Progressive upgrading of trucking fleet • Continued road haulage of ROM coal to the Port Kembla Coal Terminal. • 6ML Settling Pond • Continuing use of No.4 Shaft for mine access, bathhouse, parking and offices • Ongoing maintenance and refurbishment of ventilation shafts, water and electrical facilities. • Ongoing geological and geotechnical investigations to determine coal quality and geotechnical conditions	• No changes proposed

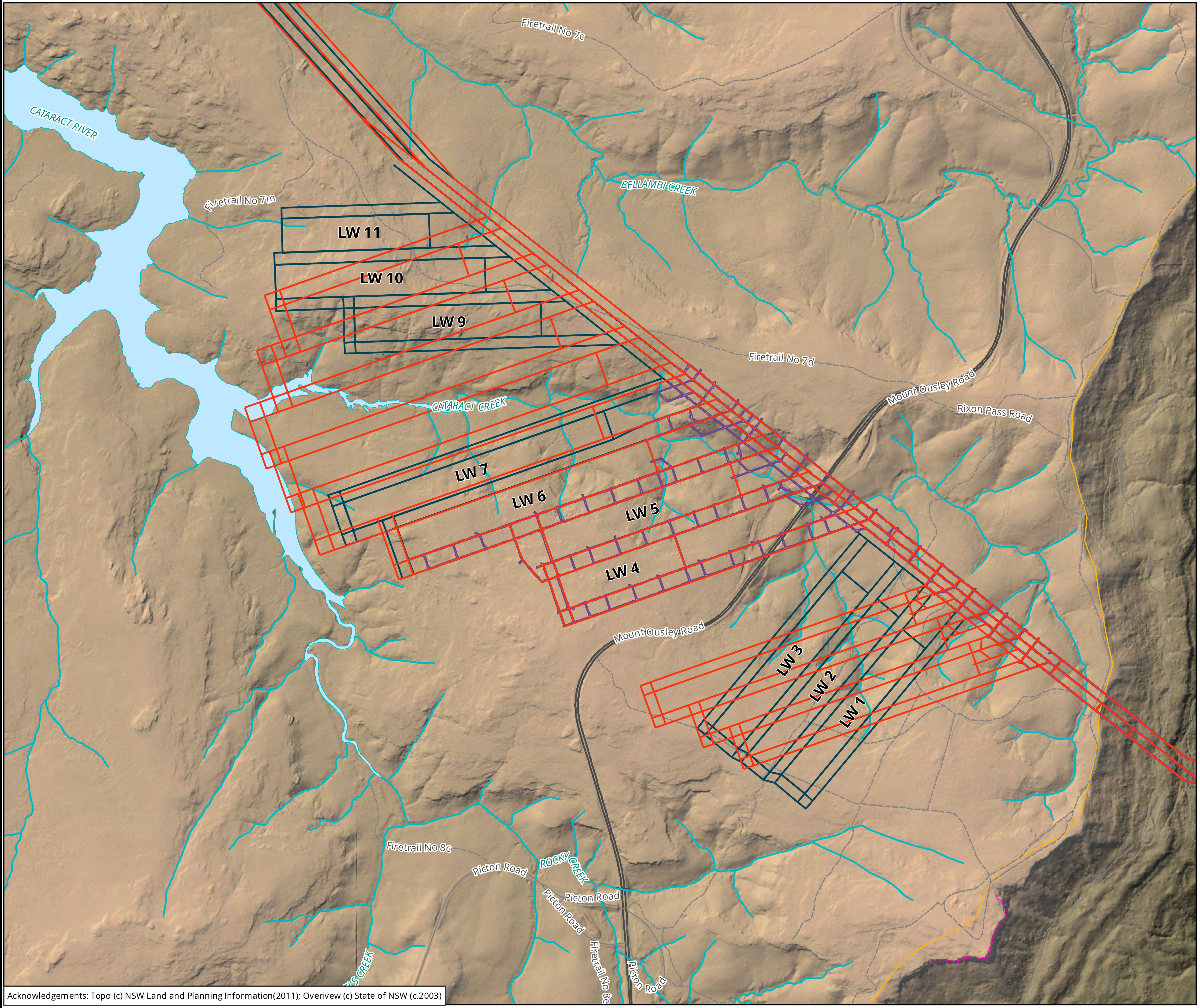
Project Area	Original Project	PPR
	using drilling and related techniques.	
Wonga East Longwalls	• 9 longwalls (LW) in two Areas – Area 1 – LW's 1-3 – Area 2 – LW's 6-11	• 8 longwalls in two Areas (see Figure 2). – Area 1 – LW's 1-3 shortened and reoriented to the southwest – Area 2 – LW 6 shortened – Area 2 – LW7 shortened and moved slightly south east – Area 2 – LW 8 removed – Area 2 – LW9-11 shortened and reoriented to the northwest
Wonga Mains	• Mains drivage from the end of the Preliminary Works approved drivage heading north west, beneath Cataract Reservoir to bisect the proposed Wonga West Areas 3 and 4.	• Mains drivage from the end of the Preliminary Works approved drivage heading west-northwest to what was the southern end of Wonga West Area 3.
Wonga West Longwalls	• 7 longwalls in two Areas – Area 3 – LW's 1-5 – Area 4 – LW's 6-7	• Removed from this application. To be resubmitted as a separate application to Department of Planning and Environment.
Bulli West - Bulli Seam 1st Workings	• 1st workings to the Bulli Seam to access the Bulli Seam in the western area of the Project Application Area.	• No changes proposed
Balgownie Seam 1st Workings	• 1st workings in the Balgownie Seam to access the Balgownie Seam in the western area of the Project Application Area.	• No changes proposed

For further detail see Section 1 of the PPR (NRE 2013).

These changes have resulted in the following changes to significant natural features in the Wonga East area:

- Cataract Creek will no longer be mined beneath.
- A reduction in mining beneath cliffs associated with Cataract Creek.
- Upland swamp CCUS1 will no longer be mined beneath.
- Minimisation of the extent of upland swamps CCUS5 and CCUS10 that will be mined beneath.
- Changes in impacts to significant natural features based on revised subsidence predictions.

These changes and their impacts are discussed further below.



Acknowledgements: Topo (c) NSW Land and Planning Information(2011); Overivew (c) State of NSW (c.2003)

Legend

Previous Wonga East Longwalls

Longwall Layout

Approved Longwalls (Preliminary Works Project)

Proposed Longwalls (Underground Expansion)

Figure 2: Proposed PPR mine plan

0 150 300 450 600 750

Metres

Scale: 1:15,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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3. Revised Impact Assessment

This section provides a revised impact assessment for ecological features within the Wonga East study area. The study area is defined as the area located within 600m of proposed secondary extraction for the revised longwall layout (Figure 3).

The Wonga East study area supports a wide range of ecological features, including the following significant natural features:

- Thirty-nine upland swamps (an Endangered Ecological Community (EEC)).
- Third and fourth order streams, including Cataract Creek and Cataract River.
- Rocky habitats, including rocky outcrops and cliffs.
- Threatened species and their habitats.

Significant natural features are shown in Figure 4. For a comprehensive discussion of these features see Section 2.4 of ERM (2013b).

This revised impact assessment focuses on those species, populations and communities listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and/or the NSW *Threatened Species Conservation Act 1995* (TSC Act) and deemed at risk of impact due to subsidence associated with longwall mining. This includes species that are reliant on natural features at risk of impact; particularly aquatic ecosystems (streams and creeks), upland swamps and rocky environments (including caves and overhangs) (DECC 2007a, DoP 2008). Past experience with longwall mining in the Southern Coalfield indicates that impacts to terrestrial ecosystems are generally less significant than those experienced by aquatic ecosystems, upland swamps and rocky environments, and terrestrial ecosystems are considered to be at negligible risk of impact from subsidence associated with longwall mining (DECC 2007a) and are not considered further.

3.1 Terrestrial ecology

A number of ecological assessments of the Wonga East area have been undertaken by ERM (summarised in ERM 2013b) and Biosis (2012a, 2012b, 2013). Together, these assessments provide a comprehensive inventory of the terrestrial biodiversity values present within the Wonga East area. A summary of these assessments can be found in ERM (2013a, 2013b).

Species, populations and communities either recorded during previous assessment, or deemed likely to occur within the study area, and considered vulnerable to impacts due to subsidence (DECC 2007a, ERM 2013b) are listed in Table 2.

Table 2: Threatened species, populations and communities likely to occur in the study area and vulnerable to indirect subsidence impacts (DECC 2007a, ERM 2013b)

E – Endangered, V - Vulnerable

Scientific name	Common name	EPBC Act status	TSC Act status
Flora			
Acacia baueri* ssp. *aspera	-	-	V
Epacris purpurascens* var. *purpurascens	-	-	V
Grevillea parviflora* ssp. *parviflora	Small-flowered Grevillea	V	V
Leucopogon exolasius	Woronora Beard-heath	V	V
Melaleuca deanei	Deane's Melaleuca	V	V
Persoonia bargoensis	Bargo Geebung	V	E
Pultenaea aristata	Prickly Bush-pea	V	V
Threatened ecological communities			
-	*Coastal Upland swamp in the Sydney Basin Bioregion*	-	E
Birds			
Pezoporus wallicus wallicus	Eastern Ground Parrot	-	V
Mammals (excl. bats)			
Cercartetus nanus	Eastern Pygmy Possum	-	V
Dasyurus maculatus maculatus	Spotted-tailed Quoll	E	V
Mammals - Bats			
Chalinolobus dwyeri	Large-eared Pied Bat	V	V
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	-	V
Myotis macropus	Large-footed Myotis	-	V
Reptiles			
Hoplocephalus bungaroides	Broad-headed Snake	V	E
Varanus rosenbergi	Rosenberg's Goanna	-	V
Frogs			
Heleioporus australiacus	Giant Burrowing Frog	V	V
Litoria littlejohni	Littlejohn's Tree frog	V	V
Pseudophryne australis	Red-crowned Toadlet	-	V
Mixophyes balbus	Stuttering Frog	V	E
Invertebrates			

Scientific name	Common name	EPBC Act status	TSC Act status
Petalura gigantea	Giant Dragonfly	-	E

These species are discussed further below in Sections 3.1.1 (flora) and Section 3.1.2 (fauna). A revised impact assessment is provided in Section 3.1.4.

Upland swamps are discussed further in Section 3.3.

3.1.1 Flora

ERM (2013b) identified seven threatened flora species at risk of indirect impact due to subsidence associated with extraction of coal from the Wonga East and Wonga West areas. Given the changes to the project, including the removal of the Wonga West area from the application, a reassessment of the potential for species to occur within the study area is required.

Table 3 provides a reassessment of habitat for these species, the potential for this habitat to occur within the study area, and a determination of the reliance of these species on microhabitats that are at risk of impacts from subsidence associated with the Preferred Project.

Species that are considered likely to occur within the study area and are considered to be at risk of impact from subsidence associated with the Preferred Project are considered further in Section 3.1.4.

Table 3: Terrestrial flora species vulnerable to impacts from subsidence (DECC 2007a) and an assessment of microhabitats within the study area

Species	Description	Does the species occur in, and is it reliant on, susceptible microhabitats within the study area?
Acacia baueri* ssp. *aspera	*Acacia baueri* ssp. *baueri* occurs in damp heaths associated with sandstone woodland (ERM 2013b) and often occurs in small depressions on rocky outcrops. Further, targeted and opportunistic surveys in the study area have not recorded this species. The Wonga East area does not contain many rocky outcrops, and suitable habitat for this species within the study area is limited.	Yes but limited Rocky outcrops
Epacris purpurascens* var. *purpurascens	*Epacris purpurascens* var. *purpurascens* is found within a wide range of habitat, usually associated with moisture, most of which have a strong shale influence (ERM 2013b, BHPBIC 2009). It is not considered to be a swamp specialist. This habitat is considered to be at negligible risk of impact. Further opportunistic surveys in the study area have not recorded this species.	No
Small-flowered Grevillea	Small-flower Grevillea grows in sandy or light clay soils, usually over thin shales, and occurs in a wide range of vegetation types (ERM 2013b). Habitat for this species is considered to be at negligible risk of impact. Further, targeted and opportunistic surveys in the study area have not recorded this species.	No
Woronora Beard-heath	Woronora Beard-heath occurs in a wide range of habitat types, including woodland, rocky hillsides and creeks (ERM 2013b). The wide range of habitats this species occurs in are considered to be at negligible risk of impact. Further, targeted and opportunistic surveys in the study area have not recorded this species.	No
Deane's Melaleuca	Deane's Paperbark grows in heath communities on sand, and has been recorded from ridgetops, dry ridges and slopes. It is often associated with sandy loam soils (ERM 2013b). This species is not considered to be reliant on microhabitats that are at risk of impact due to subsidence. Further, targeted and opportunistic surveys in the study area have not recorded this species.	No

Species	Description	Does the species occur in, and is it reliant on, susceptible microhabitats within the study area?
Bargo Geebung	Bargo Geebung grows in woodland and dry Sclerophyll forest on a wide variety of soils types. This species is not reliant on microhabitats at risk of impact from subsidence. Further, targeted and opportunistic surveys in the study area have not recorded this species.	No
Prickly Bush-pea	Prickly Bush-pea has been recorded within the study area from open habitats, including upland swamps and adjacent woodland. The species occurs where drainage is impeded (NPWS 2003), usually in areas where low degree slopes result in slowing of surface and groundwater flows (Biosis pers. obs.). Since the original EA (ERM 2013a) was submitted this species has been recorded at a number of additional locations and the species is known to be common and widely distributed in the study area.	Yes Upland swamps

3.1.2 Fauna

ERM (2013b) identified thirteen threatened fauna species at risk of impact due to subsidence associated with the original project. This assessment considered available habitat in the Wonga East and Wonga West area.

Given changes to the project, including the removal of the Wonga West area from the application, a reassessment of the potential for species to occur within the study area is required. Table 4 provides a reassessment of habitat for these species, the potential for this habitat to occur within the study area, and a determination of the reliance of these species on microhabitats that are at risk of impacts from subsidence.

Species that are considered likely to occur within the study area and at risk of impact from subsidence associated with the Preferred Project are considered further in Section 3.1.4.

Table 4: Terrestrial fauna species vulnerable to impacts from subsidence (DECC 2007a) and an assessment of microhabitats within the study area

Species	Description	Does the species occur in, and is it reliant on, susceptible microhabitats within the study area?
Eastern Ground Parrot	The Eastern Ground Parrot was previously thought to be extinct within the local area (DECC 2007b) prior to several observations of this species during surveys for the Metropolitan Coal Project and the Bulli Seam Operations Project. The Eastern Ground Parrot occurs in low heathlands and sedgelands, generally below one metre in height and very dense (OEH 2013b). Habitat within the study area is largely limited to MU 44 Upland swamp: Sedgeland-Heath Complex. This vegetation community is severely restricted and highly fragmented within the study area. The previous assessment (ERM 2013b) assessed that this species could potentially occur in the Wonga West area, but was unlikely to occur within the Wonga East area. This species is considered unlikely to occur within the study area.	No
Eastern Pygmy Possum	The Eastern Pygmy Possum occurs in a wide variety of habitat types, including rainforest, sclerophyll forest and heaths (DECC 2007b) and upland swamps (Biosis pers. obs., DECC 2007a). Given the wide range of habitat types that this species inhabits it is not considered to be at significant risk of impact from subsidence.	No
Spotted-tailed Quoll	The Spotted-tailed Quoll utilises a wide range of habitat types, with cliffs, rock benches or overhangs listed as habitat with potential to be impacted (DECC 2007a). Given the widespread nature of this species' habitat the risk of impact is considered to be negligible.	No
Large-eared Pied Bat	The Large-eared Pied Bat is considered rare within the local area and has narrow habitat requirements, including productive land close to suitable roosting habitats (DECC 2007b). The species roosts in caves and overhangs, and it is this habitat which is of high conservation significance (DECC 2007b). Cliffs that may provide suitable roosting sites within the study area are limited in extent, and restricted to an area over LW9.	Yes Cliffs over LW9
Eastern Bentwing-bat	The Eastern Bentwing-bat is common in the local area, being one of the most commonly recorded bats	Yes

Species	Description	Does the species occur in, and is it reliant on, susceptible microhabitats within the study area?
	during surveys (Biosis pers. obs.). This species has been recorded within the study area. The species forages within a wide range of habitat types and across a large area. The species roosts in caves and overhangs, and it is this habitat which is of high conservation significance (DECC 2007b). Cliffs that may provide suitable roosting sites within the study area are limited in extent, and restricted to an area over LW9.	Cliffs over LW9
Large-footed Myotis	The Large-footed Mytois is considered to be rare in the local area (DECC 2007b). The species forages along waterways, including disturbed waterways in urban environments, and is more common in more highly productive environments, although the species has been recorded on the Woronora plateau. The species roosts in caves and overhangs, and it is this habitat, which is of high conservation significance (DECC 2007b). Cliffs that may provide suitable roosting sites within the study area are limited in extent, and restricted to an area over LW9. Cataract Creek provides potential foraging habitat for this species. The species may be susceptible to changes in water quality or natural flow regimes (DECC 2007b).	Yes Cliffs over LW9 and Cataract Creek
Broad-headed Snake	The Broad-headed Snake occurs on exposed rocky outcrops with bedrock providing suitable winter sheltering habitat. This species is extremely rare in the local area (DECC 2007b). Due to the presence of this species on rocky outcrops that are susceptible to fracturing due to subsidence, the species is listed by DECC (2007a) as being at risk of impact from longwall mining. Biosis has previously undertaken monitoring of rocky outcrops for the Dendrobium, Wongawilli and Nebo mines. While subsidence effects, including fracturing of rocky outcrops, have been observed, no impacts to sheltering habitat for reptiles was observed in these areas. The Wonga East area does not contain many rocky outcrops, and suitable habitat for this species within the study area is limited. The risk of impact to this species is considered minimal. However, if specific locations for this species were identified these would be considered of high conservation value given the species' rarity. For this reason, the species is considered further below.	Yes Rocky outcrops

Species	Description	Does the species occur in, and is it reliant on, susceptible microhabitats within the study area?
Rosenberg's Goanna	Rosenberg's Goanna inhabits ridgetops with higher levels of rocks and shrubs that provide habitat for prey species (DECC 2007b). Although this species is located on rocky outcrops which are at risk of impacts from subsidence (DECC 2007a) the species or its prey do not rely on specific habitat features at risk of impact. Thus the species is considered at negligible risk of impact from the preferred project.	No
Giant Burrowing Frog	The Giant Burrowing Frog occurs in sandstone environments and is generally associated with first and second order intermittent creeks that provide suitable breeding pools (Biosis pers. obs.). Although often associated with upland swamps, DECC (2007b) assert that this association is not direct, rather that upland swamps are associated with minor drainage lines that provide suitable breeding pools and burrowing habitat for this species. Detailed habitat mapping was undertaken by Biosis (2012b, 2013a) with suitable breeding habitat for this species mapped at four locations in the study area (Figure 5). Targeted surveys undertaken by Biosis as a part of the ecological monitoring program for Wonga East in August and December 2012, February, April, August and May 2013 and January and February 2014 have detected tadpoles for the Giant Burrowing Frog in a tributary of CRUS2. A total of 17 tadpoles were observed in three breeding pools located along the 245 metre transect (Figure 5). This tributary of CRUS2 is located approximately 700 m from the nearest longwall (LW4) and is outside the active subsidence zone. The species has not been recorded elsewhere within the study area.	No
Littlejohn's Tree frog	Littlejohn's Tree Frog occurs in sandstone environments and is generally associated with first and second order intermittent creeks that provide suitable breeding pools (Biosis pers. obs.). The species has been recorded within a wide variety of vegetation types, all associated with more open habitat and intermittent creeks. This includes, but is not restricted to, upland swamps (Biosis pers. obs.). Detailed habitat mapping was undertaken by Biosis (2012b, 2013a) with suitable breeding habitat for this species mapped at four locations in the study area (Figure 5). Targeted surveys undertaken by Biosis as a part of the ecological monitoring program for Wonga East in August and December 2012, February, April, August and May 2013 and January and February 2014 have not recorded this species.	No

Species	Description	Does the species occur in, and is it reliant on, susceptible microhabitats within the study area?
Red-crowned Toadlet	The Red-crowned Toadlet is fairly common in preferred ridgetop habitat and first order ephemeral creeks below ridges (DECC 2007b) and has been recorded, using drainage lines, sheltering under bushrock on ridgetops and in depressions along fire trails (Biosis pers. obs.). Habitat for this species within the study area has not been mapped, as it is widely distributed and common. Targeted surveys for the Red-crowned Toadlet have been undertaken by Biosis as a part of the ecological monitoring program for Wonga East (Biosis 2013a). Surveys were conducted using auditory recording devices located in suitable breeding habitat along two ephemeral creeks below ridgelines above Longwall 4 and Longwall 5 (Figure 4). The Red-crowned Toadlet was recorded calling at both sites (Biosis 2013a). However, preferred habitat for this species is considered to be at limited risk of impact.	Yes Not reliant on microhabitat susceptible to impacts
Stuttering Frog	The Stuttering Frog is generally considered rare within the Sydney Basin bioregion and is now close to extinction in the local area (DECC 2007b). Detailed habitat mapping was undertaken by Biosis (2012b, 2013a) with suitable breeding habitat for this species mapped along Cataract Creek in the study area (Figure 5). Cataract Creek has been impacted by past mining of the Bulli and Balgownie coal seams, with an iron seep located along a tributary of Cataract Creek resulting in moderate to high levels of iron flocculent in the creek. This past impact is likely to reduce the suitability of the habitat for this species (ERM 2013b). Targeted surveys undertaken by Biosis as a part of the ecological monitoring program for Wonga East in October, November and December 2012, February and November 2013 and January and February 2014 have not recorded the Stuttering Frog along Cataract Creek.	No
Giant Dragonfly	OEH (2013d) identifies upland swamps with open vegetation and free water as preferred habitat for the Giant Dragonfly. Potential breeding habitat for the Giant Dragonfly can be identified based on the hydrogeomorphology, rainfall range and soils (Baird 2012). Breeding habitat is presumed to be associated with groundwater dependent habitat with some associated development of organic-rich or peaty soils. Swamp types with a negative water balance and prolonged periods of surface drying, or characterised by permanent or prolonged seasonal inundation, are not considered to provide	Yes Areas of upland swamp BCUS4, CCUS4 and CRUS1.

Species	Description	Does the species occur in, and is it reliant on, susceptible microhabitats within the study area?
	potential breeding habitat for this species. Based on this information, Biosis has undertaken a review of potential habitat within the Wonga East area and identified upland swamps CCUS1, CCUS4, CCUS5, CCUS10, CRUS1 and BCUS4 as potential habitat for this species based on presence of communities reliant on presence of groundwater and potential for organic-rich soils. Additional surveys of these areas were undertaken in December 2013 and January to February 2014. These additional surveys focused on identifying significant breeding habitat through surveys for exuviae of the Giant Dragonfly, as it is breeding habitat for this species that is likely to be susceptible to impacts from subsidence and consequent changes in soil moisture. Exuviae were located in upland swamps CCUS4, CRUS1 and BCUS4. In all upland swamps exuviae were located in areas with deep, organic soils. In CCUS4 and BCUS4 this was at the downstream extent of these swamps, where there was an accumulation of groundwater and open vegetation. In CRUS1 this was in pockets of groundwater dependent Tea-tree Thicket with an open overstorey, created by underlying geology. Of the locations where exuviae were observed only CCUS4 will be directly undermined. The potential for other locations listed above to support breeding habitat for this species cannot be discounted; however other locations will not be directly undermined.	

3.1.3 Assessment of historic impacts to terrestrial biodiversity from extraction of the Bulli and Balgownie seams

Sections 3.1.1 and 3.1.2 identify the following significant natural features at risk of impact due to subsidence:

- Rocky outcrops;
- Upland swamps;
- Cliffs over Longwall 9;
- Cataract Creek; and
- Threatened frog habitat as identified in Figure 5.

ERM (2013a) and ERM (2013b) provide a summary of potential impact mechanisms. This section assesses the potential impacts of past mining of the Bulli and Balgownie seams, before assessing the impacts of the original project versus the preferred project on these significant natural features

Extraction of the Bulli and Balgownie seams has occurred within the Wonga East area. Within the study area, the Bulli seam was extracted via hand workings and pillar extraction between 1890 and 1960. The Balgownie seam was extracted using continuous miner pillar extraction in 1969 and the retreat longwall mining method from 1970 to 1982. Assessment of subsidence data from the extraction of the Bulli and Balgownie coal seams has been undertaken by SCT Operations (2014).

Table 5 provides subsidence predictions for identified significant natural features from the extraction of the Bulli and Balgownie Seams in the Wonga East area.

Table 5: Bulli and Balgownie seam subsidence predictions for selected significant features in the study area

	Bulli seam and Balgownie seam Subsidence (m) (Balgownie Seam only in brackets)	Balgownie seam Tilt (mm/m)	Balgownie seam Max Tensile Strain (mm/m) and Typical (in brackets)	Balgownie seam Max Compressive Strain (mm/m) and Typical (in brackets)	Balgownie seam Closure (mm)
Selected natural features					
Threatened frog habitat CRUS2 Trib	0.5 (<0.1)	5	3	4	-
Threatened frog habitat CRUS1 Trib1	0.5 (<0.1)	5	3	4	-
Threatened frog habitat CRUS1 Trib2	0.9 (<0.1)	11	3	4	-
Threatened frog habitat CCUS4 Trib	1.2 (0.7)	18	8 (3)	14 (4)	-
Cliffs over LW9	0.5 (<0.1)	N/A	N/A	N/A	-
Cataract Creek	1.4 (1.2)	15	N/A	N/A	310
Giant Dragonfly habitat BCUS4	0.6 (0.1)	2	0.5	1	-
Giant Dragonfly habitat CCUS4	0.9 (0.8)	13	4	8	-
Giant Dragonfly habitat CRUS1	0.5 (0.1)	2	0.5	1	-

Available data indicates that past mining of the Bulli and Balgownie Seams is likely to have resulted in fracturing of bedrock beneath identified threatened frog habitat, and that closure in Cataract Creek is likely to have been sufficient to have resulted in diversion of surface flows using criteria identified by MSEC (DoP 2010). Fracturing of bedrock and changes in groundwater levels are likely to have occurred in upland swamps CCUS4 and CRUS1 (see Section 3.3.4 for further discussion).

Based on this data, it is likely that there are pre-existing impacts to identified natural features, as outlined above. There is evidence to support this conclusion, with iron seeping from a tributary of Cataract Creek resulting in a significant amount of iron flocculent in Cataract Creek. However, no impacts to the bed of Cataract Creek have been observed. Cliffs in the study area show signs of previous collapse, including some where likely mining-induced collapse has occurred (K. Mills pers. comm.).

This assessment of past mining in the Wonga East area indicates that natural features in the study area have been subject to subsidence resulting from extraction of the Bulli and Balgownie Seams. This data provides a baseline against which assessments of potential impacts resulting from extraction of the Wongawilli Seam, as part of the preferred project, must be assessed.

3.1.4 Revised impacts assessment for terrestrial biodiversity

A summary of subsidence predictions for extraction of the Wongawilli Seam in the Wonga East area is provided in Table 6. This table provides predicted subsidence parameters for each longwall, as well as predicted subsidence for significant natural features outlined above.

The extraction of the Wongawilli Seam in the Wonga East area will result in a maximum of 2.1 m of subsidence, with tilts between 24 and 51 mm / m, tensile strain of between 7 and 15 mm / m and compressive strains between 14 and 31 mm / m. Closure within Cataract Creek will be managed to minimise the risk of creek bed cracking and subsurface flow.

As can be seen from Table 6, the majority of significant natural features within the study area are at minimal risk of impact, with subsidence predictions indicating subsidence effects are likely to be minimal. The exception to this is threatened frog habitat in CCUS4 Trib, cliffs over Longwall 9 and Giant Dragonfly habitat in upland swamps BCUS4, CCUS4 and CRUS1.

Table 7 provides impact assessments, including an assessment of impacts from the original project compared to the preferred project, for natural features identified in Sections 3.1.1 and 3.1.2.

Tilts, tensile strains and compressive strains in CCUS4 Trib are sufficient to result in fracturing of the bedrock beneath this tributary. There is also potential for rockfall from and collapse of a sandstone formation at the downstream extent of this habitat. However, no threatened frogs have been recorded at this location to date. Known habitat for the Giant Burrowing Frog in CRUS2 Trib will not be impacted.

Subsidence predictions for cliffs over Longwall 9 are of sufficient magnitude to result in impacts to these cliffs. Impacts, including tensile cracking of the rock strata and collapse, are likely to occur, particularly where horizontal compression exceeds 50 – 100 mm per 20 m length of cliff formation. However, it is difficult to predict the location/s where impacts may occur. Given the limited extent of suitable roosting sites for microchiropteran bats the risk of impact is considered low, particularly when compared with the availability of suitable habitat in the local area. Risk of collapse is considered minimal (SCT Operations 2014).

Subsidence predictions for Cataract Creek indicate that this waterway is unlikely to be subject to negative environmental consequences. Closure will be managed to minimise the risk of creek bed cracking and subsurface flow, and tilts, compressive and tensile strains are unlikely to be of sufficient magnitude to result in fracturing of the bedrock of Cataract Creek. However, fracturing of tributaries of Cataract Creek may result in decreased inflow into Cataract Creek, and an increase in iron seepage at the base of these tributaries and resultant potential for increased iron flocculent in Cataract Creek (A. Dawkins pers. comm.).

The groundwater model indicates that the average daily stream flow from Cataract Creek to Cataract Reservoir is 11.2 ML/d, of which 3.5 ML/d is baseflow. The model predicts a 0.013 ML/d (0.12%) loss of stream baseflow following mining. This level of change is unlikely to be detectable and unlikely to result in observable changes to flow regimes in Cataract Creek. Increases in iron hydroxide flocculent are unlikely to result in observable changes to Cataract Creek above and beyond those present due to past mining.

Of the three upland swamps where exuviae of the Giant Dragonfly was observed, only CCUS4 will be directly mined under. Although impacts to Giant Dragonfly habitat in upland swamps BCUS4 and CRUS1 may be indirectly impacted through upper sections of these upland swamps being mined beneath, further discussion in Section 3.3.4 indicates the risk of impact to water availability in these upland swamps is low. The risk of changes in water availability impacting on habitat for the Giant Dragonfly in CCUS4 is considered high. However, any impacts are unlikely to result in a significant impact to the local population of this species, as the Giant Dragonfly has been recorded elsewhere in the immediate area, and the species has regularly been observed in previously undermined upland swamps, including upland swamps in Wallandoola Creek and Lizard Creek.

Further assessment and discussion of potential impacts is provided below.

Table 6: Wongawilli seam subsidence predictions for longwalls and selected significant features in the study area

	Overburden depth to Wongawilli Seam (m)	Subsidence predicted (m) and measured (in brackets)	Tilt predicted (mm/m) and measured (in brackets)	Tensile strain predicted (mm/m) and measured (in brackets)	Compressive strain predicted (mm/m) and measured (in brackets)	Closure on Cataract Creek (mm)
Longwall 1	260	2.1	40	12	24	-
Longwall 2	260	2.1	40	12	24	-
Longwall 3	255	2.6	51	15	31	-
Longwall 4	300	2.1 (1.6)	35 (30)	10.5 (7.5)	21 (14)	< 5
Longwall 5	265	1.9 (1.8)	36 (30)	11 (6)	22 (14)	130 (49)
Longwall 6	280	2.1	38	11	23	130
Longwall 7	270	1.5	28	8	17	200
Longwall 9	330	2.1	32	10	19	120
Longwall 10	340	1.6	24	7	14	20
Longwall 11	350	2.1	30	9	18	0
Selected natural features						
Threatened frog habitat CRUS2 Trib	300	0	0	0	0	-
Threatened frog habitat CRUS1 Trib1	320	0	0	0	0	-
Threatened frog habitat CRUS1 Trib2	320	0.02	0	0	0	-
Threatened frog habitat CCUS4 Trib	270	1.5	28	8	17	-
Cliffs over LW9	330	2.1	32	10	19	-

	Overburden depth to Wongawilli Seam (m)	Subsidence predicted (m) and measured (in brackets)	Tilt predicted (mm/m) and measured (in brackets)	Tensile strain predicted (mm/m) and measured (in brackets)	Compressive strain predicted (mm/m) and measured (in brackets)	Closure on Cataract Creek (mm)
Cataract Creek	260	< 0.2	1.0	0.0	N/A	200
Giant Dragonfly habitat BCUS4	295	1.0	23	6.8	13.6	-
Giant Dragonfly habitat CCUS4	290	1.4	31	9.2	18.5	-
Giant Dragonfly habitat CRUS1	300	1.4	22	6.7	13.4	-

Table 7: Impact assessment for species at risk of subsidence, including comparison of risks from the original project and preferred project

Species	Microhabitats at significant risk of impact from subsidence	Potential impacts to critical microhabitat	Notes	Risk of impact from original project (based on ERM 2013a and ERM 2013b)	Risk of impact from preferred project
Acacia baueri* ssp. *aspera	Rocky outcrops	Fracturing of the base of minor depressions in rocky outcrops, leading to reduced moisture in these areas and potential loss of individual plants.	The general risk of fracturing of rocky outcrops within the study area is considered moderately high; however suitable habitat (i.e. rocky outcrops with minor depressions) is limited within the study area	Low	Low
Prickly Bush-pea	Upland swamps	Fracturing of bedrock resulting in changes in water availability or changes in vegetation composition	The species is widespread and common within the study area, having been recorded at a greater number of locations since the submission of the EA (ERM 2013b).	Low	Low

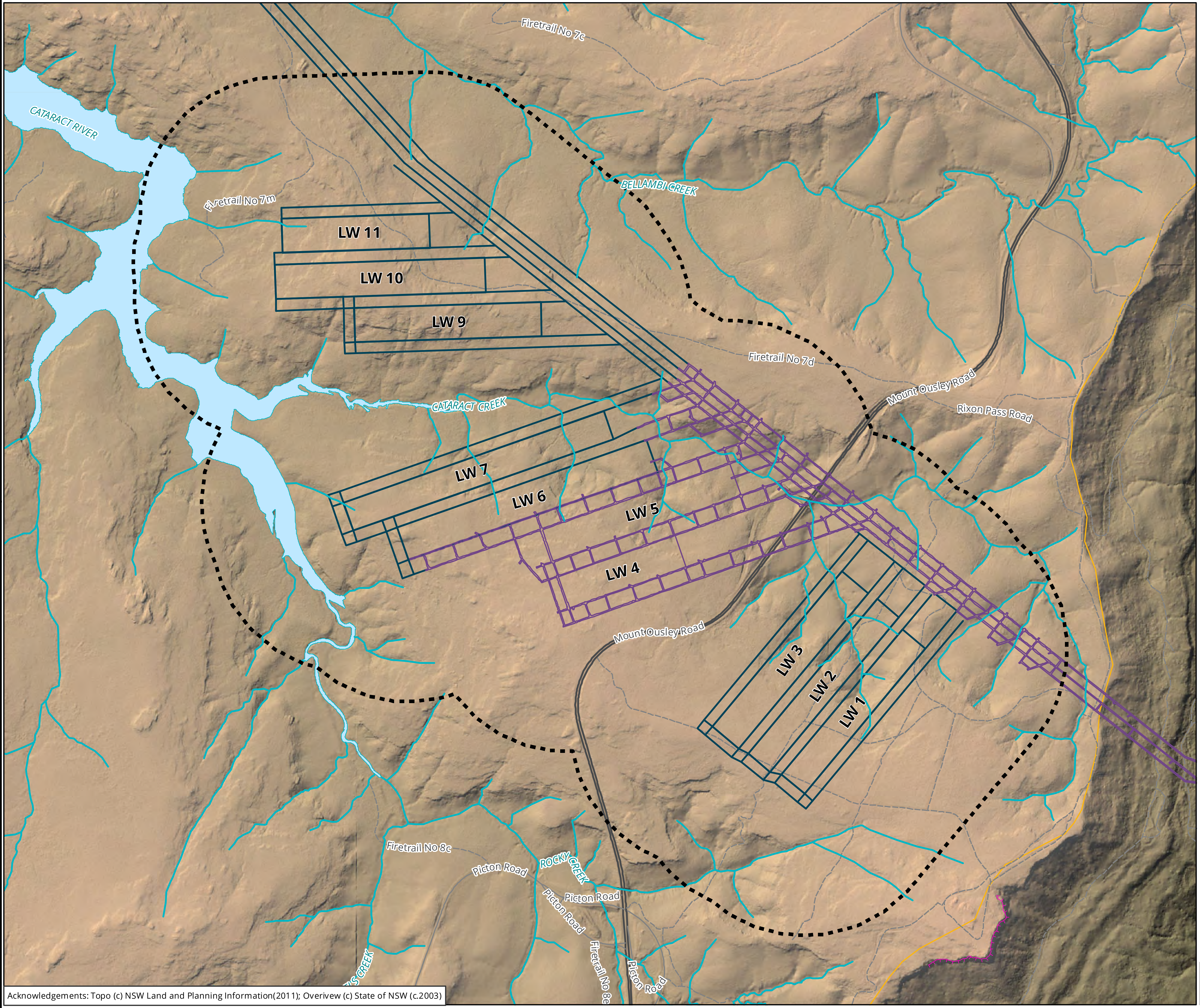
Species	Microhabitats at significant risk of impact from subsidence	Potential impacts to critical microhabitat	Notes	Risk of impact from original project (based on ERM 2013a and ERM 2013b)	Risk of impact from preferred project
		resulting in increased competition. Changes in slope gradient resulting in decreased water availability.	Although there is potential for fracturing of bedrock beneath suitable upland swamp habitat, and changes in hydrology, impacts to wider habitat are predicted to be minimal.		
Large-eared Pied Bat **Eastern Bentwing-bat** **Large-footed Myotis**	Cliffs	Overhang collapse resulting in destruction of roosting habitat.	Potential roosting habitat within the study area is limited in extent, and restricted to an area above LW9. Further, the risk of collapse of these cliffs is considered to be low (~5%; K. Mills pers. comm.). The removal of Wonga West from the project, where suitable habitat was much more prevalent along Lizard and Wallandoola Creeks, has resulted in a reduction in risk.	Moderate (Wonga West)	Low
	Cataract Creek (Large-footed Mytois only)	Fracturing of stream bed resulting in diversion of flows along sections of creeks. Increased iron entering the waterway, resulting in changes in water quality and choking of vegetation by iron flocculent.	The revision of the mine plan now avoids mining below Cataract Creek. No impacts to the bed of Cataract Creek are predicted to occur and diversion of flows is unlikely (A. Dawkins pers. comm.). There is potential for fracturing of the base of tributaries of Cataract Creek, resulting in diversion of flows, decreased inflow into Cataract Creek and iron seepage (A. Dawkins pers. comm.). The extent and magnitude of impact will be dependent on past impacts from extraction of the Bulli and Balgownie seams.	Low	Low

Species	Microhabitats at significant risk of impact from subsidence	Potential impacts to critical microhabitat	Notes	Risk of impact from original project (based on ERM 2013a and ERM 2013b)	Risk of impact from preferred project
Broad-headed Snake	Rocky outcrops	Fracturing of rocky outcrops leading to a loss or change in shelter sites for this species or its prey.	The general risk of fracturing of rocky outcrops within the study area is considered moderately high with perceptible cracking in up to 30% of bare rock areas located directly above longwalls (k. Mills pers. comm.). However suitable habitat (i.e. rocky outcrops with suitable shelter) is limited within the study area. Suitable habitat for the species, identified within the EA (ERM 2013b) was largely limited to Wonga West.	Moderate (Wonga West)	Low
Giant Burrowing Frog **Littlejohn's Tree frog**	Creeks shown in Figure 5	Fracturing of stream bed resulting in diversion of flows along sections of creeks providing breeding habitat, resulting in loss of breeding pools. Fracturing of the base and draining of breeding pools. Increased iron entering the waterway, resulting in changes in water quality and choking of vegetation by iron flocculent. Release of methane gas into the water column, resulting in vegetation dieback in riparian	Suitable habitat for these species has been identified in three tributaries of Cataract River and one tributary of Cataract Creek (Figure 5; Biosis 2012a, Biosis 2013a). Surveys undertaken as a part of the ecological monitoring program for Longwalls 4 and 5 have identified Giant Burrowing Frog tadpoles at one of these locations, in a tributary of Cataract River below CRUS2. This site is located outside of the predicted subsidence impact zone. These species have not been recorded at any other sites. Additional targeted surveys and the removal of Wonga West from the project application have resulted in a significant reduction in risk of impact to this species.	High	Low

Species	Microhabitats at significant risk of impact from subsidence	Potential impacts to critical microhabitat	Notes	Risk of impact from original project (based on ERM 2013a and ERM 2013b)	Risk of impact from preferred project
		environments and impacts to water quality.			
Stuttering Frog	Yes Cataract Creek (Figure 5)	Fracturing of stream bed resulting in diversion of flows along sections of creeks providing breeding habitat, resulting in impacts to suitable breeding habitat. Fracturing of the base and draining of breeding pools. Increased iron entering the waterway, resulting in changes in water quality and choking of vegetation by iron flocculent. Release of methane gas into the water column, resulting in vegetation dieback in riparian environments and impacts to	Suitable habitat for this species has been identified in Cataract Creek (Figure 5; Biosis 2012a, Biosis 2013a). Surveys undertaken as a part of the ecological monitoring program for Longwalls 4 and 5 have not recorded this species in the study area. Additional targeted surveys have resulted in a reduction in risk of impact to this species.	Moderate	Low

Species	Microhabitats at significant risk of impact from subsidence	Potential impacts to critical microhabitat	Notes	Risk of impact from original project (based on ERM 2013a and ERM 2013b)	Risk of impact from preferred project
		water quality.			
Giant Dragonfly	Yes Areas of upland swamp BCUS4, CCUS4 and CRUS1.	Fracturing of bedrock resulting in changes in water availability resulting in loss of habitat. Changes in slope gradient resulting in decreased water availability and loss of habitat.	Targeted surveys undertaken by Biosis in December 2013 and January to February 2014 identified habitat for this species in upland swamps BCUS4, CCUS4 and CRUS1. Of the locations where exuviae were observed only CCUS4 will be directly undermined. The potential for other locations listed above to support breeding habitat for this species cannot be discounted; however other locations will not be directly undermined.	Low	Moderate[1]

[1] Note: this is not an increase in impact from previous impact assessment. Recent targeted surveys have identified habitat for this species.



Legend

Longwall Layout

- Approved Longwalls (Preliminary Works Project)
- Proposed Longwalls (Underground Expansion)
- 600m Study Area

Figure 3: Wonga East study area

0 150 300 450 600 750

Metres

Scale: 1:15,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

biosis

Biosis Pty Ltd

Ballarat, Brisbane, Canberra, Melbourne, Sydney, Wangaratta & Wollongong

Matter: 16646
Date: 09 September 2013,
Checked by: NMG, Drawn by: ANP, Last edited by: apritchard
Location:P:\16600s\16646\Mapping\Report Figures
16646 PPR_F3_Study Area

Acknowledgements: Topo (c) NSW Land and Planning Information(2011); Overivew (c) State of NSW (c.2003)

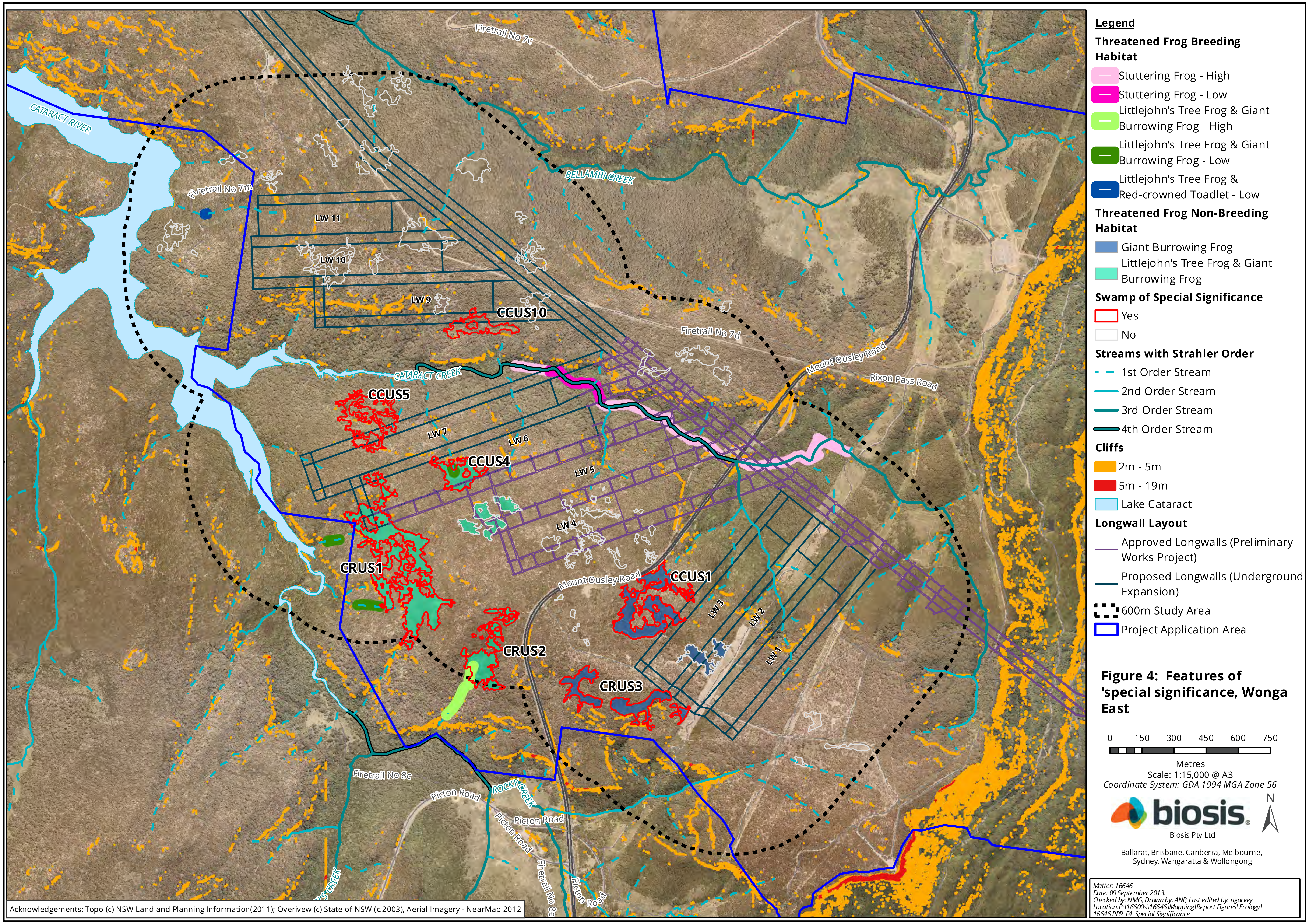
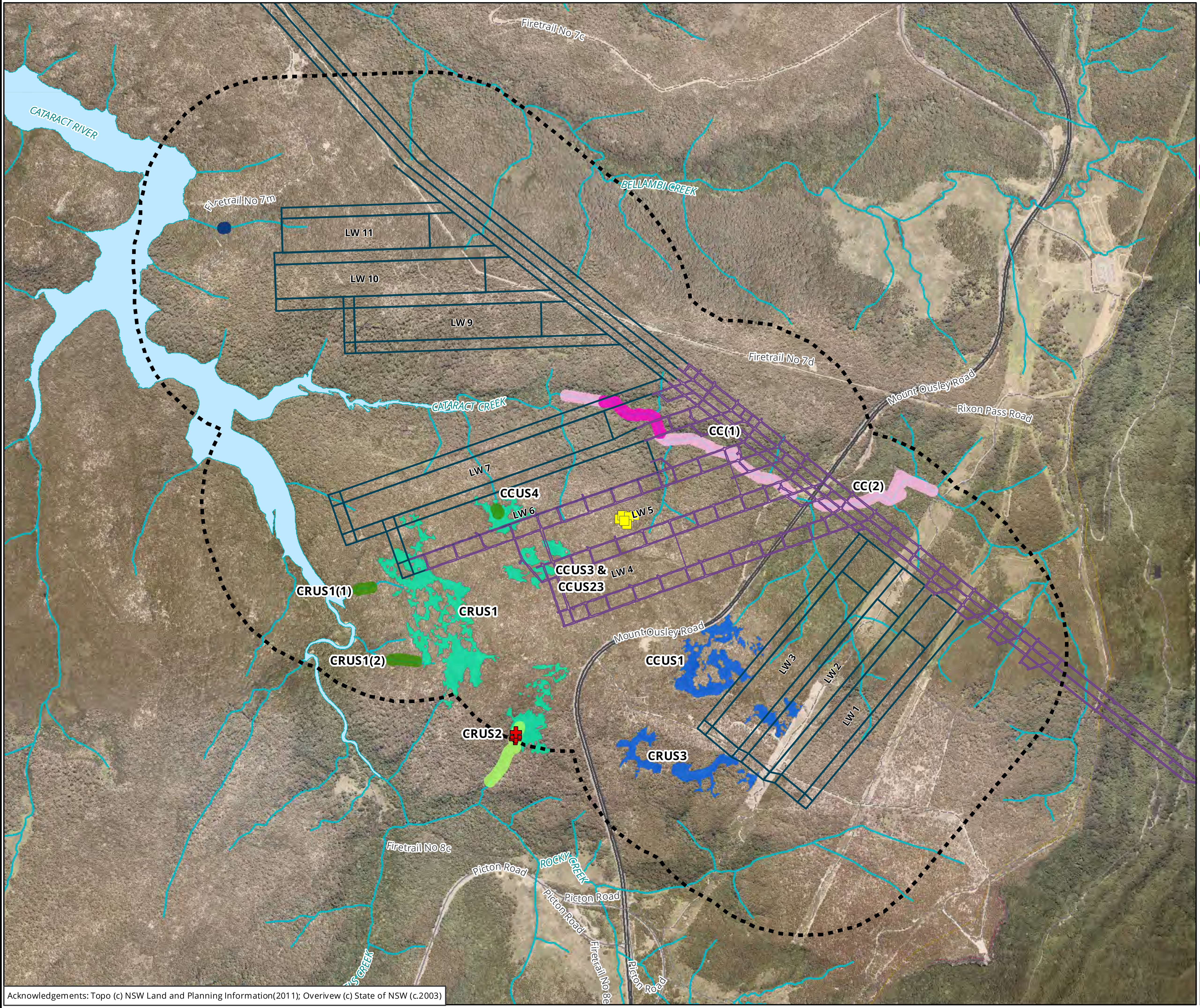


Figure 4: Features of 'special significance, Wonga East



Legend

Threatened Frogs Located by Biosis

- Red-crowned Toadlet - Adult
- Giant Burrowing Frog - Pool Containing Tadpoles

Threatened Frog Breeding Habitat

- Stuttering Frog - High
- Stuttering Frog - Low
- Littlejohn's Tree Frog & Giant Burrowing Frog - High
- Littlejohn's Tree Frog & Giant Burrowing Frog - Low
- Littlejohn's Tree Frog & Red-crowned Toadlet - Low

Threatened Frog Non-Breeding Habitat

- Giant Burrowing Frog
- Littlejohn's Tree Frog & Giant Burrowing Frog

Longwall Layout

- Approved Longwalls (Preliminary Works Project)
- Proposed Longwalls (Underground Expansion)
- 600m Study Area

Figure 5: Breeding and non-breeding habitat for threatened frogs, Wonga East

0 150 300 450 600 750

Metres

Scale: 1:15,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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Date: 10 September 2013,
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Location:P:\16600s\16646\Mapping\Report Figures\16646 PPR_F5_Frog Habitat

3.2 Aquatic ecology

Cardno Ecology Lab (2009; 2011a, b; 2012a, b) and Biosis (2014) have undertaken seasonal assessments of aquatic habitat condition and macroinvertebrate assemblages at impact and control monitoring reaches in spring and autumn each year since 2008. Table 8 and Table 9 provide a summary of work undertaken to date. These assessments provide a comprehensive inventory and understanding of the aquatic biodiversity values present in the Wonga East area.

Table 8: Aquatic ecology monitoring approach

Aquatic Ecological Value	Monitoring	Frequency
Aquatic Habitat	Habitat assessment (including photopoint monitoring).	Baseline monitoring has been conducted twice per year specifically during spring and autumn each year.
Aquatic Macroinvertebrates	Macroinvertebrates (AUSRIVAS) including threatened species.	Baseline monitoring has been conducted twice per year specifically during spring and autumn each year.
Fish	Targeted threatened fish surveys.	Surveys have been undertaken according to the 'Survey guidelines for Australia's threatened fish' (DSEWPaC 2011).
Water Quality	In-situ water quality provides a snapshot of each monitoring reach.	During each monitoring event.

Table 9: Overview of previous aquatic surveys in Cataract Creek (*n* = 2), Cataract River (*n* = 2) and Allen Creek (*n* = 2)

✓ = sampled, N/A = not sampled

	Spring 2008	Autumn 2009	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011	Spring 2011	Autumn 2012	Spring 2012	Autumn 2013
Water Quality (*in situ*)	✓	✓	✓	✓	N/A	✓	✓	✓	N/A	✓
Aquatic Habitat Assessments (HABSCORE)	✓	✓	✓	✓	N/A	✓	✓	✓	N/A	✓
Aquatic Macronvertebrate Sampling (AUSRIVAS)	✓	✓	✓	✓	N/A	✓	✓	✓	N/A	✓
Threatened Fish Surveys	N/A	✓	N/A	Summer 2010	N/A	Summer 2011	N/A	Summer 2012	N/A	✓
Reference	Cardno Ecology Lab (2010)	Cardno Ecology Lab (2010)	Cardno Ecology Lab (2012a)	Cardno Ecology Lab (2012a)		Cardno Ecology Lab (2012a) Cardno Ecology Lab (2012b)	Cardno Ecology Lab (2012a) Cardno Ecology Lab (2012b)	Cardno Ecology Lab (2012a) Cardno Ecology Lab (2012c)	N/A	Biosis (2014)

3.2.1 Threatened aquatic species

Due to the potential presence of threatened aquatic species and the potential of suitable habitat for these species, targeted threatened species surveys were undertaken to confirm their presence/absence. An overview of the threatened species relevant to the Wonga East Domain is provided in Table 10 . An overview of the survey locations is presented in Figure 6.

Table 10: Aquatic species likely to occur in the study area and vulnerable to impacts due to subsidence

E = endangered, V = vulnerable

Scientific name	Common name	EPBC Act status	FM Act status
Fish			
Macquaria australasica	Macquarie Perch	E	E
Maccullochella macquariensis	Trout Cod	E	E
Maccullochella peelii	Murray Cod	V	-
Bidyanus bidyanus	Silver Perch	CE	V
Macroinvertebrates			
Archaeophya adamsi	Adam's Emerald Dragonfly	-	E
Austrocordulia leonardi	Sydney Hawk Dragonfly	-	E

Silver Perch have previously been captured from Lake Cataract (Cardno Ecology Lab 2012; Horrobin 1996) and these individuals would have resulted from a translocation of these species into this catchment. Targeted threatened fish surveys undertaken in the Wonga East area between Spring 2008 and Spring 2011 have confirmed the presence of Macquarie Perch and Silver Perch, and an unidentified freshwater cod, which was assumed to be either Murray Cod or Trout Cod, within the lower reaches of Cataract Creek (Cardno Ecology Lab 2010; 2011).

Biosis (2014) has undertaken surveys of additional sections of Cataract Creek upstream of the sites surveyed by Cardno Ecology Lab (see Fish Reach 19US in Figure 6 and Additional Fish Reach in Figure 7). These additional surveys did not record any threatened fish species.

Numbers of Macquarie Perch, Murray Cod, Silver Perch and Trout Cod recorded between 2009 and 2013 are presented in Table 11. The locations of Macquarie Perch and Murray Cod captured during the most recent survey undertaken in Cataract Creek (Biosis 2014) are presented in Figure 7.

Table 11: Numbers of threatened fish captured in Cataract Creek

	2009/2010	2010/2011	20011/2012	2012/2013
Macquarie Perch	30	90	18	14
Murray Cod	0	0	0	16
Silver Perch	9	9	0	0
Trout Cod	0	0	0	0

In order to ascertain the presence/absence of two species of threatened dragonfly listed under the NSW *Fisheries Management Act 1994* (FM Act), Adam's Emerald Dragonfly and Sydney Hawk Dragonfly, surveys undertaken in autumn 2013 included an assessment of habitat suitability for these two species, based on the habitat requirements outlined in DPI (2007) and DPI (2012), as well as targeted searches for exuviae.

Furthermore, the presence of individuals of the appropriate dragonfly family was assessed during live-picking of macorinvertabrates undertaken in the field. Neither of the two threatened dragonfly species have been recorded during aquatic surveys in the Wonga East area since 2008.

3.2.2 Aquatic macroinvertebrates (AUSRIVAS)

A summary of aquatic macroinvertabrate data is provided in Table 12.

Table 12: AUSRIVAS, OE50 Taxa and SIGNAL2 scores for Wonga East (including control sites)

a) AUSRIVAS data, 2008 – 2012

X = Invertebrate assemblage is richer than reference condition; A = equivalent to reference condition; B = below reference condition (i.e. significantly impaired); C= well below reference condition (i.e. severely impaired).

	Site	2008a	2008b	2009a		2009b	2010		2011		2012	
		Spring	Spring	Spring	Autumn	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
Cataract Creek	WGE-AQ5	B	A	B	B	B	A	C	B	B	C	B
	WGE-AQ6	B	B	B	A	A	A	C	C	B	B	A
Cataract River	WGE-AQ9	A	B	A	A	B	B	B	C	B	A	B
	WGE-AQ10	A	A	B	A	A	X	C	B	A	B	B
Allen's Creek	WGE-AQ13	-	-	B	A	A	A	B	B	A	A	A
	WGE-AQ14	-	-	A	A	A	A	B	B	A	B	A

b) OE50 Taxa scores, 2008 – 2012

A score of 1 indicates that the observed water bug community is similar to the expected one and therefore equivalent to that of a reference or undisturbed stream. A score lower than 1 means that less water bugs were observed than expected and that the community is impoverished when compared to a reference site.

	Site	2008a	2008b	2009a		2009b	2010		2011		2012	
		Spring	Spring	Spring	Autumn	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
Cataract Creek	WGE-AQ5	0.6	0.85	0.6	0.7	0.7	0.85	0.3	0.7	0.65	0.5	0.625
	WGE-AQ6	0.7	0.7	0.6	1.05	0.825	0.875	0.3	0.35	0.75	0.6	0.925
Cataract	WGE-AQ9	0.925	0.8	1.1	1.125	0.725	0.8	0.5	0.375	0.575	0.85	0.7

	Site	2008a	2008b	2009a		2009b	2010		2011		2012	
		Spring	Spring	Spring	Autumn	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
River	WGE-AQ10	0.925	0.925	0.575	1.1	1	1.2	0.35	0.6	0.8	0.575	0.5
Allen's Creek	WGE-AQ13	-	-	0.8	1.1	0.95	1.175	0.5	0.525	1	0.875	0.9
	WGE-AQ14	-	-	0.9	1.1	0.025	0.925	0.625	0.675	1.025	0.7	0.85

c) SIGNAL2 scores, 2008 – 2012

Score < 4 = severely polluted; 4-5 moderately polluted, 5-6 mildly polluted

	Site	2008a	2008b	2009a		2009b	2010		2011		2012	
		Spring	Spring	Spring	Autumn	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
Cataract Creek	WGE-AQ5	4.9	4.6	4.9	6	5.8	4.9	4.5	4.6	5	5.2	5.8
	WGE-AQ6	4.9	4.8	4.5	5.2	5.1	4.9	4.8	3.6	4.9	5.1	5.1
Cataract River	WGE-AQ9	4.9	4.8	4.9	4.8	5.2	5.2	4.5	2.8	5.5	5.1	5.5
	WGE-AQ10	5	4.5	5.7	5.3	4.6	4.6	4.5	4	4.9	5.5	6
Allen's Creek	WGE-AQ13	-	-	5	5	5	4.7	4.9	4	5.2	4.8	5.5
	WGE-AQ14	-	-	5.2	5.4	4.8	4.9	5.2	2.9	5	5.2	5.5

The number of taxa collected at each monitoring reach varied at a temporal and spatial scale (Cardno Ecology Lab 2009; 2011a, b; 2012a, b; Biosis 2014). Samples collected from Cataract Creek were generally less diverse than those collected from Cataract River and Allen's Creek. However, AUSRIVAS and OE50 Taxa scores indicate that there is little difference in the macroinvertebrate assemblage present in Cataract Creek when compared to control sites. SIGNAL2 scores indicate that, while Cataract Creek is moderately polluted (potentially from upstream runoff from Mount Ousley Road and / or historic mining impacts), there is little difference in the presence or absence of pollution sensitive aquatic macroinvertebrate species when compared to control sites.

More detail on each of these surveys can be found in Cardno Ecology Lab (2009; 2011a, b; 2012a, b) and Biosis (2013a).

3.2.3 Impact Assessment

The main aquatic habitat present in the Wonga East area is along Cataract Creek, which provides habitat for several threatened fish species. Macroinvertebrate monitoring of Cataract Creek indicates that there is a lower diversity of macroinvertebrate taxa, but AUSRIVAS, OE50 Taxa and SIGNAL2 scores indicate that there is little difference between Cataract Creek and control sites in Cataract River and Allen's Creek. Lower diversity of macoinvertebrate taxa in Cataract Creek may be indicative of historic impacts to this waterway from extraction of the Bulli and Balgownie seams.

Extraction of the Bulli seam has resulted in up to 0.4 m of subsidence, whilst extraction of the Balgownie seams has resulted in subsidence of up to 1.3 m beneath Cataract Creek. Whilst disturbance to the overlying Hawkesbury Sandstone has resulted in release of iron hydroxide flocculent from tributaries of Cataract Creek, no observable physical disturbance, such as fracturing or iron hydroxide seeps, have been observed (SCT Operations 2014).

Extraction of Longwalls 6 – 9 will not result in direct subsidence of Cataract Creek. Subsidence adjacent will result in negligible tensile and compressive strains. Maximum total closure along Cataract Creek is predicted to be 279 mm at the completion of Longwall 9 (SCT Operations 2014). Based on Barbato *et al.* (2014) for Hawkesbury Sandstone this level of closure indicates there is a 25% probability of fracturing and flow diversion. However, it should be noted that the floor of Cataract Creek downstream of Mount Ousley Road is comprised of Newport Formation, Garu Formation and Bald Hill Claystone. Maximum total closure in the lower reaches of Cataract Creek where threatened fish have been observed is predicted to be 203 mm at the completion of Longwall 9 (SCT Operations 2014). This level of closure indicates there is a 12% probability of fracturing and flow diversion.

Tributaries of Cataract Creek are likely to be subject to higher levels of subsidence resulting in increased strains, tilts and valley closure. For some tributaries of Cataract Creek valley closures are expected to cause perceptible cracking and surface flow diversion, particularly in the upper reaches of the southern tributaries of Cataract Creek, particularly where it flows across Hawkesbury Sandstone outcrop above Longwall 1 (SCT Operations 2014).

As outlined above and in Section 3.1.4, there are unlikely to be any direct impacts to Cataract Creek; however additional fracturing of tributaries of Cataract Creek may result in decreased flow in the tributaries and reduced flow into Cataract Creek and an increase in iron hydroxide seepage at the base of these tributaries (Geoterra and GES 2014).

The groundwater model indicates that the average daily stream flow from Cataract Creek to Cataract Reservoir is 11.2 ML/d, of which 3.5 ML/d is baseflow. The model predicts a 0.013 ML/d (0.12%) loss of stream baseflow following mining. This level of change is unlikely to be detectable and unlikely to result in observable changes to flow regimes in Cataract Creek.

Increases in iron hydroxide flocculent has potential to smother eggs of threatened fish such as the Macquarie Perch and result in changes in water quality, whilst reduced flows into Cataract Creek have the potential to reduce the quality of habitat for threatened fish and result in changes to community composition of macroinvertebrate communities. However, given past mining, it is considered unlikely that these impacts will result in observable changes to Cataract Creek above and beyond those present.

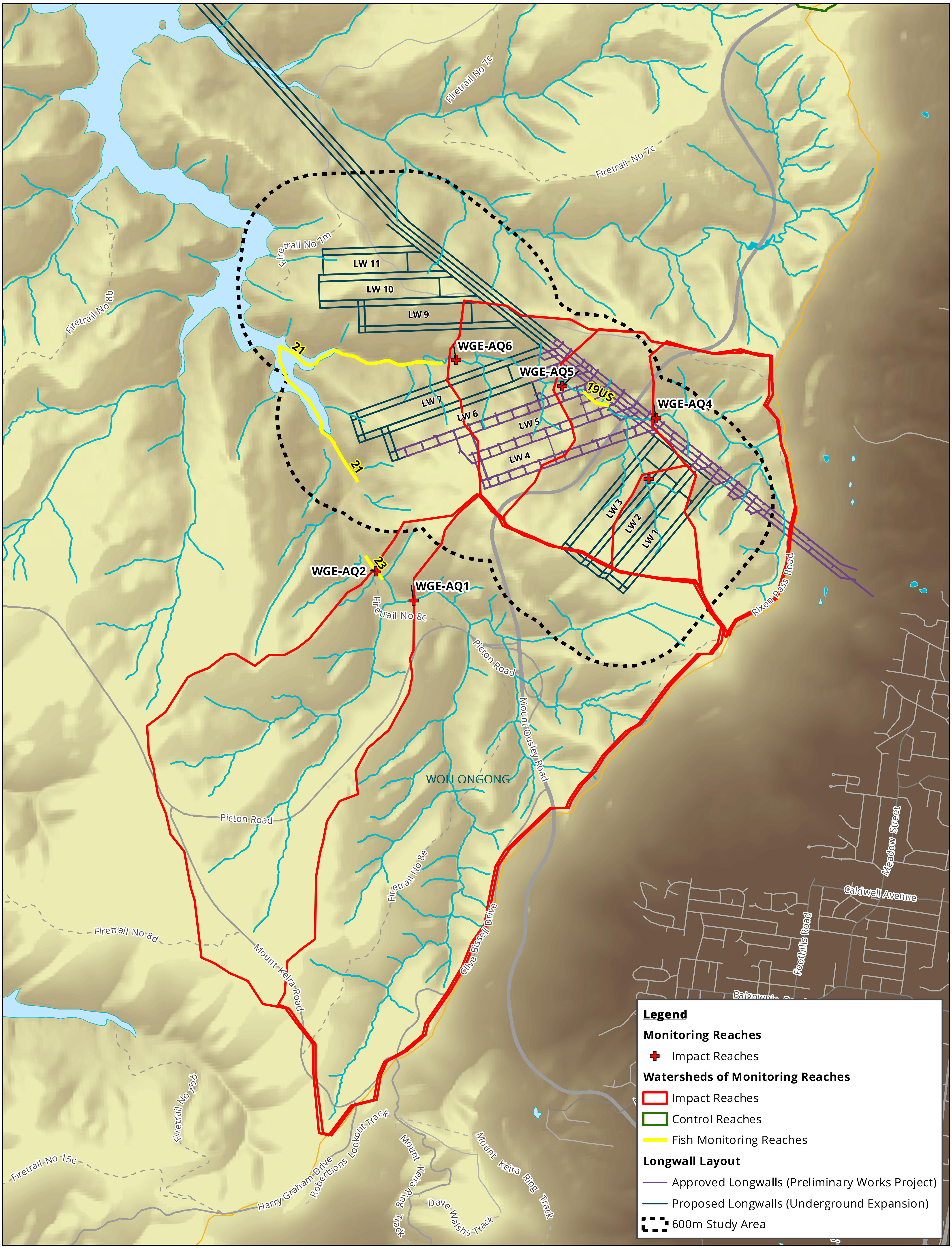

Figure 6: Study Area and Catchment of Monitoring Reaches

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Acknowledgements: Topo (c) NSW Land and Planning Information (2012)

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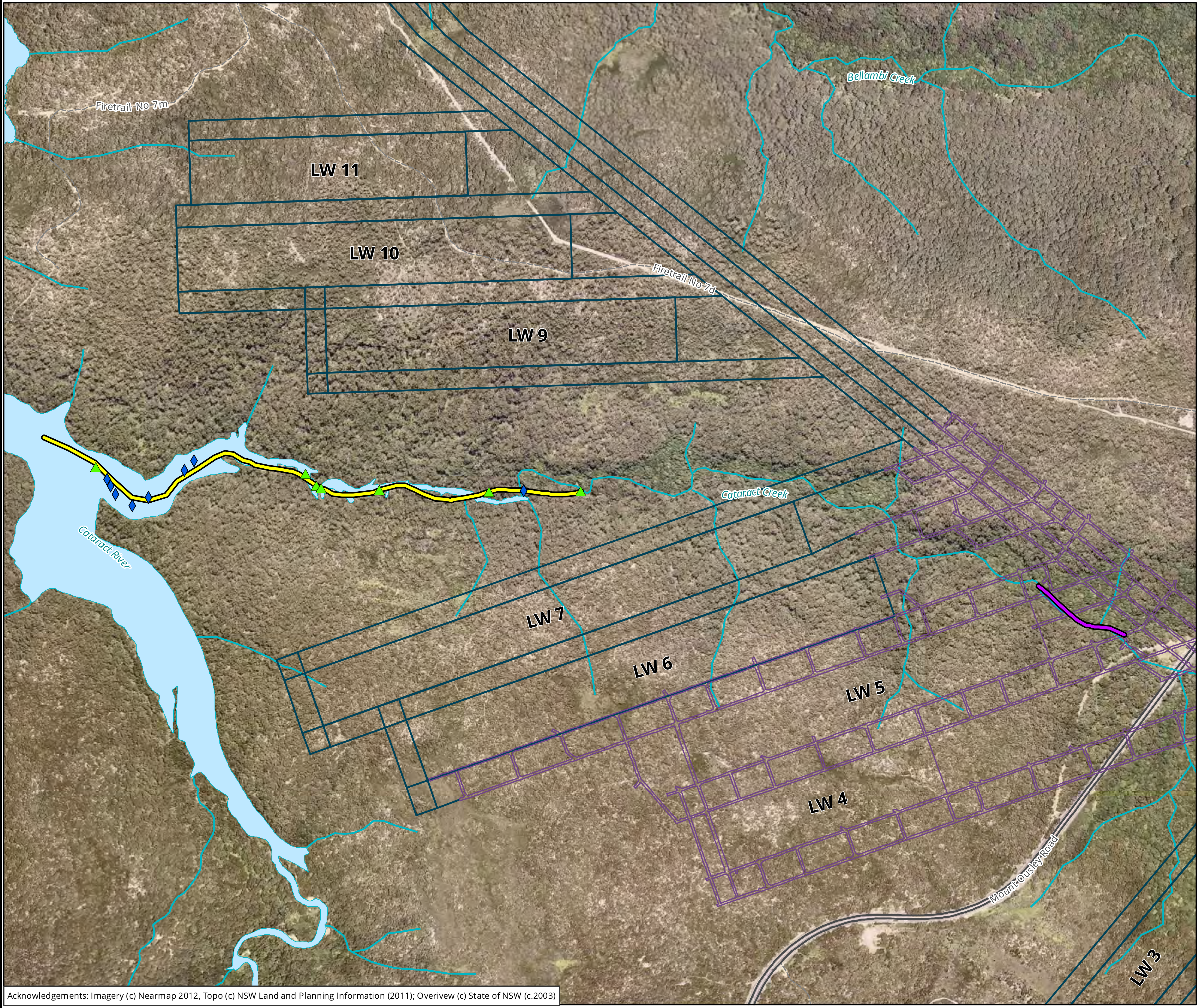

Legend

- Fish Monitoring Reaches
- Additional Fish Monitoring Reach (Biosis in Prep.)

Recorded fish locations

- Macquarie Perch
- Murray Cod

Longwall Layout

- Approved Longwalls (Preliminary Works Project)
- Proposed Longwalls (Underground Expansion)

Figure 7: Threatened fish species locations in Cataract Creek

0 80 160 240 320 400

Metres

Scale: 1:8,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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3.3 Upland swamps

Mapping and characterisation of upland swamps in the Wonga East and Wonga West area was undertaken by Biosis (2012b). This assessment identified thirty-nine (39) upland headwater swamps, which meet the definition of the Coastal Upland Swamp EEC, within the Wonga East Study Area. No valley fill swamps are present at Wonga East.

The study highlighted the complexity and variability of the associated vegetation communities, with some swamps having a fully developed, saturated, humic sandy clay matrix up to 1.8 m deep, through to essentially dry, shallow sandy clay locations with a high degree of shallow or subcropping sandstone and a thin weathered, colluvial, sandy clay soil profile.

The Wonga East swamps are markedly different to other upland swamps on the Woronora plateau in that they are predominantly drier, generally smaller with shallower soils, have less humic material, have more interspersed sandstone outcrops within their outlines and are less spatially continuous than a "typical" humic, saturated swamp.

Swamps in the Wonga East Area have relatively small upstream catchments, with their saturation relying on rainfall recharge directly into the sandy sediments, seepage out of upslope Hawkesbury Sandstone and their organic (humic) content. The storage and water transmission characteristics of the surrounding and underlying Hawkesbury Sandstone is critical in sustaining these environments. Whilst in other areas of the Woronora plateau upland swamps occur along the riparian zone of the major creeks or in headwater valleys, upland swamps in the Wonga East area occur in headwater tributary valleys that are characteristically derived from colluvial sand erosion from Hawkesbury Sandstone dominated ridgelines only. They are only located over Hawkesbury Sandstone which provides a low permeability base on which the swamp sediments and organic matter accumulate. Regional groundwater flow within the Hawkesbury Sandstone is hydraulically beneath, and separated by approximately 15m from the surficial swamps.

The headwater swamps are predominantly located within gently sloping, shallow trough-shaped gullies although can partially extend onto steep slopes, benches or valley sides, where the plateau is not dissected by the Study Area creeks. The central axes of the swamps are generally saturated after substantial recharge events, though the margins can comparatively dry out after extended dry periods.

The sand and humic material increases the swamp's water holding capacity and subsequently discharges rainfall infiltration, groundwater seeps and low-flow runoff into the local streams. Rainfall saturates the swamp after storms and with a slow, delayed discharge due to the low slopes when the recharge exceeds evaporation. Sediments below and laterally lensing into the humic material are variable in nature and can be composed of fine to medium grained sands that can contain clayey bands and comprise a grey to mottled red-orange colour due to in-situ weathering.

This previous assessment by Biosis (2012b) included assessment of the 'special significance' of upland swamps in the project area using criteria outlined in OEH (2012). Biosis (2012b) identified that seven swamps in Wonga East are considered to be of 'special significance' using OEH (2012) criteria, including CCUS1, CCUS4, CCUS5, CCUS10, CRUS1, CRUS2 and CRUS3.

Biosis (2012b) included an assessment of impacts to upland swamps, based on the previous mine plan. This impact assessment included several steps:

- An initial risk assessment using criteria outlined in DoP (2010) and OEH (2012);
- A comparative analysis of impacts to upland swamps that have resulted from previous mining, as required by OEH (2012);
- A summary of available data on groundwater in upland swamps within the project area;

- An analysis of flow accumulation based on changes in water flow due to subsidence levels; and,
- Use of tensile and compressive strains to assess where fracturing of bedrock may occur, and potential resultant impacts to upland swamp vegetation communities.

This impact assessment identified a number of upland swamps considered to be at risk of negative environmental impacts. Based on this impact assessment, Biosis recommended a number of changes to the original mine plan with the objective of avoiding and mitigating impacts to upland swamps.

A number of submissions were received critiquing the methodology used in the upland swamp impact assessment process. Section 3.3.1 provides further information on how the methodology used addresses issues and recommendations raised in DoP (2008), DoP (2009), DoP (2010) and OEH (2012), while Section 3.3.2 provides a rationale for the upland swamps impact assessment and discusses how criticisms have been addressed in the updated assessment.

An assessment of potential impacts arising from historic mining of the Bulli and Balgownie Seams in the Wonga East area is provided in Section 3.3.3.

Section 3.3.4 provides an updated upland swamp impact assessment based on the revised mine plan and revised subsidence calculations.

3.3.1 Criticisms of the upland swamp impact assessment

The upland swamp impact assessment (Biosis 2012b) was the first upland swamp impact assessment to utilise the methodology outlined in OEH (2012). Although the impact assessment was commended by OEH for the mapping and characterisation of swamps as well as how upland swamps of 'special significance' were determined, a number of concerns and criticisms were raised. These criticisms, and our response to these criticisms, are provided below.

The previous assessment did not consider impacts to all swamps, only swamps of special significance

OEH (2012, p.3) sets out several steps that are required to undertake an environmental assessment of the level of significance and risks to upland swamps. Step 4 requires that, following the initial risk assessment and comparative analysis, the mine plan should be adjusted if damage to swamps of 'special significance' is predicted to occur. This is further detailed in Section 3 (p.12) of the guidelines, which states proponents must assess the following:

- *'If negative outcomes are predicted for a special significance swamp, the mining plan should be adjusted in advance so that no negative environmental outcomes are anticipated.*
- *If no negative environmental outcomes are predicted, then proceeding to mining, monitoring and adaptive management.'* (OEH 2012, p.12)

Given the focus of this section on swamps of 'special significance' Biosis understood the intent of the guidelines was to assess potential impacts to these 'special' swamps.

In the current impact assessment (Section 3.3.4) potential impacts to all upland swamps within the study area has been undertaken.

Consideration of measures other than the fracturing of bedrock, and resultant changes in hydrology, in the assessment of impacts to upland swamps

Section 3 of OEH (2012, p.11) defines six criteria used to identify upland swamps at risk of negative environmental outcomes. It is our understanding that these criteria come from values defined by MSEC to determine longwall setback distances from major creeks, and were used by DoP (2010) and OEH (2012) for assessment of upland swamps to be considered at risk of negative environmental impacts. As stated in DoP (2010), these criteria are a '*threshold for investigation – not a conclusion that the swamp will be impacted or suffer consequences*' (p. 120), i.e. these swamps are at risk and further assessment is required.

The use of multiple criteria in Biosis (2012b) is an attempt to address this requirement, by assessing other factors such as groundwater availability (and thus potential for draining), changes in flow accumulation (to assess risk of erosion and scouring and potential changes in water availability), orientation in relation to longwalls (to assess potential for ponding) and vegetation sub-communities (to assess the presence of species reliant on soil moisture and thus with greatest risk of change).

We believe this multi-criteria approach is valid, and have used a similar methodology in the current assessment. See Section 3.3.2 for a rational behind our methodology.

Reliance on flow accumulation modeling and poor definition of 'small' potential for change to flow accumulation

DoP (2009) identifies three potential impact mechanisms to upland swamps:

1. The bedrock below the swamp cracks as a consequence of tensile strains and water drains into the fracture zone. If the fracture zone is large enough or connected to a source of escape (e.g. a deeper aquifer or bedding shear pathway to an open hillside) then it is possible for sufficient water to drain to alter the hydrologic balance of the swamp.
2. Tilting of sufficient magnitude occurs to either re-concentrate runoff leading to scour and erosion, potentially allowing water to escape from the swamp margins (possibly affecting the whole swamp) or to alter water distribution in parts of the swamp, thus favouring some flora species associations over others.
3. Buckling and bedding shear enhances fracture connectivity in the host bedrock which promotes vertical then lateral drainage of the swamp. This mechanism is similar to redirected surface flow observed in subsidence-upsidence affected creek beds.

Flow accumulation modelling pre- and post-mining is undertaken by modelling flow pathways across a catchment using a digital elevation model (DEM) constructed from LiDAR data. Changes in surface topography are modelled by deducting predicted subsidence values (Smax) from the pre-mining DEM. Flow accumulation is then re-modelled. This is used to predict changes to surface and sub-surface flow through an upland swamp in relation to changes in ground level (tilt) and is unrelated to tilts and strains. This method directly addresses swamp impact mechanism 2 outlined above, and in particular addresses dot point 2 on page 116 of DoP (2010), which states that changes in water distribution in parts of the swamp can lead to changes in swamp health or vegetation composition.

In previous upland swamps assessments (BHPBIC 2009) changes in water flow through an upland swamp have been assessed using a single cross-section of an upland swamp. This methodology was criticised in DoP (2010) due to the reliance on a single cross-sectional representation. The use of flow accumulation modelling across an entire swamp addresses this concern.

In line with DoP (2010) Biosis (2012b) has used multiple criteria to determine the potential for impacts to upland swamps. These criteria have been developed with reference to the three potential upland swamp impact mechanisms outlined in DoP (2009) and outlined above. In this case we believe that the use of flow accumulation modelling in the assessment of impacts to upland swamps is valid.

Use of inexact subsidence predictions to determine potential zones of fracturing

Upland swamps form across a range of soil moisture gradients supporting different flora species and vegetation communities (Keith et al. 2006, NSW Scientific Committee 2012). The model of upland swamp response to climatic change outlined in Keith et al. (2006) describes a transition between MU43 Tea-tree Thicket to MU44c Cyperoid Heath and MU44a Sedgeland / MU44b Restioid heath / MU42 Banksia Thicket in response to changes on soil moisture. MU43 Tea-tree Thicket is likely to be reliant on semi-permanent to permanent waterlogging and MU44C Cyperoid heath on intermittent waterlogging, whilst the water table is likely to reach the root zone in other vegetation communities only following heavy rains. Similar changes in vegetation community composition within an upland swamp would be expected to occur due to changes in soil moisture resulting from fracturing of bedrock beneath an upland swamp.

Changes in soil moisture can occur in two ways; either through loss of water through fracturing of the bedrock and / or through changes in water flow through an upland swamp resulting in changes in water availability. Whilst we use the flow accumulation model to assess the second potential mechanism of change, we must use predictions for tensile and compressive strain to assess the potential for fracturing of the base of upland swamps and potential for loss of groundwater availability.

In light of this, we believe it is reasonable to use such parameters to assess potential for impacts to particular vegetation communities within an upland swamp, despite their inexact nature.

3.3.2 Rationale behind Biosis' approach to upland swamp impact assessment

DoP (2008) recognises that certain swamp characteristics mean some upland swamps are more susceptible to impacts from subsidence than others. For example, given their location in the landscape, valley infill swamps are more likely to be in direct contact with surrounding groundwater, and much more susceptible to fracturing due to valley closure and upsidence (swamp impact mechanism 3 above). DoP (2009) states that, other than one headwater swamp (Swamp 1) in Dendrobium Area 2, the panel was not aware of any other headwater swamps that have been negatively impacted. However, in DoP (2010) evidence of impacts to several other upland swamps were bought to the attention of the panel, and available data now indicates that changes in groundwater availability have occurred at Swamp 12 (also a headwater swamp) and Swamp 15B (a valley infill swamp).

Changes in groundwater availability through fracturing of bedrock beneath an upland swamp is one type of impact. Fracturing of the bedrock beneath upland swamps, and/or changes in groundwater availability have been observed at a number of upland swamps on the Woronora plateau. To date, secondary impacts, including erosion, gullying, changes in size of an upland swamp or changes in vegetation within an upland swamps have been observed at a limited number of undermined upland swamps. This may be due to a lack of suitable quantitative monitoring (DoP 2010). Given the long history of mining on the Woronora plateau, and evidence of significant, observable impacts to only a limited number of previously undermined upland swamps, we do not believe that the available scientific evidence supports a conclusion that this primary impact (our term) will lead to secondary impacts (our term) in all cases, or will result in the catastrophic loss of upland swamps.

In their submission OEH raise statistical analysis of Swamp 1 in Symbolix (2011), as discussed in Krogh (2012), and a lack of the use of this data by Biosis (2012b) in our comparative analysis. The Krogh (2012) paper is not currently available for Biosis to comment on, but further analysis of data available from Swamp 1 indicates a gradual change in species diversity and richness indices at two out of three monitoring sites between 2006 and 2012. However, this change has also been observed at a number of control sites over the same period, albeit not at the same rate. Further to this, the rate of change at Swamp 1 appears to be slowing, with an increase in both indices in recent years. To date, the data does not clearly indicate whether changes in groundwater in Swamp 1 have resulted in secondary impacts to vegetation or vegetation communities above and beyond what has been observed at control swamps, using a Before After Control Impact (BACI) design.

Biosis does not assert that subsidence associated with longwall mining does not result in impacts to upland swamps, or that a change in groundwater availability is not an impact to upland swamps. Rather, that the maintenance and persistence of upland swamps is much more complex than has been recognised, and that further research, monitoring and assessment is required to understand the complex processes that maintain upland swamps, particularly in relation to changes brought about by longwall mining.

The swamp impact assessment methodology employed by Biosis (2012b) assesses multiple upland swamp characteristics to determine the potential for impact, in line with the recommendation of DoP (2010) that upland swamps that exceed these thresholds indicating they are risk of negative environmental consequences require further investigation.

3.3.3 Assessment of the historic impacts to upland swamps in Wonga East

Extraction of the Bulli and Balgownie seams has occurred within the Wonga East area. Within the study area, the Bulli Seam was extracted via hand workings and pillar extraction between 1890 and 1960. The Balgownie Seam was extracted using continuous miner pillar extraction in 1969 and the retreat longwall mining method from 1970 to 1982. Table 13, Table 14 and Table 15 provide modelled subsidence data for upland swamps within the study area.

Table 13: Subsidence data from extraction of the Bulli seams for upland swamps within the study area (values in bold exceed subsidence criteria in OEH 2012)

Swamp	Subsidence (m)	Overburden Depth (m)	Longwall Panel Width	Ratio of Overburden to Panel Width	Max Tensile Strain (mm/m)	Max Compressive Strain (mm/m)	Max Tilt (mm/m)
CCUS1	0.7	285	945	**0.3**	**3.7**	**7.4**	**12**
CCUS2	0.1	285	-	-	0.5	1.1	2
CCUS3	1	300	55	5.45	**5**	**10**	**17**
CCUS4	0.1	290	50	5.8	0.5	1	2
CCUS5	0.5	272	230	**1.18**	**2.8**	**5.5**	**9**
CCUS6	1	285	605	**0.47**	**5.3**	**10.5**	**18**
CCUS7	1	270	276	**0.98**	**5.6**	**11.1**	**19**
CCUS8	0.1	270	20	13.5	**0.6**	1.1	2
CCUS9	0.1	293	25	11.72	0.5	1	2
CCUS10	0.5	280	185	1.51	**2.7**	**5.4**	**9**
CCUS12	0.5	355	185	1.92	**2.1**	**4.2**	**7**
CCUS13	0.1	335	195	1.72	0.4	0.9	1
CCUS14	1	275	-	-	**5.5**	**10.9**	**18**

Swamp	Subsidence (m)	Overburden Depth (m)	Longwall Panel Width	Ratio of Overburden to Panel Width	Max Tensile Strain (mm/m)	Max Compressive Strain (mm/m)	Max Tilt (mm/m)
CCUS15	0.1	325	40	8.13	0.5	0.9	2
CCUS16	0.5	300	-	-	**2.5**	**5**	**8**
CCUS17	0.1	325	45	7.22	0.5	0.9	2
CCUS18	0.1	325	30	10.83	0.5	0.9	2
CCUS19	0.1	325	10	32.5	0.5	0.9	2
CCUS20	1	290	570	**0.51**	**5.2**	**10.3**	**17**
CCUS21	1	280	490	**0.57**	**5.4**	**10.7**	**18**
CCUS22	0.5	317	150	2.11	**2.4**	**4.7**	**8**
CCUS23	0.1	310	45	6.89	0.5	1	2
CRUS1	0.5	300	310	**0.97**	**2.5**	**5**	**8**
CRUS2	0.5	210	280	**0.75**	**3.6**	**7.1**	**12**
CRUS3	0.4	295	45	6.56	**2**	**4.1**	**7**
BCUS1	1	270	270	**1**	**5.6**	**11.1**	**19**
BCUS2	0.5	285	40	7.13	**2.6**	**5.3**	**9**
BCUS3	0.5	265	80	3.31	**2.8**	**5.7**	**9**
BCUS4	0.5	295	230	**1.28**	**2.5**	**5.1**	**8**
BCUS5	0.5	273	105	2.6	**2.7**	**5.5**	**9**
BCUS6	0.1	308	15	20.53	0.5	1	2
BCUS11	0.5	335	225	1.49	**2.2**	**4.5**	**7**

Table 14: Incremental subsidence data from extraction of the Balgownie seams for upland swamps within the study area (values in bold exceed subsidence criteria in OEH 2012)

Swamp	Subsidence Used (m)	Overburden Depth (m)	Longwall Panel Width	Ratio of Overburden to Panel Width	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)
CCUS1	0.8	295	130	2.27	**4.1**	**8.1**	**14**
CCUS2	1	295	130	2.27	**5.1**	**10.2**	**17**
CCUS3	1	310	170	1.82	**4.8**	**9.7**	**16**
CCUS4	0.8	300	170	1.76	**4**	**8**	**13**

Swamp	Subsidence Used (m)	Overburden Depth (m)	Longwall Panel Width	Ratio of Overburden to Panel Width	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)
CCUS5	0.1	282	-	-	0.5	1.1	2
CCUS6	1	295	170	1.74	**5.1**	**10.2**	**17**
CCUS7	0.1	280	-	-	0.5	1.1	2
CCUS8	0.1	280	-	-	0.5	1.1	2
CCUS9	0.1	303	-	-	0.5	1	2
CCUS10	0.1	290	-	-	0.5	1	2
CCUS12	0.1	365	-	-	0.4	0.8	1
CCUS13	0.1	345	-	-	0.4	0.9	1
CCUS14	0.1	285	130	2.19	0.5	1.1	2
CCUS15	0.5	335	-	-	**2.2**	**4.5**	**7**
CCUS16	0.1	310	-	-	0.5	1	2
CCUS17	0.3	335	-	-	**1.3**	**2.7**	4
CCUS18	0.1	335	-	-	0.4	0.9	1
CCUS19	0.1	335	-	-	0.4	0.9	1
CCUS20	1	300	170	1.76	**5**	**10**	**17**
CCUS21	1	290	170	1.71	**5.2**	**10.3**	**17**
CCUS22	0.1	327	-	-	0.5	0.9	2
CCUS23	1	320	170	1.88	**4.7**	**9.4**	**16**
CRUS1	0.1	310	-	-	0.5	1	2
CRUS2	0.1	220	-	-	**0.7**	1.4	2
CRUS3	0.1	305	-	-	0.5	1	2
BCUS1	0.1	280	-	-	0.5	1.1	2
BCUS2	0.1	295	-	-	0.5	1	2
BCUS3	0.1	275	-	-	0.5	1.1	2
BCUS4	0.1	305	-	-	0.5	1	2
BCUS5	0.1	283	-	-	0.5	1.1	2
BCUS6	0.1	318	-	-	0.5	0.9	2
BCUS11	0.1	345	-	-	0.4	0.9	1

Table 15: Subsidence data from extraction of the Bulli and Balgownie seams for upland swamps within the study area (values in bold exceed subsidence criteria in OEH 2012)

Swamp	Relevant Workings	Subsidence Used (m)	Overburden Depth (m)	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)
CCUS1	Bulli PE / Bg LW	2	285	**10.5**	**21.1**	**35**
CCUS2	Bulli 1st wkgs / Bg LW	1.1	285	**5.8**	**11.6**	**19**
CCUS3	Bulli 1st wkgs / Bg LW	1.1	300	**5.5**	**11.0**	**18**
CCUS4	Bulli 1st wkgs / Bg LW	0.9	290	**4.7**	**9.3**	**16**
CCUS5	Bulli PE, 1st wkgs / Bg 1st wkgs	0.6	272	**3.3**	**6.6**	**11**
CCUS6	Bulli PE / Bg LW	2	285	**10.5**	**21.1**	**35**
CCUS7	Bulli PE	1	270	**5.6**	**11.1**	**19**
CCUS8	Bulli 1st wkgs	0.1	270	**0.6**	1.1	2
CCUS9	Bulli 1st wkgs	0.1	293	0.5	1.0	2
CCUS10	Bulli PE, 1st wkgs / Bg LW	0.6	280	**3.2**	**6.4**	**11**
CCUS12	Bulli PE, 1st wkgs	0.5	355	**2.1**	**4.2**	**7**
CCUS13	Bulli 1st wkgs	0.1	335	0.4	0.9	1
CCUS14	Bulli PE / Bg LW	1.2	275	**6.5**	**13.1**	**22**
CCUS15	Bulli 1st wkgs	0.2	325	**0.9**	1.8	3
CCUS16	Corrimal wkgs	0.5	300	**2.5**	**5.0**	**8**
CCUS17	Bulli 1st wkgs	0.1	325	0.5	0.9	2
CCUS18	Bulli 1st wkgs	0.1	325	0.5	0.9	2
CCUS19	Bulli 1st wkgs	0.1	325	0.5	0.9	2
CCUS20	Bulli PE / Bg LW	2	290	**10.3**	**20.7**	**34**
CCUS21	Bulli PE / Bg LW	2	280	**10.7**	**21.4**	**36**

Swamp	Relevant Workings	Subsidence Used (m)	Overburden Depth (m)	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)
CCUS22	Bulli PE, no wkgs	0.5	317	**2.4**	**4.7**	**8**
CCUS23	Bulli1st wkgs / Bg LW	0.9	310	**4.4**	**8.7**	**15**
CRUS1	Bulli PE	0.5	300	**2.5**	**5.0**	**8**
CRUS2	Bulli PE, 1st wkgs	0.6	210	**4.3**	**8.6**	**14**
CRUS3	Bulli PE, 1st wkgs	0.6	295	**3.1**	**6.1**	**10**
BCUS1	Bulli PE	1	270	**5.6**	**11.1**	**19**
BCUS2	Bulli 1st wkgs	0.5	285	**2.6**	**5.3**	**9**
BCUS3	Bulli PE	0.5	265	**2.8**	**5.7**	**9**
BCUS4	Bulli PE	0.6	295	**3.1**	**6.1**	**10**
BCUS5	Bulli PE	0.5	273	**2.7**	**5.5**	**9**
BCUS6	Bulli Headings	0.1	308	0.5	1.0	2
BCUS11	Bulli PE	0.5	335	**2.2**	**4.5**	**7**

NOTE: RV = Russell Vale Colliery, BG = Balgownie, PE = Pillar Extraction, LW = Longwall

Subsidence data for upland swamps in the study area from extraction of the Bulli and Balgownie seams indicates that all upland swamps in the study area, except CCUS9, CCUS13, CCUS18, CCUS19 and BCUS6, have been subject to subsidence criteria sufficient to have placed these upland swamps at risk of negative environmental consequences, according to criteria outlined in DoP (2010) and OEH (2012).

This assessment of past mining in the Wonga East area indicates that natural features in the study area have been subject to subsidence resulting from extraction of the Bulli and Balgownie Seams sufficient to have placed the majority of upland swamps in the study area at risk of negative environmental consequences. This data provides a baseline against which assessments of potential impacts resulting from extraction of the Wongawilli Seam, as part of the preferred project, must be assessed.

3.3.4 Revised upland swamp impact assessment

Following on from the swamp impact assessment undertaken by Biosis (2012b), a recommendation was made suggesting a number of changes to the original mine plan with the objective of avoiding and mitigating impacts to upland swamps. Wollongong Coal has now redesigned the mine plan for Wonga East and have removed Wonga West from the project application. This revised impact assessment follows the methodology outlined in Biosis (2012b), and is based on the revised mine plan and revised subsidence predictions.

In summary, 39 upland swamps have been mapped as occurring within the study area (Figure 8). Section 3.1 and Appendix 1 of Biosis (2012b) provide a summary of upland swamps within the study area, while Table 6 in Biosis (2012b) provides an assessment of 'special significance' against criteria outlined in OEH (2012).

This assessment identified that seven upland swamps in the Wonga East area meet the criteria of 'special significance', including CCUS1, CCUS4, CCUS5, CCUS10, CRUS1, CRUS2 and CRUS3. Swamps of 'special significance' are shown in Figure 9.

Initial risk assessment

Following step 1 of OEH (2012), a risk assessment has been undertaken to determine upland swamps at risk of negative environmental consequences. To address concerns raised by OEH (2012), the risk assessment has been undertaken for all upland swamps within the study area (Table 16). Subsidence values for upland swamps are presented in Figure 10.

Table 16: Initial Risk Assessment for Wonga East (Swamp names in italics indicate 'special significance'

Figures in bold are greater than criteria outlined in OEH (2012).

Swamp	Maximum subsidence within swamp boundary (m)	Adjacent subsidence used to calculate strains and tilts (m)	Overburden Depth (m)	Longwall panel width (m)	Ratio of Overburden to Panel Width	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)
BCUS1	< 0.2	0.1	270	-	-	0.5	1	2
BCUS2	< 0.2	0.1	285	-	-	0.5	0.9	2
BCUS3	< 0.2	0.1	265	-	-	0.5	1	2
BCUS4	1.0	1.5	295	150	1.97	**6.8**	**13.6**	**23**
BCUS5	< 0.2	0.1	273	-	-	0.5	1	2
BCUS6	< 0.2	0.1	308	-	-	0.4	0.9	1
BCUS11	1.4	1.5	335	150	2.23	**6.1**	**12.2**	**20**
CCUS1	0.6	1.5	285	-	-	**7**	**14.1**	**23**
CCUS2	1.8	2.0	285	150	1.90	**9.4**	**18.8**	**31**
CCUS3	1	1.5	300	125	2.40	**6.7**	**13.4**	**22**
CCUS4	1.4	2.0	290	150	1.93	**9.2**	**18.5**	**31**
CCUS5	1.2	1.5	272	131	2.08	**7.3**	**14.7**	**24**
CCUS6	2	2.0	285	125	2.28	**9.4**	**18.8**	**31**
CCUS7	< 0.2	0.1	270	-	-	0.5	1	2
CCUS8	< 0.2	0.1	270	-	-	0.5	1	2

Swamp	Maximum subsidence within swamp boundary (m)	Adjacent subsidence used to calculate strains and tilts (m)	Overburden Depth (m)	Longwall panel width (m)	Ratio of Overburden to Panel Width	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)
CCUS9	< 0.2	0.1	293	-	-	0.5	0.9	2
CCUS10	0.8	0.8	280	150	1.87	**3.8**	**7.6**	**13**
CCUS11	1.8	2.0	340	150	2.27	**8.8**	**18**	**29**
CCUS12	1.2	1.5	355	150	2.37	**5.8**	**11.5**	**19**
CCUS13	< 0.2	0.1	335	-	-	0.4	0.8	1
CCUS14	< 0.2	0.1	275	-	-	0.5	1	2
CCUS15	< 0.2	0.1	325	-	-	0.4	0.8	1
CCUS16	< 0.2	0.1	300	-	-	0.4	0.9	1
CCUS17	< 0.2	0.1	325	-	-	0.4	0.8	1
CCUS18	< 0.2	0.1	325	-	-	0.4	0.8	1
CCUS19	< 0.2	0.1	325	-	-	0.4	0.8	1
CCUS20	< 0.2	0.1	290	-	-	0.5	0.9	2
CCUS21	< 0.2	2.0	280	-	-	**9.5**	**19**	**32**
CCUS22	< 0.2	0.1	317	-	-	0.4	0.9	1
CCUS23	0.2	1.5	310	125	2.48	**6.5**	**13**	**22**
CRUS1	1.4	1.5	300	150	2.00	**6.7**	**13.4**	**22**
CRUS2	< 0.2	0.1	210	-	-	0.6	1.2	2

Swamp	Maximum subsidence within swamp boundary (m)	Adjacent subsidence used to calculate strains and tilts (m)	Overburden Depth (m)	Longwall panel width (m)	Ratio of Overburden to Panel Width	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)
CRUS3	< 0.2	0.1	295	-	-	0.5	0.9	2

Reassessment of subsidence predictions following monitoring of Longwalls 4 and 5 indicates that past mining has resulted in the softening of the bridging capacity of the underlying rock strata, and that subsidence is largely restricted to immediately overlying the goaf. Whilst this means that subsidence movements occur over a smaller area, it also means that tilts and strains are greater than previously predicted (SCT Operations 2014). The revised subsidence predictions for all upland swamps within the predicted impact subsidence zone, except upland swamp CCUS10, are greater than previously predicted.

Upland swamps outside of the predicted subsidence impact zone are not discussed further. To address criticisms received on the previous upland swamps impact assessment (Biosis 2012b), all upland swamps within the predicted subsidence impact zone are considered further.

Comparative analysis

A comparative analysis was undertaken in Biosis (2012b). Additional data has become available following the completion of mining in the Wongawilli domain at Wongawilli Colliery. Table 17 provides a summary of observed subsidence values for four upland swamps located above the Wongawilli longwalls.

Table 17: Observed subsidence for four upland swamps located above the Wongawilli domain

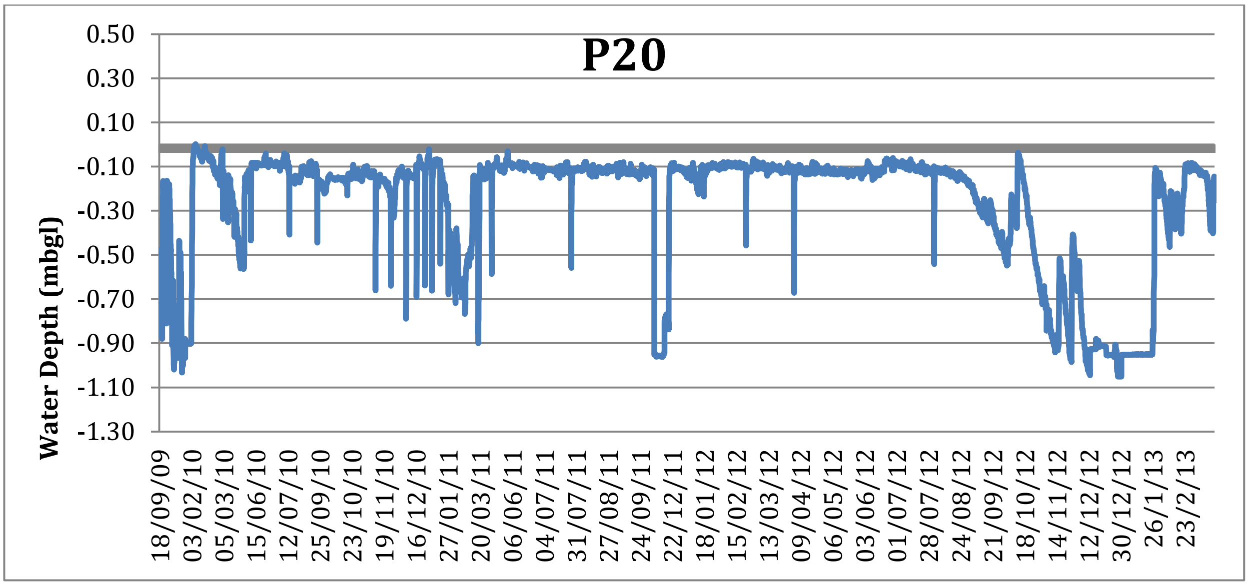
Swamp	Subsidence (mm)	Tensile strain (mm / m)	Compressive strain (mm / m)	Tilt (mm / m)
20	387	**0.6**	0.3	**(6.8)**
21a	170	0.2	0.5	1.1
24	270	0.3	0.3	2.2
46	285	0.3	0.8	2.0

Note: Figures in bold are greater than criteria outlined in OEH (2012). No measured tilts are available for Swamp 20, so predicted tilt is provided in brackets.

Subsidence predictions outlined above indicate that predictions for Swamp 20 exceeded criteria in OEH (2012), and thus upland swamps would be considered at risk of negative environmental consequences from extraction of Longwalls 11 and 20. Observed values for tensile strain are above these thresholds, although observed compressive strain is below. One swamp piezometer is located approximately 100m east of Longwall 20 and overlies the eastern end of Longwall 11. Data from this piezometer is presented in Graph 1. This data indicates that "*no sustained change in groundwater levels in Swamp 20 due to subsidence induced impacts from extraction of Longwalls 11, 12, 19 and 20 has been observed*" (Geoterra 2012a, p.8). Further, no impacts to vegetation within Swamp 20 have been observed (Biosis 2013b). Although Swamp 20 has been undermined previously by the Elouera Colliery, mining under the swamp used a bord and pillar mining method, resulting in negligible subsidence. Extraction of Longwalls 11 and 20 was undertaken using longwall mining techniques.

This data indicates that, despite subsidence predictions exceeding criteria in DoP (2010) and OEH (2012) for determining risk of negative environmental consequences, no observable adverse impacts to the swamp groundwater level variation or vegetation have been observed.

Graph 1: Swamp piezometer, P20, groundwater levels



In addition, the recent extraction of Longwalls 4 and 5 in the Wonga East area allow for some, limited, assessment of impacts to upland swamps CCUS3 and CCUS6. Longwall 4 underlies upland swamp CCUS6, whilst Longwall 5 underlies upland swamp CCUS3. In addition, Longwall 5 underlies the colluvial sandy clay soil piezometers SP1 and SP2.

Monitoring of water levels in the two swamp and two soil piezometers over Longwalls 4 and 5 did not indicate any adverse effects on the swamp / soil water holding capacity due to extraction of Longwall 4 or Longwall 5. In the period of Longwall 4 / 5 extraction, and after, the piezometer water levels have principally responded to rainfall recharge into the swamp / soil profile, or the lack of it, with no evidence of adverse effects due to extraction and subsidence associated with Longwalls 4 and 5. Ecological monitoring of swamp CCUS3 does not indicate any changes in any monitored ecological parameters.

No effects or impacts on swamp water levels, water retention, outflow discharge or ecological parameters due to mining induced subsidence have been observed on any swamps in the Wonga East area.

Hydrogeological investigations

Swamp piezometers

Eight shallow piezometers have been installed at Wonga East, with five auger holes not completed with piezometers as they were too shallow, dry or did not encounter swamp materials within a designated swamp domain. In addition, 2 shallow soil piezometers (SP1 and SP2) were installed down slope of two swamps as shown in Table 18 and Figure 8.

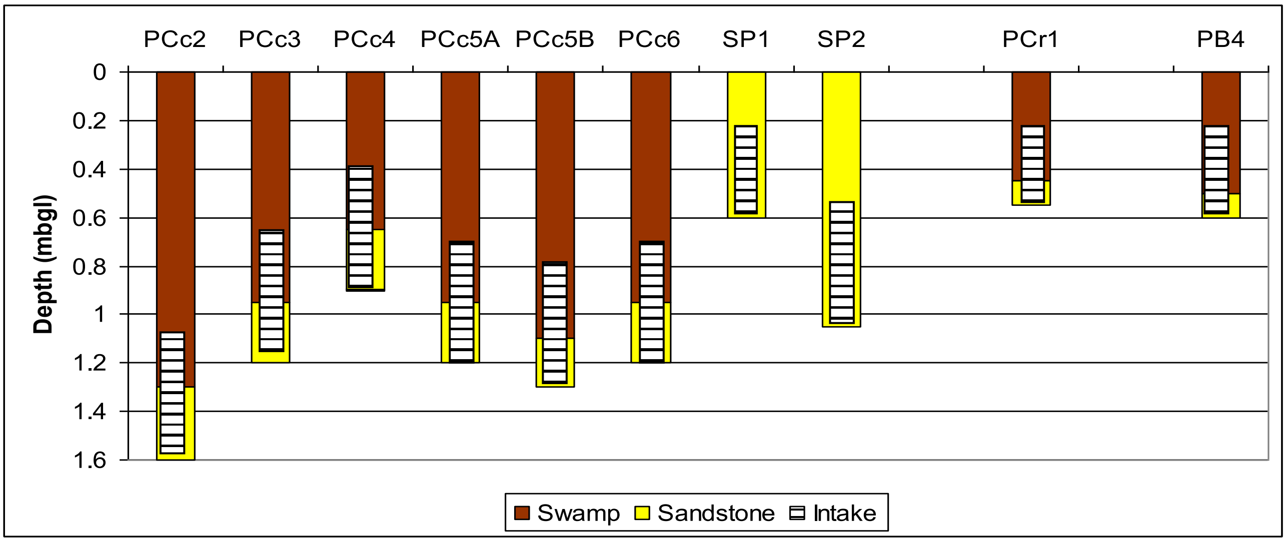
Table 18: Wonga East Piezometers (# indicates dry hole with no piezometer)

Bore	Swamp	Installed	Easting	Northing	Total Depth (mbgl)	Intake Screen (m)	Intake Lithology
PCc2	CCUS2	May 12	303745	6196095	1.60	1.1 – 1.6	humic sandy clay / weathered sandstone
	CCUS2#	May 12	303735	6196100	-	Dry at 0.75	weathered sandstone

Bore	Swamp	Installed	Easting	Northing	Total Depth (mbgl)	Intake Screen (m)	Intake Lithology
	CCUS2#	May 12	303730	6196080	-	Dry at 0.75	weathered sandstone
PCc3	CCUS3	Mar 12	302820	6196810	1.2	0.7 – 1.2	sandy clay / weathered sandstone
PCc4	CCUS4	Mar 12	302615	6196925	0.95	0.45 – 0.95	sandy clay / weathered sandstone
PCc5A	CCUS5	May 12	302110	6197135	1.24	0.7 – 1.2	humic sandy clay / weathered sandstone
	CCUS5#	May 12	302135	6197155	-	Dry at 0.3	weathered sandstone
	CCUS5#	May 12	302135	6197160	-	Dry at 0.5	weathered sandstone
	CCUS5#	May 12	302105	6197130	-	Dry at 1.6	weathered sandstone
PCc5B	CCUS5	May 12	302245	6197250	1.31	0.8 – 1.3	humic sandy clay / weathered sandstone
PCc6	CCUS6	Mar 12	303165	6196790	1.2	0.7 – 1.2	weathered sast
PCr1	CRUS1	Mar 12	302290	6196625	0.55	0.3 – 0.55	humic sandy clay / weathered sandstone
PB4	BCUS4	May 12	302485	6198060	0.6	0.25 – 0.6	humic sandy clay / weathered sandstone
SP1	No swamp	Mar 12	303245	6196955	0.60	0.1 – 0.6	sandy clay / weathered sandstone
SP2	No swamp	Mar 12	302830	6196905	1.05	0.55 – 1.05	sandy clay / weathered sandstone

Drill hole depth and piezometer construction details are shown in Graph 2.

Graph 2: Wonga East Swamp Piezometers

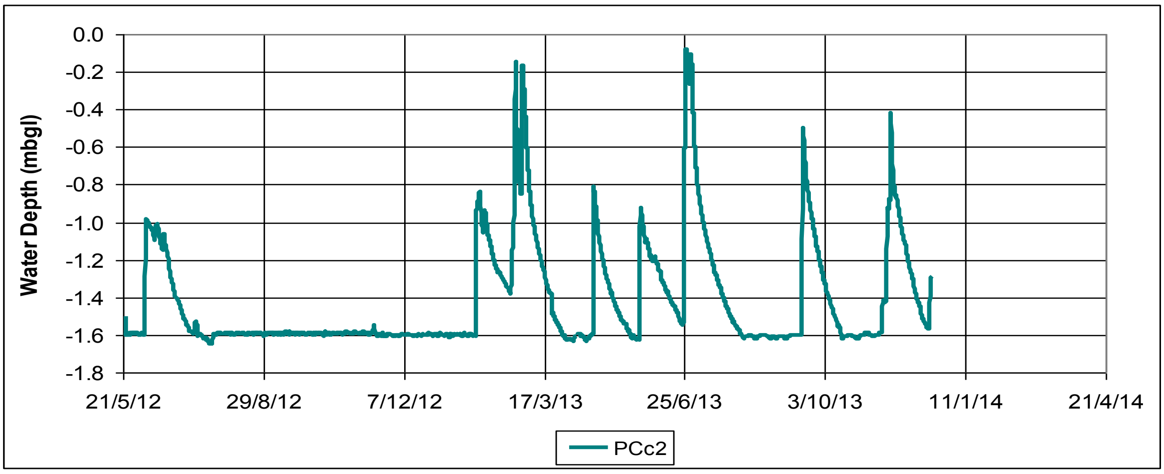


Swamp water levels

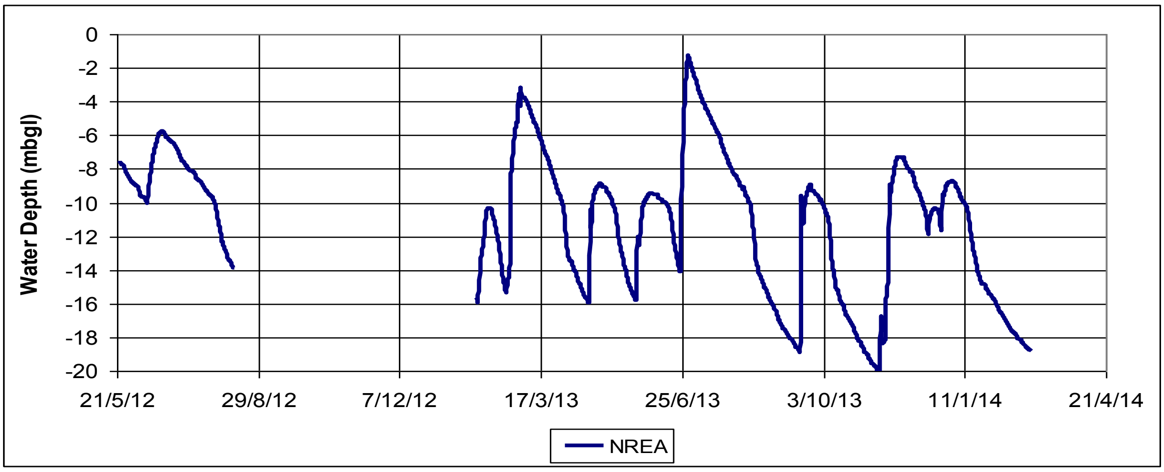
The upland swamps are perched systems that are hydraulically separated from the deeper, regional groundwater table in the Hawkesbury Sandstone by an unsaturated zone. This is illustrated in two examples below.

Paired swamp and Hawkesbury Sandstone monitoring at PCc2 and NRE-A, as shown in Graph 3 and Graph 4 respectively, indicate the two systems have variable separation thicknesses of unsaturated sandstone, which ranges from 1.3 - 18.4m. Recharge following rain events through the sandstone to the regional aquifer is apparent, with the swamp and regional sandstone aquifer having similar temporal, although different quantum responses to rainfall recharge.

Graph 3: Hydrograph – Upland Swamp CCUS2

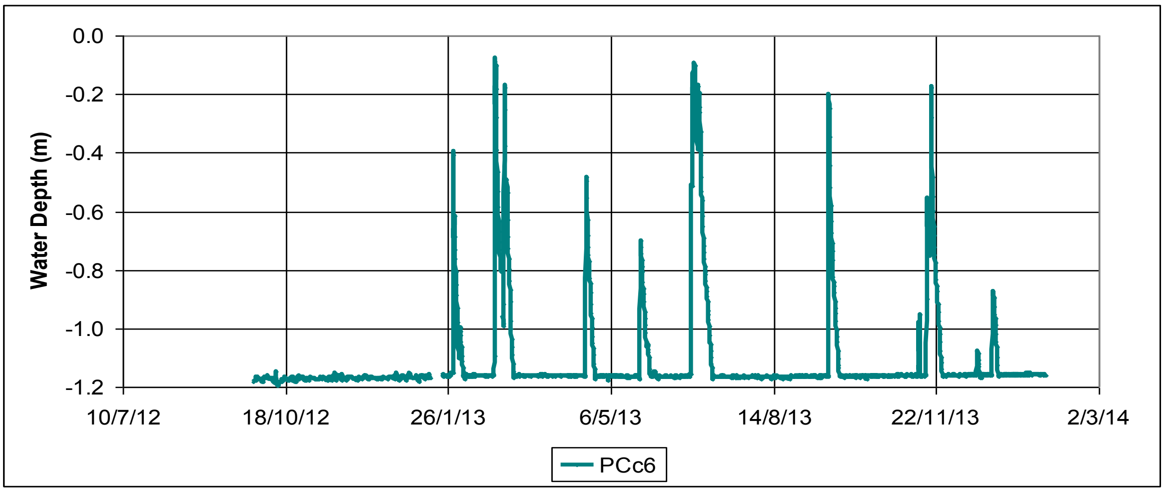


Graph 4: Hydrograph – Borehole NRE-A

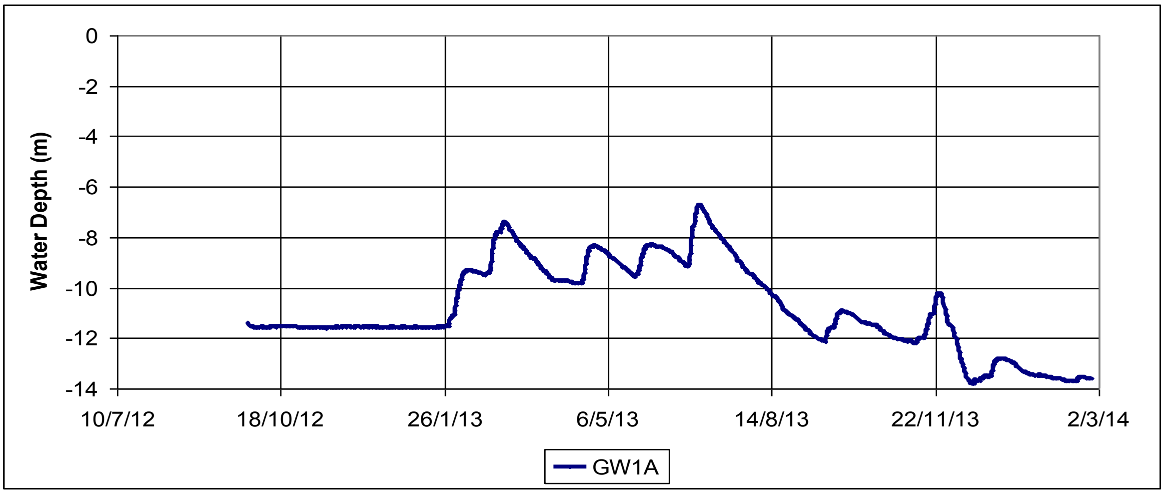


Although they are not immediately adjacent to each other, comparison of water levels in GW1 and PCc6 in swamp CCUS6, as shown in Graph 5 and Graph 6 respectively, indicate a 6.8 – 11.9m unsaturated sandstone separation thickness. Recharge following rain events through the sandstone to the regional aquifer is apparent, with the swamp and the regional sandstone aquifer having similar temporal, although different quantum responses to rainfall recharge.

Graph 5: Hydrograph – Upland Swamp CCUS6



Graph 6: Hydrograph – Borehole GW1A



Although hydraulically separated from the deeper, regional groundwater table in the Hawkesbury Sandstone, upland swamps can, however, be connected to shallower, ephemeral seepage from the upper Hawkesbury Sandstone where bedding discontinuities or low permeabilities enhance horizontal flow into a swamp after high rainfall periods. Depending on the relative height of the ephemeral, perched and regional water tables, groundwater seepage can supplement swamp moisture or, alternatively, unsaturated swamp moisture can seep into the underlying shallow ephemeral sandstone aquifer. In turn, the shallow bedrock aquifers are also usually ephemeral, and are hydraulically disconnected via an unsaturated zone from the deeper, regional aquifers within the Hawkesbury Sandstone.

The water table within the swamps is dependent on surface inflow recharge after rain and can be supported by ephemeral seepage of near surface groundwater from the Hawkesbury Sandstone. Water storage is usually limited within the humic, clayey, rich sandy sediments, although this can allow relatively small inflows to support a highly variable ephemeral water table in the more organic layers.

Recharge into the Hawkesbury Sandstone shallow aquifer that seeps into a swamp is generally moderated by connate water stored in a swamp, which is also recharged by rainfall. Water can enter a swamp from ephemeral seeps located at the upper and lower section of any topographic or basement steps that may be present.

Episodes of inundation and surface run off within a swamp are directly related to the extent and duration of storm events, with the short term, post storm drainage occurring within indistinct channels or dispersed flow paths in the swamp.

Groundwater seepage into a swamp is usually transmitted within the more sandy or humic layers and can "daylight" where the water table extends to surface. Water accumulation within a swamp is a balance between:

- rainfall / surface runoff recharge;
- horizontal seepage and downstream outflow;
- swamp storage capacity, based on the size and depth of the swamp, its humic organic material as well as sand and clay composition;
- vertical seepage rates into the underlying weathered sandstone; and,
- swamp evapotranspiration.

Groundwater levels within the Wonga East swamps have been monitored since February 2012. Hydrographs for all monitored swamps, two shallow soil piezometers and rainfall data are presented in Graph 7 to Graph 12. Data from this monitoring indicates that swamp water levels are variable, and can range from fully saturated to dry. Some of the swamps have been essentially dry since piezometers were installed.

Analysis of the swamp hydrographs shown in Graph 7 to Graph 9 indicates;

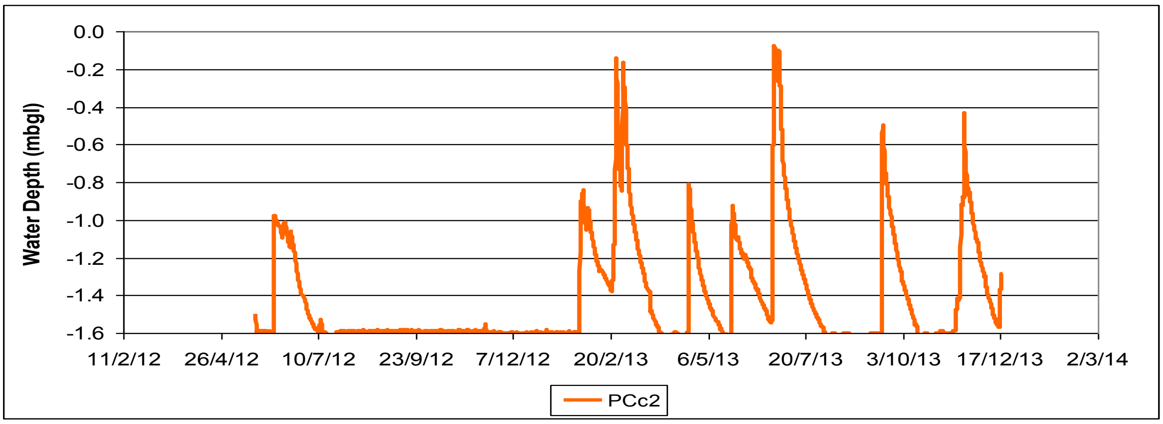
- PCc2 in swamp CCUS2 overlies first workings in the Bulli Seam as well as the end of LW4 in the Balgownie workings, undergoes evapotranspiration as well as gradual drainage after rainfall with overland seepage outflow to a northerly draining gully then to Cataract Creek. No evidence of adverse effects due to prior subsidence are evident in this swamp.
- PCc5A and PCC5B in swamp CCUS5 overlies both first workings and pillar extraction in the Bulli Seam as well as first workings in the Balgownie workings, undergoes evapotranspiration as well as gradual drainage after rainfall with overland seepage outflow to a northerly draining gully then to Cataract Creek. No evidence of adverse effects due to prior subsidence are evident in this swamp.
- PB4 in swamp BCUS4 overlies only pillar extraction in the Bulli Seam, also undergoes evapotranspiration as well as gradual drainage after rainfall with overland seepage outflow to a southerly draining gully then to Bellambi Creek. No evidence of adverse effects due to prior subsidence are evident in this swamp.
- PCc4 in swamp CCUS4 overlies first workings in the Bulli Seam as well as LW11 in the Balgownie workings, undergoes evapotranspiration as well as drainage after rainfall with overland seepage outflow to a northerly draining gully then to Cataract Creek. Possible adverse effects due to prior subsidence may be evident in this swamp due to its enhanced drainage recession rates.
- PCr1 in swamp CRUS1 overlies pillar extraction workings in the Bulli Seam, undergoes evapotranspiration as well as drainage after rainfall with overland seepage outflow to a southerly draining gully then to Cataract River. Possible adverse effects due to prior subsidence may be evident in this swamp due to its enhanced drainage recession rates. However, as the swamp has limited humic matter with numerous shallow outcropping or subcropping sandstone outliers, it is equally possible that the swamp has little storage capacity and drains / evaporates rapidly as a result.

Monitoring of water levels in the vicinity of the Longwalls 4 and 5 in the Wonga East Area, as shown in Graph 10 and Graph 11, indicates that;

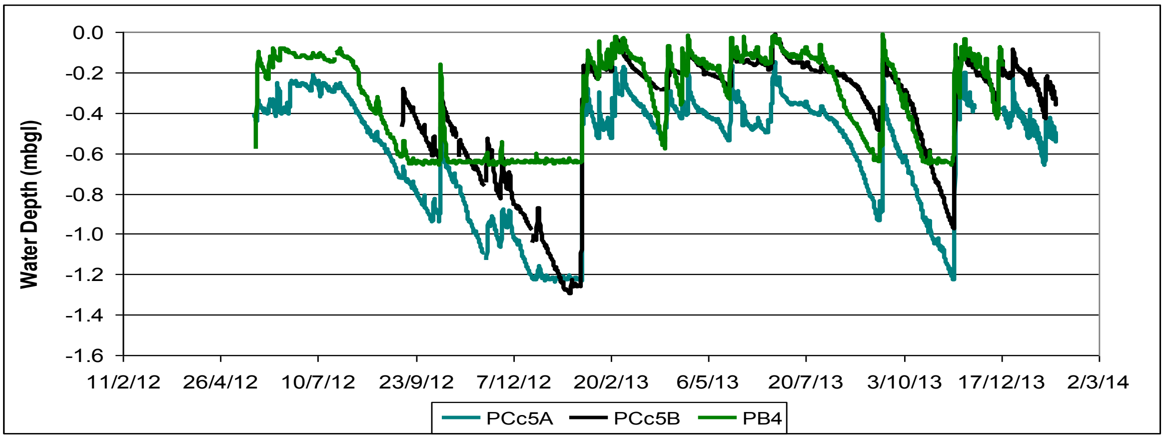
- PCc3 in swamp CCUS3 overlies first workings in the Bulli Seam as well as LW10 in the Balgownie workings, undergoes evapotranspiration as well as rapid drainage after rainfall with overland seepage outflow to a northerly draining gully then to Cataract Creek. Possible adverse effects due to prior subsidence may be evident in this swamp due to its enhanced drainage recession rates. However, as the swamp is small, has essentially no humic matter with numerous shallow outcropping or subcropping sandstone outliers, it is equally possible that the swamp has little storage capacity and drains / evaporates rapidly as a result.
- PCc6 in swamp CCUS6 overlies pillar extraction in the Bulli Seam as well as LW8 in the Balgownie workings, undergoes evapotranspiration as well as rapid drainage after rainfall with overland seepage outflow to a northerly draining gully then to Cataract Creek. Possible adverse effects due to prior subsidence may also be evident in this swamp due to its enhanced drainage recession rates. However, as the swamp is also small, has essentially no humic matter with numerous shallow outcropping or subcropping sandstone outliers, it is equally possible that the swamp has little storage capacity and drains / evaporates rapidly as a result.

- SP1, which is not located in a swamp, is located to the west of the freeway, and overlies the edge of a pillar extraction area in the Bulli Seam as well as LW9 in the Balgownie workings. The piezometer, which is located down gradient of swamp CCUS6, undergoes evapotranspiration as well as rapid drainage after rainfall with overland seepage outflow to a northerly draining gully then to Cataract Creek. It is possible that adverse effects due to prior subsidence may be evident. However, as the piezometer is located in a sandy clay soil / weathered sandstone profile, with no humic matter and numerous shallow outcropping or subcropping sandstone outliers, it is interpreted that the colluvial soil profile has little storage capacity and drains / evaporates rapidly as a result.
- SP2, which is also not located in a swamp, is located to the west of the freeway, and overlies the edge of a pillar extraction area in the Bulli Seam as well as LW10 in the Balgownie workings. The piezometer, which is located down gradient of swamp CCUS3, undergoes evapotranspiration as well as rapid drainage after rainfall with overland seepage outflow to a northerly draining gully then to Cataract Creek. It is possible that adverse effects due to prior subsidence may be evident. However, as the piezometer is located in a sandy clay soil / weathered sandstone profile, with no humic matter and numerous shallow outcropping or subcropping sandstone outliers, it is interpreted that the colluvial soil profile has little storage capacity and drains / evaporates rapidly as a result.

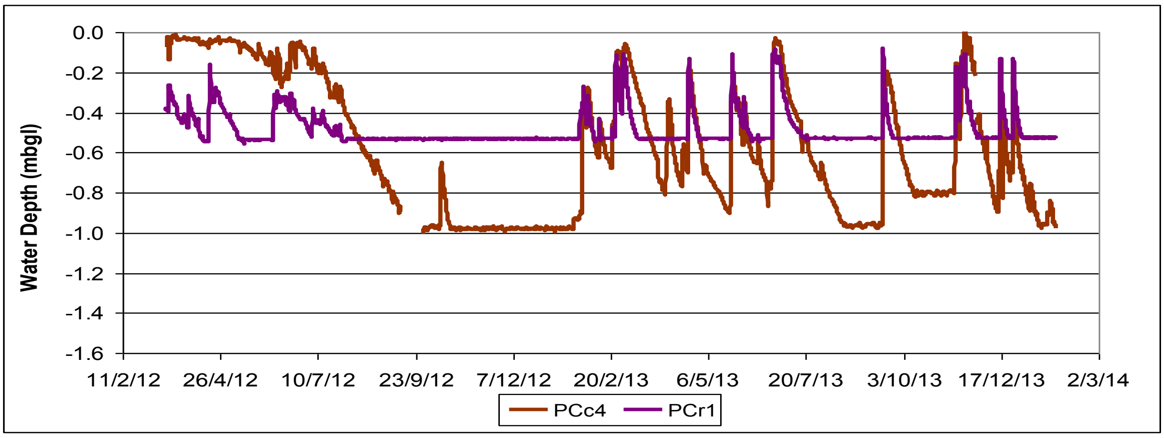
Graph 7: Hydrograph – Upland Swamp CCUS2



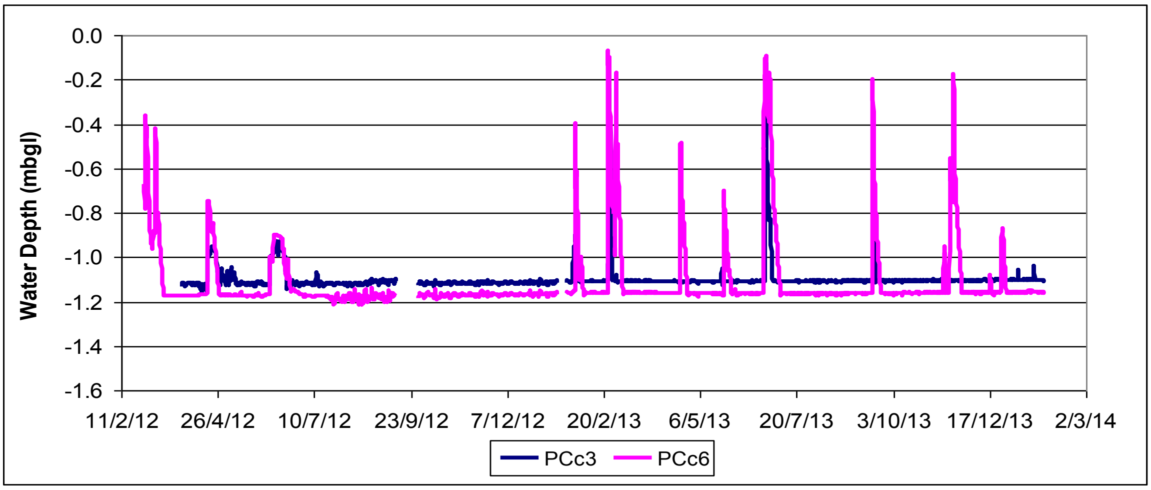
Graph 8: Hydrograph – Upland Swamps CCUS5 and BCUS4



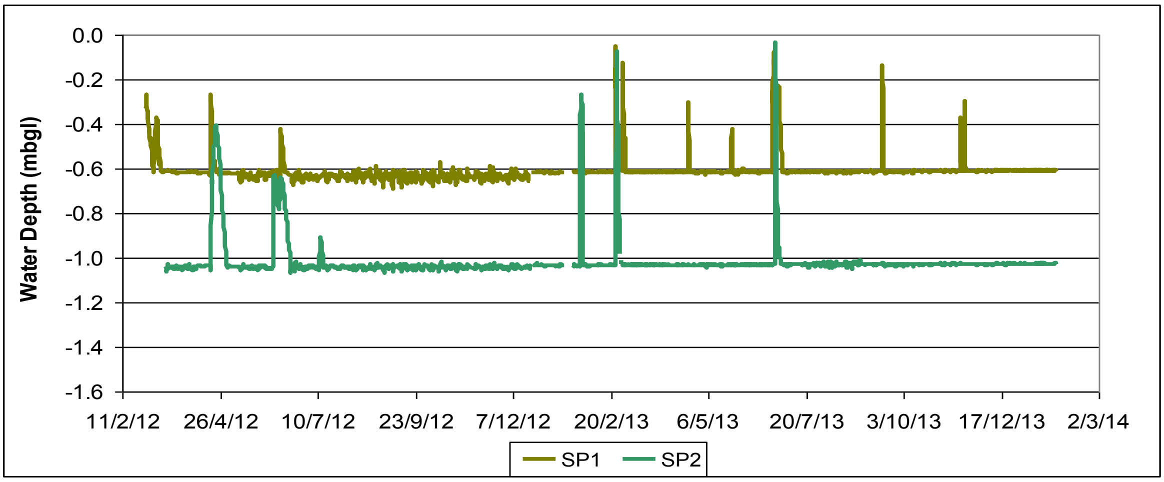
Graph 9: Hydrograph – Upland Swamps CCUS4 and CRUS1



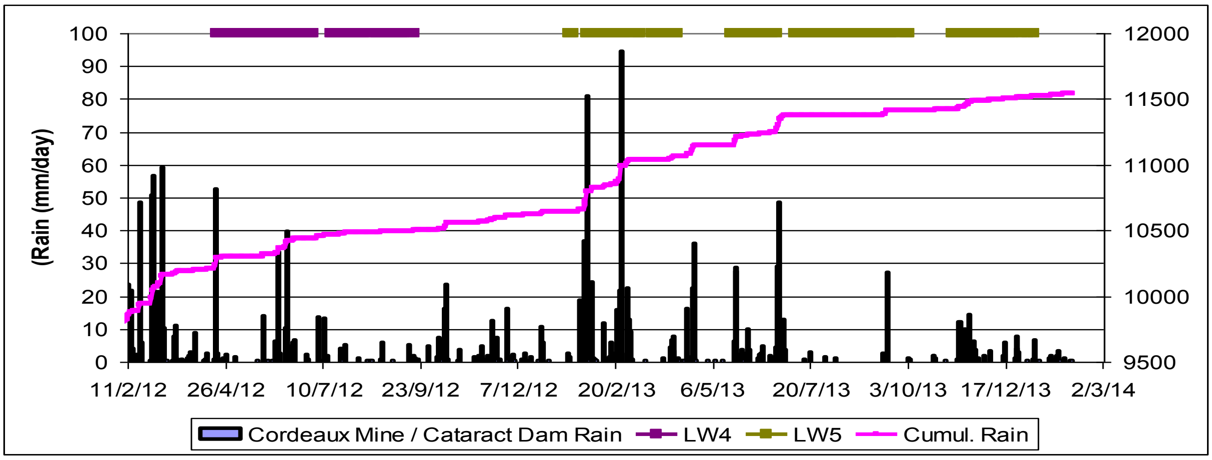
Graph 10: Hydrograph – Upland Swamps CCUS3 and CCUS6



Graph 11: Hydrograph – SP1 and SP2



Graph 12: Rainfall



Groundwater data from piezometers located in upland swamps within the study area indicates that there are varying water levels in these upland swamps. The monitored locations within swamps CCUS4 and CCUS5 show sustained groundwater levels for prolonged periods following rainfall, CCUS2 shows gradual recession of groundwater following rainfall, while CCUS3 and CCUS6 show little groundwater recharge following rainfall. This corresponds with the vegetation communities within these upland swamps, with CCUS4 and CCUS5 supporting areas of MU43 Tea-tree Thicket (both upland swamps) and MU44c Cyperoid Heath (CCUS4 only), which both rely on permanent to intermittent waterlogging. In contrast, CCUS2, CCUS3 and CCUS6 support MU42 Banksia Thicket (CCUS3 and CCUS6) or MU44a Sedgeland and MU44b Restioid Heath (CCUS2) which are less reliant on waterlogging. CRUS1, which supports a mix of MU42 and MU43, is an anomaly. This upland swamp has shallow soils and some areas of MU43 are known to be located in "bowls" within the underlying geology, resulting in water accumulation in depressions in bedrock.

It is worth noting that all of the upland swamps listed above have been subject to significant tilts and strains from past mining (see Table 13 and Table 14), substantially above what has been predicted by MSEC to result in fracturing of bedrock in waterways (DoP 2010) and the criteria listed in OEH (2012) for assessing the risk of negative environmental consequences to upland swamps. These levels of tilts and strains are likely to have resulted in fracturing of the bedrock beneath these upland swamps from past mining. However, monitoring data is not available to confirm whether this has occurred.

Groundwater model

Geoterra and Groundwater Exploration Services (2014) have recently completed the groundwater modelling and associated revised groundwater assessment for the Preferred Project Report for the Underground Expansion Project. Aspects of the model that are of relevance to upland swamps are discussed below.

The model indicates that the depressurisation zone may reach the surface over the eastern and central sections of Longwall 6 and 7 and over the eastern and central sections of Longwalls 1 to 3. It should be noted that although the depressurisation "halo" may extend to the surface this does not mean that this will result in a "full" direct connection between the perched ephemeral water table associated with upland swamps and the mine workings. This is supported by the model predicting depressurisation over the extracted Longwalls 4 and 5; however there have not been any observable adverse change in piezometric water levels in upland swamps above Longwalls 4 and 5 (Graph 10: Hydrograph – Upland Swamps CCUS3 and CCUS6).

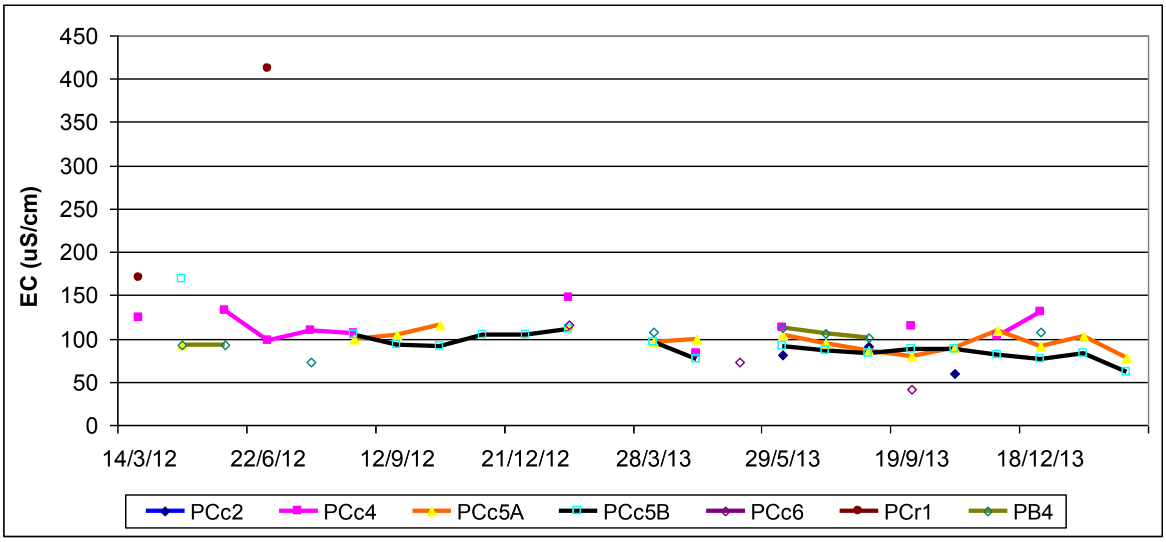
Given the location of likely depressurisation there is an increased risk of drainage for upland swamp CCUS2 and upland swamp of 'special significance' CCUS4. However, for other upland swamps in the Wonga East area the risk of depressurisation is low.

The modelling indicates that although the perched, ephemeral groundwater water table associated with upland swamps could undergo a water level reduction it is not anticipated to have a significant overall effect on stream baseflow or stream water quality. However, temporary, localised effects may be observed.

Groundwater chemistry

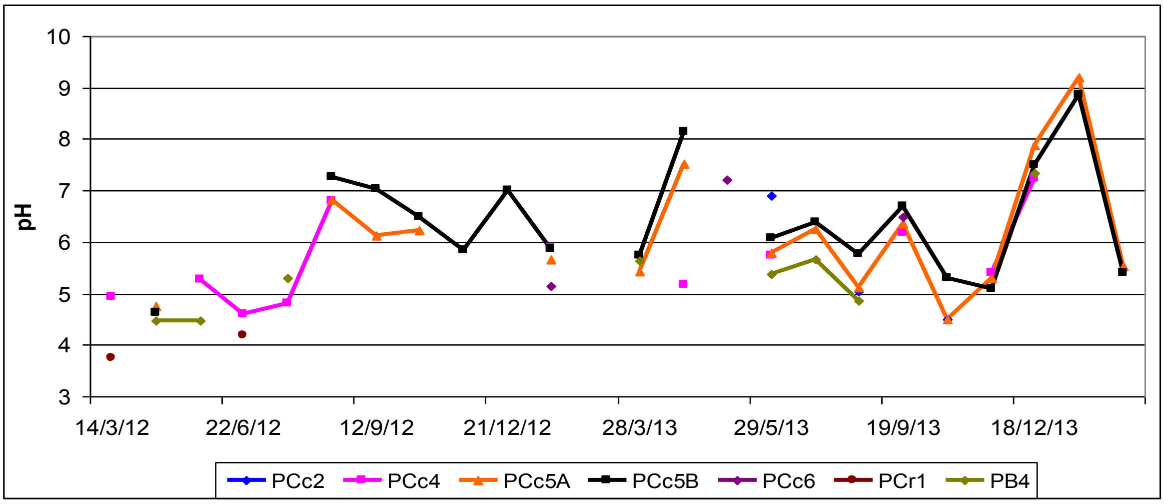
The Cataract Creek, Bellambi Creek and Cataract River swamps at Wonga East have electrical conductivities ranging from 70 – 170µS/cm (Graph 13), with the salinity varying in relationship to rainfall recharge that occurs prior to sampling, along with the degree of brackish seepage from the weathered Hawkesbury Sandstone.

Graph 13: Electrical conductivity – Wonga East upland swamps



The pH ranges from 3.8 – 7.3 as shown in Graph 14.

Graph 14: pH – Wonga East upland swamps



Monitoring indicates the swamp salinity is within the acceptable range for potable water; however it is generally outside the ANZECC 2000 South Eastern Australia Upland Stream criteria for pH and can be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines for:

- Filtered copper, lead, zinc, nickel, and occasionally aluminium (where its pH exceeds 6.5, which it rarely occurs), as well as.
- Total nitrogen, and total phosphorous.

Flow accumulation

Flow accumulation modelling was undertaken based on the revised longwall layout and revised subsidence predictions (SCT Consultants 2013). The methodology for undertaking flow accumulation modelling is presented in Biosis (2012b). To address criticism regarding quantification of impacts from flow accumulation modelling, the percentage change in flow accumulation following mining is presented in Table 19, in addition to a discussion on flow accumulation.

Table 19: Discussion of changes in flow accumulation pre- versus post-mining for upland swamps in Wonga East (swamps of 'special significance' are shown in italics)

Swamp	Percentage change in flow accumulation following mining	Discussion of changes in flow accumulation
BCUS4	114.64	Flow accumulation modeling for BCUS4 pre-mining indicates that there is a dispersed flow through this upland swamp, with four exit points from the base of the upland swamp. Modeling of post-mining flow indicates an increase in catchment yield of 14.64%. There are minimal changes to the exit points within this upland swamp; however a redistribution of water within the swamp may result in decreased water flow through a small patch of MU43 Tea-tree Thicket. This may result in changes to vegetation composition in this area.
BCUS11	108.29	Flow accumulation modeling for BCUS11 pre-mining indicates that this small upland swamp has three flow pathways through the swamp. Following mining, changes in tilt are likely to result in a very minor increase in summed flow within this upland swamp of 8.29%. There is unlikely to be any change to flow pathways through the upland swamp. Changes are predicted to be negligible.
CCUS1	98.32	Flow accumulation modeling pre-mining indicates the presence of two main flow pathways through this upland swamp – one exiting the swamp in the northeast section of the swamp and one in the southeast section of the swamp. These exit points coincide with area of MU42 Tea-tree Thicket and MU44c Cyperoid Heath. Flow accumulation modeling post-mining indicates that tilts associated with Longwall 3 will result in a minor change to the flow pathway through the southeast section of the upland swamp with a minor (8.32%) increase in catchment area. This is likely to result in an increase in water availability for a small section of MU44a Sedgeland in this southeastern section.

Swamp	Percentage change in flow accumulation following mining	Discussion of changes in flow accumulation
		Any changes are likely to be minor.
CCUS2	99.62	Pre-mining flow accumulation modeling for CCUS2 indicates a dispersed flow of water through this upland swamp. Tilts associated with Longwalls 2 and 3 will result in only a negligible (0.38%) change to water availability across the swamp. Flow pathways through the swamp are likely to change following mining; however there are no significant concentrations of water, and given the dispersed nature of flow prior to mining this is predicted to result in minor changes.
CCUS3	99.18	Modeling of pre-mining flow accumulation through CCUS3 indicates the presence of two main flow pathways through this upland swamp, largely through areas of MU42 Banksia Thicket. Tilts associated with extraction of Longwall 5 are likely to result in only negligible (0.72%) changes in overall catchment yield for this upland swamp, and a minor re-direction of flow from the western edge of CCUS3 to the centre. This change will result in any negligible impacts to this upland swamp.
CCUS4	95.23	Flow accumulation modeling pre-mining indicates the presence of two main flow pathways through this upland swamp. One minor flow path passes through the eastern section of the swamp, while the main flow pathway passes through the western section of the swamp. The western flow pathway corresponds with areas of MU43 Tea-tree Thicket and MU44c Cyperoid Heath. Post-mining, tilts will result in a minor (4.77%) decline in overall catchment yield. Only negligible changes in the western flow accumulation pathway are predicted to occur, with minor changes in flows through the patches of MU43 and MU44c. Tilts will result in result in a new flow pathway through the centre of this upland swamp, with resultant increases in water availability to patches of MU42 Banksia Thicket. A shift in the flow pathway through the eastern section of the swamp will result in a minor redistribution of water in this eastern section. This may result in minor impacts to vegetation communities reliant on permanent and intermittent waterlogging.
CCUS5	73.49	Pre-mining flow accumulation modeling indicates that this upland swamp has a dispersed flow accumulation, with numerous flow pathways through the swamp. There is a significant flow pathway through the eastern section of the swamp, corresponding with an area of MU43 Tea-Tree Thicket. Substantial benching within this swamp appears to be correlated with vegetation sub-communities; with areas of Tea-Tree Thicket (MU43) corresponding with the location of rockbars within the swamp, and it is likely that community composition in this swamp relates to a combination of flow and these rockbars allowing pooling of water at these locations. Tilts associated with Longwall 7 are likely to result in a significant (26.51%) decline in overall water availability within this swamp. This decline is likely to

Swamp	Percentage change in flow accumulation following mining	Discussion of changes in flow accumulation
		impact most on the eastern section of this upland swamp, diverting flow away from the major flow pathway mentioned above, resulting in a decrease in water availability for a patch of MU43. This may result in changes to vegetation composition within this swamp; however it is predicted to impact on a small section of the swamp only.
CCUS6	97.69	Flow pathways through CCUS6 prior to mining are dispersed, with multiple entry and exit points reflecting the disconnected nature of this upland swamp. Tilt associated with extraction of Longwall 4 and 5 may result in a minor (2.31%) decrease in flow accumulation, but is unlikely to result in any significant changes in these pathways. Minor changes are predicted to occur.
CCUS10	106.91	Flow accumulation modeling pre-mining indicates a dispersed flow accumulation across this upland swamp. This swamp has a small catchment area that commences just above Longwall 9. Vegetation sub-communities appear to correspond with area of benching down the slope, with these rockbars resulting in accumulation of water in these areas. Post-mining flow accumulation modeling indicates a small (6.91%) increase in catchment yield, and only minor changes in flow pathways through this swamp.
CCUS11	50.35	Flow accumulation modeling indicates that this upland swamp has a small catchment, with the upland swamp likely to be reliant on terracing and accumulation of water. Post-mining modeling indicates a significant (49.65%) decline in this catchment yield. Tilts associated with extraction of Longwall 8 are likely to result in a diversion of this flow pathway around this upland swamp, reducing water availability. There is potential that this decline in water availability may result in impacts to this upland swamp.
CCUS12	103.58	CCUS12is located at the boundary between the catchments of Cataract Creek and Bellambi Creek, and as a result, has a very small catchment area. Pre- versus post-mining flow accumulation modeling indicates that only minor (3.58%) increases in catchment yield and no change in flow pathways. Negligible changes are predicted to occur.
CCUS23	97.06	Given the orientation of the flow pathway perpendicular to the longwall, flow accumulation modeling pre- versus post-mining indicates only a minor (2.94%) increase in catchment yield for this upland swamp. There is unlikely to be any change in flow pathways through this swamp. Negligible changes in water availability due to flow are predicted.
CRUS1	100.21	Only the upper northern section of CRUS1 is located above Longwall 6. An assessment of pre- versus post-mining flow accumulation through the upland swamp indicates a negligible (0.21%) increase in catchment yield and negligible changes in flow pathways through this upland swamps.

Swamp	Percentage change in flow accumulation following mining	Discussion of changes in flow accumulation
		No changes in water availability are predicted to occur.

Flow accumulation modelling for upland swamps within the study area indicates that, for the majority of upland swamps, only negligible or minor changes in both cumulative flow and flow pathways are likely to occur following mining. No significant reconcentration of flows that may result in increased erosion risk, are likely to occur. For the majority of upland swamps mining is likely to result in only minor changes in water availability.

Flow accumulation modelling indicates that BCUS4, CCUS5 and CCUS11 are at risk of impact due to changes in water availability, particularly to vegetation communities sensitive to decreases in water availability. Of these, only CCUS5 is considered to be of 'special significance'.

Compressive and tensile strain

Reassessment of subsidence predictions following monitoring of Longwalls 4 and 5 indicates that past mining has resulted in the softening of the underlying rock strata, and that subsidence is occurring over a much shorter distance than has previously occurred in un-mined areas, with subsidence largely restricted to immediately above the goaf. Whilst this means that subsidence movements occur over a smaller area, it also means that tilts and strains are greater than previously predicted (SCT Operations 2014).

Maximum subsidence within the bounds of the swamp may not necessarily be a good indicator of the maximum subsidence parameters of strain and tilt given that maximum strain and tilt typically occur on the fringes of a subsided area. The maximum strain and tilt values have been estimated based on the level of subsidence within the general proximity of a swamp that would contribute to maximum strains and tilts within the swamp boundary (SCT Operations 2014).

When strains are greater than about 1-2 mm/m in tension and 2-3 mm/m in compression, perceptible fracturing of the sandstone strata below swamps may occur (SCT Operations 2014).

Subsidence predictions are presented in Table 16. This data indicates that tensile and compressive strains and tilts are of sufficient magnitude to result in fracturing of bedrock beneath upland swamps within the Wonga East area. Table 20 assesses the risk of a significant impact to these upland swamps based on vegetation communities present, and recorded response to groundwater (for upland swamps with groundwater data available).

Table 20: Discussion of tensile and compressive and strains for upland swamps within the study area (swamps of 'special significance' are shown in italics)

Swamp	Discussion of tilts and strains
BCUS4	BCUS4 is located over the edge of Longwall 9. Soils in BCUS4 are up to 160 cm in depth and consist of humic sandy clay. Tilts and strains affect a small section of MU43 Tea-tree Thicket. Lower sections of the upland swamp are unlikely to be subject to strains of sufficient magnitude to fracture bedrock.

Swamp	Discussion of tilts and strains
	Undergoes evapotranspiration as well as gradual drainage after rainfall. No evidence of adverse effects due to prior subsidence are evident in this swamp. Risk is assessed as low due to impacts to a small section of this swamp.
BCUS11	BCUS11 does not support vegetation communities reliant on waterlogging. No groundwater data is available. Risk is assessed as low.
CCUS1	Given changes to the longwall layout, impacts are likely to be restricted to a very small section of this upland swamp at the eastern end. Any changes here are likely to be limited in extent, and are unlikely to result in a significant impact to this upland swamp. No groundwater data is available. Risk is assessed as low.
CCUS2	CCUS2 does not support vegetation communities reliant on waterlogging. Undergoes evapotranspiration as well as gradual drainage after rainfall. No evidence of adverse effects due to prior subsidence are evident in this swamp. Risk of impact is considered low.
CCUS3	CCUS3 supports MU42 Banksia Thicket and MU44a Sedgeland, which are not reliant on waterlogging and are thus deemed less susceptible to decreased groundwater availability. Groundwater data indicates rapid recession to basement levels following rainfall. Risk is assessed as low.
CCUS4	CCUS4 supports MU43 Tea-tree Thicket and MU44c Cyperoid heath, which are reliant on permanent to semi-permanent water availability, as well as MU42 Banksia Thicket. Soils are 15 – 179 cm in depth and consist of humic sandy clays to minerals sands. Strains and tilts have increased following the revision of subsidence data by SCT Operations (2014). The location of water-dependent communities, including MU44C Cyperoid Heath and MU43 Tea-tree Thicket at the base of the longwall, in areas of lowest strain and tilt, are likely to mitigate impacts to some degree. Undergoes evapotranspiration as well as gradual drainage after rainfall. An overhanging sandstone formation, approximately 7.1 m high, forms a waterfall at the base of CCUS4. This sandstone formation forms a rockbar at the downstream extent of upland swamps CCUS4. There is evidence of impacts from previous mining, including collapse of a section of this sandstone formation and some cracking of the sandstone outcrop, to the west of the waterfall below CCUS4. Horizontal compression of this sandstone formation has the potential to result in rockfall or tensile cracking of this sandstone formation (SCT Operations 2014). As this sandstone formation forms a rockbar at the downstream extent of CCUS4 any fracturing is likely to result in changes in hydrology. Any rockfall that impacts on the integrity of the sandstone formation may result in significant impacts to the water holding capacity of CCUS4. No evidence of adverse effects due to prior subsidence are evident in this swamp. Risk is assessed as high.
CCUS5	CCUS5 supports a mix of MU43 Tea-tree Thicket, which depends on permanent water availability, and MU42 Banksia Thicket and MU44a Sedgeland. Upper sections overlying Longwall 6 consist of MU42 and MU44a. Soils in this section of CCUS5 are up to 80 cm in depth and consist of a mix of humic sandy clay and sandy clay to minerals sands.

Swamp	Discussion of tilts and strains
	Following revision of the longwall layout only a small section of this swamp will be subject to subsidence, and areas of MU43 Tea-tree Thicket are located in areas of lower strain. Undergoes evapotranspiration as well as gradual drainage after rainfall. No evidence of adverse effects due to prior subsidence are evident in this swamp. Risk is assessed as low.
CCUS6	CCUS6 supports MU42 Banksia Thicket, which is not reliant on waterlogging and is thus deemed less susceptible to decreased groundwater availability. Groundwater data indicates rapid recession to basement levels rapidly following rainfall. Risk is assessed as low.
CCUS10	CCUS10 supports a mix of MU43 Tea-tree Thicket and MU44c Cyperoid Heath, which depends on permanent water availability, and MU42 Banksia Thicket. Following revision of the longwall layout only a small section of this swamp will be subject to subsidence, and areas of MU43 Tea-tree Thicket and MU44c Cyperoid Heath are located in areas of lower strain. Soils in the section of CCUS10 overlying Longwall 9 are up to 75 cm in depth and consist of sandy clay. No groundwater data is available. Risk is assessed as low.
CCUS11	CCUS11 supports MU42 Banksia Thicket, which is not reliant on waterlogging and is thus deemed less susceptible to decreased groundwater availability. No groundwater data is available. Risk is assessed as low.
CCUS12	CCUS12 supports MU42 Banksia Thicket, which is not reliant on waterlogging and is thus deemed less susceptible to decreased groundwater availability. Soils are between 5 and 85 cm in depth and consist largely of minerals sands with little organic material. No groundwater data is available. However this upland swamp is unlikely to support significant groundwater. Risk is assessed as low.
CCUS23	CCUS23 supports MU42 Banksia Thicket and MU44a Sedgeland. No groundwater data is available. Risk is assessed as low.
CRUS1	CRUS1 supports a mix of MU43 Tea-tree Thicket and MU42 Banksia Thicket. Based on shallow soil profile, MU43 Tea-tree Thicket is likely to persist in areas of water accumulation resulting from rock terracing, as evident from analysis of slope and testing of soil depths. Only the upper section of this upland swamp is located within the predicted subsidence zone. Soils in this area are between 25 and 70 cm, and consisting of mineral sands. These areas are unlikely to support significant groundwater. Undergoes evapotranspiration as well as gradual drainage after rainfall. Possible adverse effects due to prior subsidence may be evident in this swamp due to its enhanced drainage recession rates. However, as the swamp has limited humic matter with numerous shallow outcropping or subcropping sandstone outliers, it is equally possible that the swamp has little storage capacity and drains / evaporates rapidly as a result. Risk is assessed as low.

Final risk assessment

Potential impacts

Potential impacts to upland swamps in the Wonga East area may result from the following mechanisms:

- Fracturing of bedrock beneath upland swamps, resulting in increased secondary porosity and permeability, with potential to drain into deeper sandstone strata.
- Tilting in and upland swamps resulting in the re-distribution of perched water levels and surface run-off. This may result in changes in in-flow to upland swamps and / or changes in saturation of vegetation sub-communities.
- Titling in upland swamps resulting in increased potential for development of nick points, scouring and erosion.
- Changes in baseflow discharge and from upland swamps.

Subsidence could affect upland swamps directly overlying the proposed longwalls due to either transient and/or spatial changes in secondary porosity and permeability of a swamp or its underlying weathered sandstone substrate through generation of cracks or differential displacement of the perched aquifer. If a swamp overlies an extracted panel, it may undergo temporary extensional “face line” cracking (perpendicular to the long axis of the panel) as a panel advances, followed by re-compression as the maximum subsidence occurs at any one location. In addition, where a swamp overlies a longwall, it may also undergo both longer term extensional “rib line” cracking (parallel to the long axis of the panel) along the outer edge and compression within the central portion of a panel’s subsidence trough. The more susceptible portions of a swamp to increased secondary porosity and / or permeability changes are where it undergoes “rib line” cracking. Any adverse effects, if they occur, would be related to the extent and degree of cracking that occurs in the underlying weathered sandstone, as cracking is unlikely to manifest in a swamp due to its saturated, clayey, humic, plastic nature.

It should be noted that the headwater swamps at Wonga East have undergone up to an estimated 3.8 m of subsidence in the centre of Longwall 4 with up to 1.0 m of subsidence estimated for mining in the Bulli Seam 1.0 measured during mining in Balgownie Seam, and 1.8 m measured during mining in Wongawilli Seam. This level of subsidence would be expected to cause up to an estimated 21 mm/m of tensile strain, 41 mm/m of compressive strain, and 68 mm/m of tilt. Bulli Seam mining occurred from the late 19th Century through to about 1950. Balgownie Seam longwalls were mined between 1970 and 1982. Longwalls 4 and 5 in the Wongawilli Seam were mined in 2012 and 2013.

Where a swamp straddles a chain pillar, or is on the edge of the subsidence bowl, it could experience temporary, localised, re-distribution of perched water levels through differential subsidence of the ground. Tilting of a swamp could also potentially re-distribute surface runoff, resulting in a re-distribution of water flow and storage, thereby causing changes to the saturation characteristics which may alter the vegetation associations within a swamp.

Changes in flow regimes within swamps can result in changed flow paths or runoff characteristics within a swamp, with the potential for development of nick points, scouring and erosion. Dewatering and drying of swamps due to subsidence fracturing of the bedrock may increase the erosion potential of swamps. Negative environmental consequences may be caused by erosion and drying out of the swamp via channel erosion, by redistribution of water, or by water diversion through connected pathways exposed by buckling or shearing of the underlying sandstone. The swamps, however, contain sediment and organic material that may either seal or reduce water loss into the underlying fracture network. Drying, in conjunction with fire and substantial rainfall, can increase the susceptibility of swamps, particularly valley fill swamps, to erosion. However, it is often the case that no single factor can be directly implicated in enhanced erosion of upland swamps. The only swamp in the Russell Vale lease area that has undergone notable erosion is the valley fill swamp LCUS4 at Wonga West, which is outside the Study Area for this assessment.

Upland swamp water is stored within the shallow, perched, ephemeral groundwater system, whilst regional water is contained within the deeper Hawkesbury Sandstone aquifers. Empirical observation and field mapping (Biosis, 2013) indicates that past undermining of swamps in the Wollongong Coal lease area has not generated adverse ecological effects on swamps. It is therefore anticipated that observable reduction of swamp discharge to the Study Area catchments will not occur following subsidence across the subject catchment areas, although generation of potentially enhanced leakage from the base of the swamps may occur. Seepage from the swamp is currently highly ephemeral, with the volume and duration of baseflow being directly related to the degree of rainfall recharge and stream flow in the catchment.

Detailed risk assessment

Following assessment of a variety of risk factors, Table 21 provides an overall assessment of the potential for a significant impact to occur. This final risk assessment assesses the overall risk of a primary impact (based on the initial risk assessment) and the consequent risk of a secondary impact (based on factors such as groundwater data, reliance of vegetation communities on water availability, changes in flow accumulation and the position of water dependent communities within the upland swamp compared to areas of greatest tilt and strain).

The changes in storativity and permeability are estimated to have no observable impact above the water level variability due to climatic influences. Connective cracking to deeper strata is not predicted and, as such, it is not anticipated that the swamps could freely drain into the deeper sandstone strata. Based on observation of previously undermined swamps in the Wonga East area that have undergone similar strains to those predicted due to undermining by the previous Bulli and Balgownie workings, no observable adverse consequences are anticipated on the water holding capacity, water quality or ecosystem health of the majority of swamps, except possibly CCUS4. In addition to fracturing of the base of CCUS4, there is potential for impacts to the sandstone formation that forms a rockbar at the downstream extent of this upland swamp. Any rockfall that impacts on the integrity of this rockbar is likely to result in a significant impact to the water holding capacity of CCUS4.

Although the upper margins of upland swamps CCUS5 and CCUS10 overlie Longwalls 6 and 9 respectively, soil depths indicate that these upper margins are largely dry and unlikely to support significant groundwater resources. All other designated 'special significance' swamps are not anticipated to undergo sufficient compressional or extensional strains to generate cracks in the underlying or adjacent sandstone, and therefore are not anticipated to undergo any adverse effects or consequences from the proposed mining.

While there is some limited potential for redistribution of perched water levels and surface water run-off in some upland swamps, significant changes in water run-off are likely to be limited to small sections of upland swamps this is limited to smaller sections of upland swamps.

Although erosion of swamps is possible where elevated tilts occur due to subsidence, it is only generally valley fill swamps which have been directly undermined that are susceptible to erosion and scouring. No valley fill swamps are present at Wonga East.

It is not anticipated that the ephemeral water levels or baseflow seepage will be significantly adversely affected.

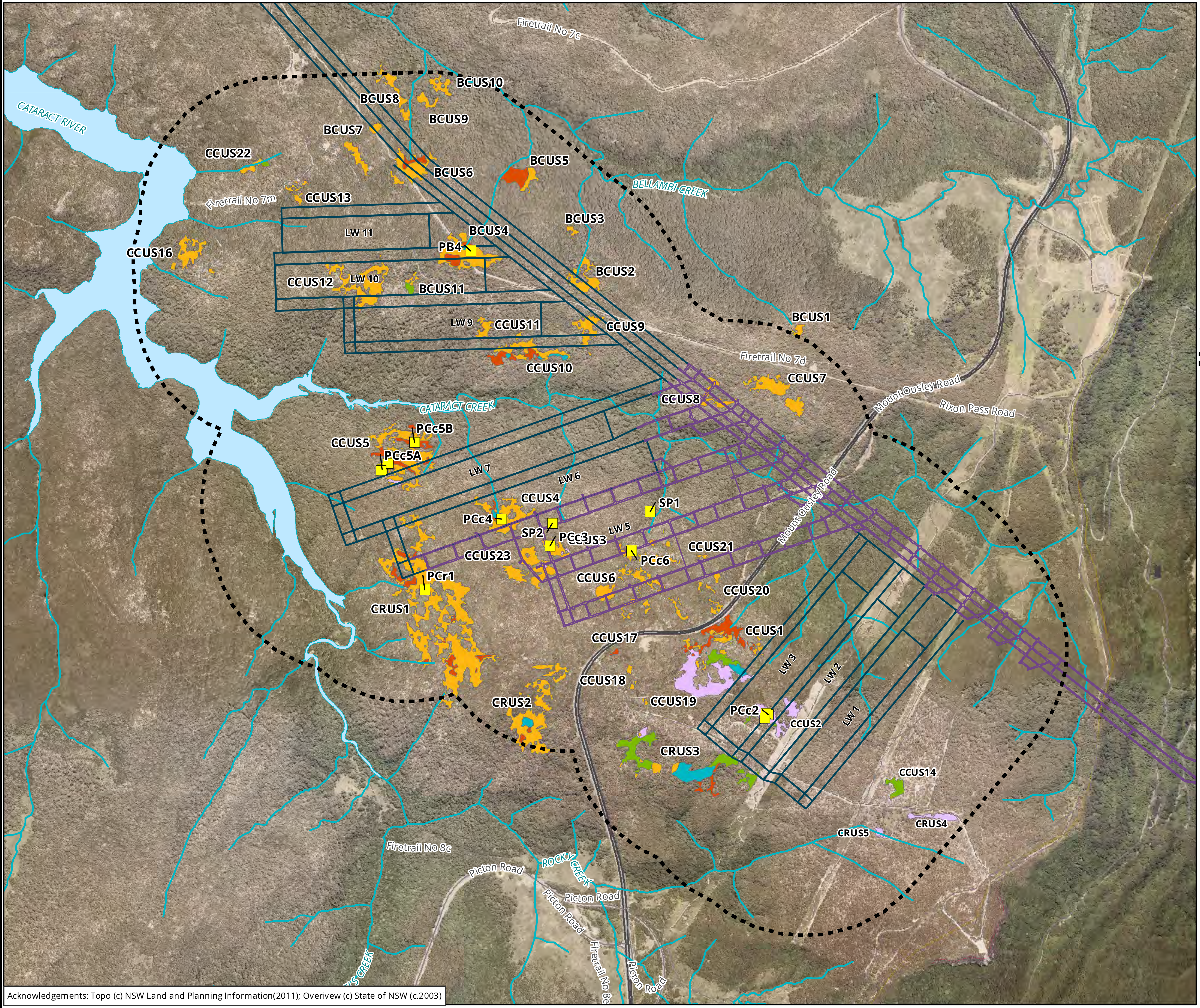
This final risk assessment indicates that there is a risk of a secondary impact to upland swamps BCUS4 and CCUS4 from the proposed extraction of coal in Wonga East. Only CCUS4 is considered to be of 'special significance'.

The revision of the mine plan for Wonga East has resulted in a reduction in risk to upland swamps of 'special significance' CRUS2 and CRUS3 due to these upland swamps now being situated outside of the predicted subsidence impact zone. Revision of the longwall layout has also resulted in a reduction in risk for CCUS5, as only the upper reaches of this upland swamp are now within the predicted subsidence impact zone.

The changes in subsidence predictions and higher tilts and strains have resulted in an increase in risk level for CCUS4.

Table 21: Final risk assessment for upland swamp sin the Wonga East area (swamps of 'special significance' are shown in italics)

Swamp	Initial risk assessment (risk of negative environmental consequences?)	Groundwater	Flow accumulation	Compressive tilts and strains	Final risk assessment
BCUS4	No	Low	Moderate	Low	Moderate
BCUS11	Yes	N/A	Negligible	Low	Low
CCUS1	Yes	N/A	Low	Moderate	Low
CCUS2	Yes	Low	Low	Low	Low
CCUS3	Yes	Low	Low	Moderate	Low
CCUS4	Yes	Moderate	Low	High	High
CCUS5	Yes	Low	Moderate	Low	Low
CCUS6	Yes	Low	Low	Low	Low
CCUS10	Yes	N/A	Low	Low	Low
CCUS11	Yes	N/A	Moderate	Low	Low
CCUS12	Yes	N/A	Negligible	Low	Low
CCUS23	Yes	N/A	Negligible	Low	Low
CRUS1	Yes	Low	Low	Low	Low



Legend

Peizo Locations

Vegetation Sub-Communities

- MU42, Upland Swamps: Banksia Thicket
- MU43, Upland Swamps: Tea-Tree Thicket
- MU44a, Upland Swamps: Sedgeland-Heath Complex (Sedgeland)
- MU44b, Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
- MU44c, Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)

Longwall Layout

- Approved Longwalls (Preliminary works project)
- Proposed Longwalls (Underground Expansion)
- 600m Study Area

Figure 8: Upland swamps in the study area

0 150 300 450 600 750

Metres

Scale: 1:15,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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Matter: 16646
Date: 28 May 2014,
Checked by: NMG, Drawn by: ANP, Last edited by: apritchard
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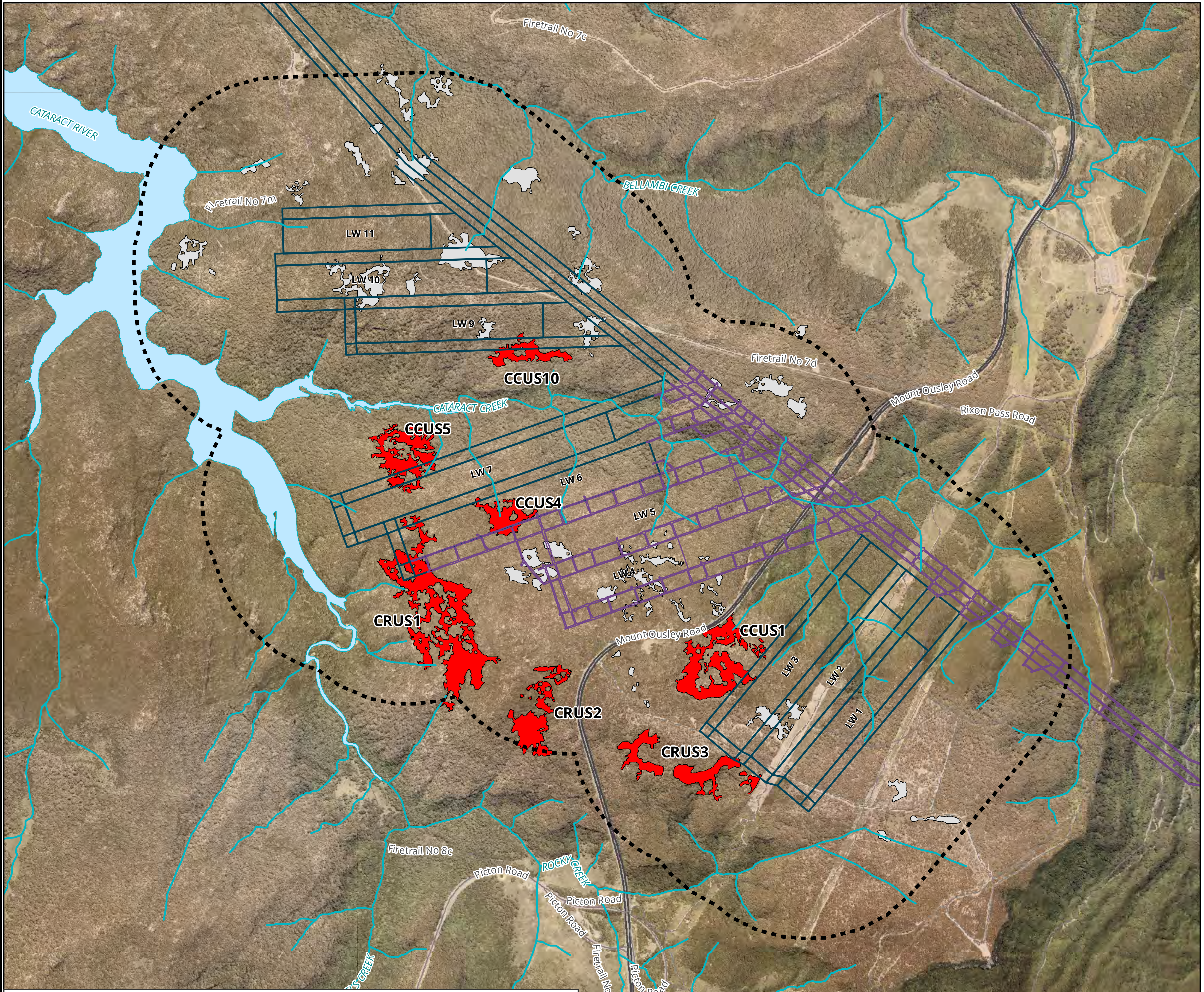

Acknowledgements: Topo (c) NSW Land and Planning Information(2011); Overivew (c) State of NSW (c.2003), Aerial Imagery - NearMap 2012

Legend

Swamp of Special Significance

Yes

No

Longwall Layout

Approved Longwalls (Preliminary Works Project)

Proposed Longwalls (Underground Expansion)

600m Study Area

Figure 9: Upland swamps of 'special significance' in the study area

0 150 300 450 600 750

Metres

Scale: 1:15,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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Date: 09 September 2013,
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16646 PPR_F9_Swamps of Special Significance

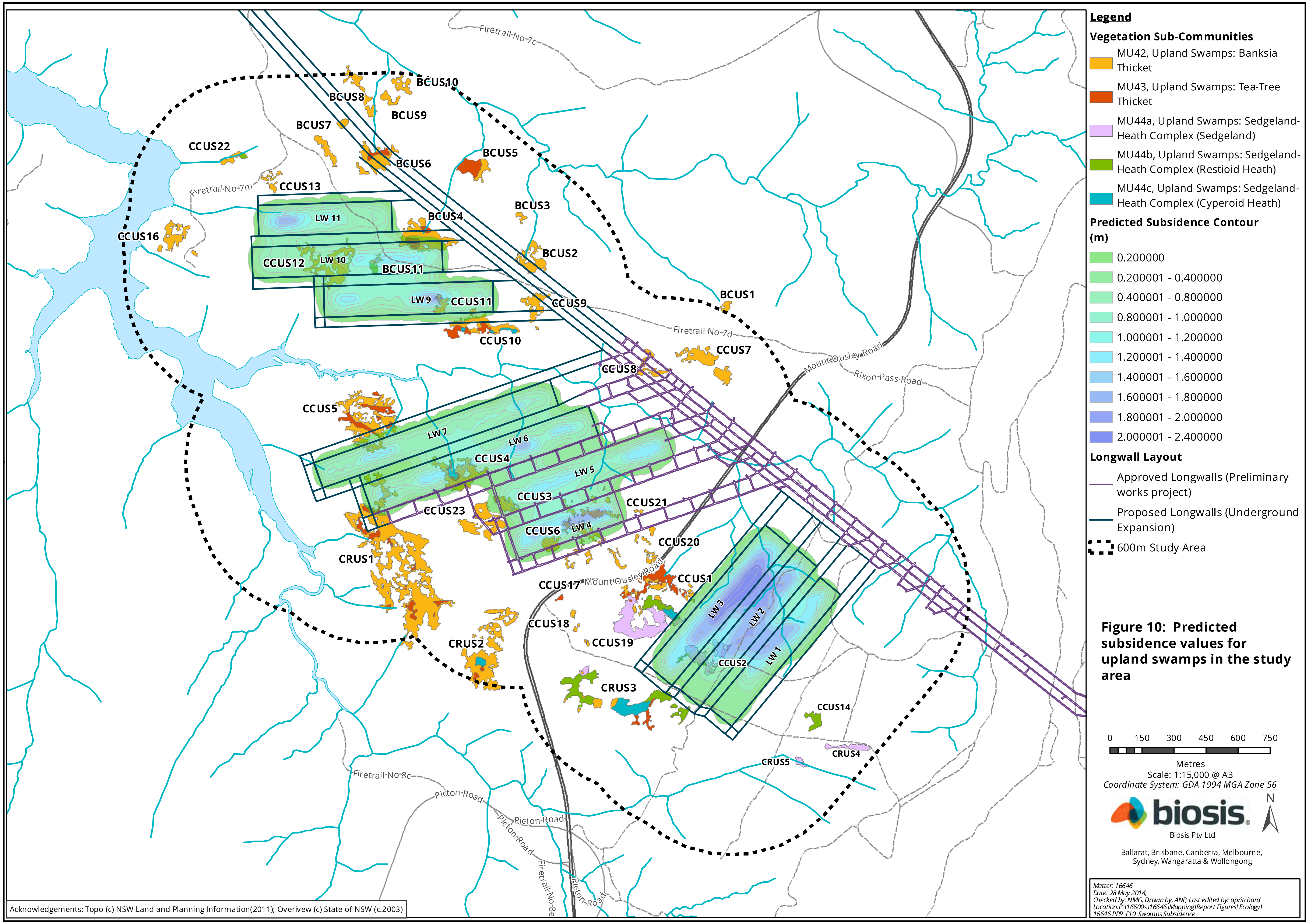
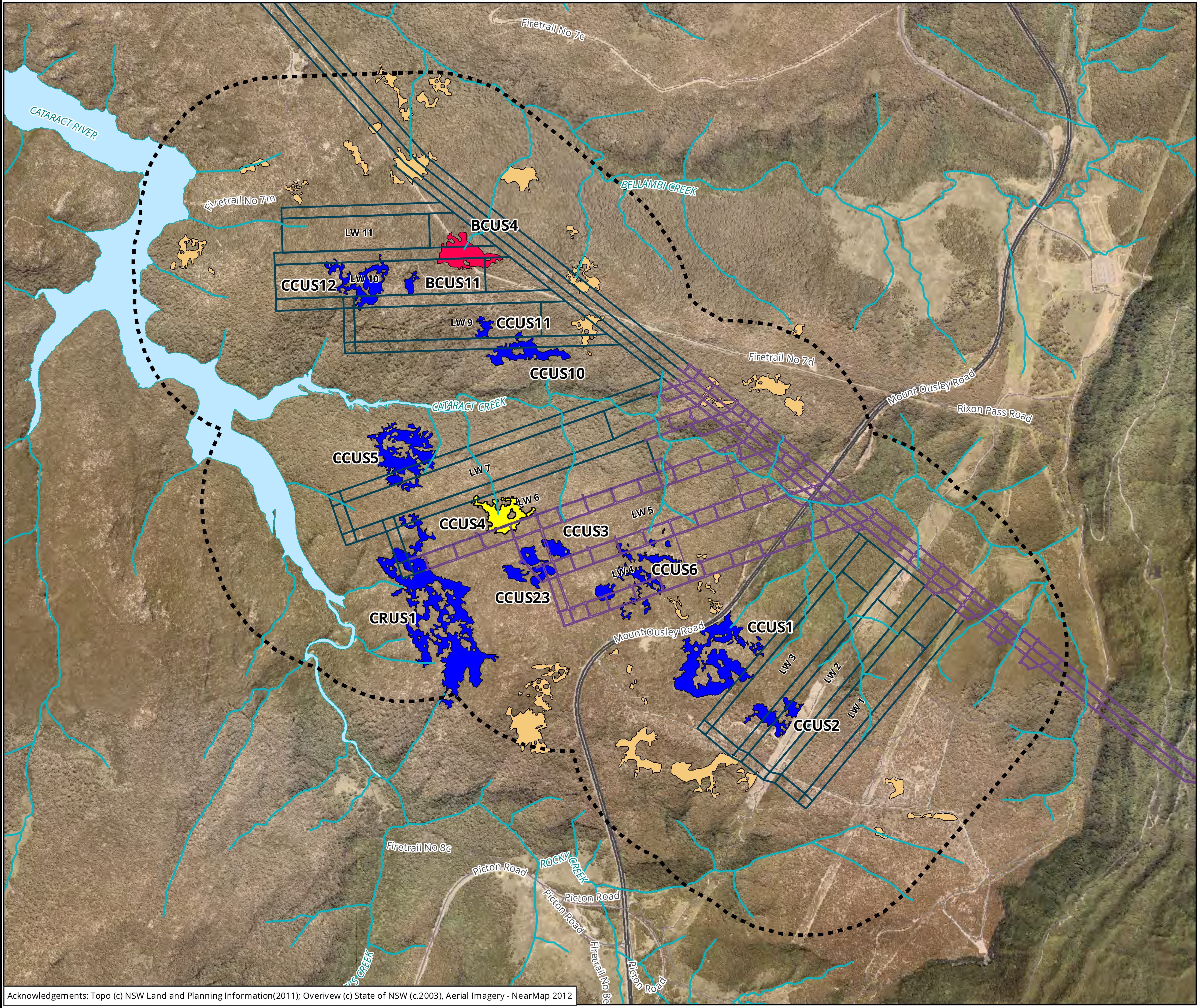


Figure 10: Predicted subsidence values for upland swamps in the study area

Acknowledgements: Topo (c) NSW Land and Planning Information(2011); Overivew (c) State of NSW (c.2003)



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Risk Assessment

- High
- Moderate
- Low
- Negligible

Longwall Layout

- Approved Longwalls (Preliminary Works Project)
- Proposed Longwalls (Underground Expansion)
- 600m Study Area

Figure 11: Final risk assessment for upland swamps in Wonga East

0 150 300 450 600 750

Metres

Scale: 1:15,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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4. Impact Management

The following impact management strategies are reiterated from the Preferred Project Report (NRE 2013).

4.1 Terrestrial Ecology

The majority of potential impacts to terrestrial biodiversity have been avoided as a result of the Preferred Project mine layout. Impact management will be broadly undertaken as outlined in Section 24.6of the EA, (ERM 2013b) as far as it pertains to the Preferred Project.

The existing Biodiversity Management Plan (BMP) for Longwalls 4 and 5 (Biosis 2012a) will be updated for the preferred Project. A monitoring plan consistent with the monitoring plan outlined in the existing BMP for Longwalls 4 and 5 (Biosis 2012a) will be adopted and expanded for the Preferred Project and included in the revised BMP. The current monitoring focuses on natural features at risk of subsidence effects in particular upland swamps and streams in particular, Coastal Upland Swamp EEC, Giant Burrowing Frog, Heath Frog, Red-crowned Toadlet, Stuttering Barred Frog and Broad-headed Snake. The BMP includes:

- Monitoring of vegetation in upland swamps according to the Before-After Control-Impact (BACI) design where data is collected before (baseline) and after impact at control and impact sites. Data collected during baseline monitoring will be used for comparison of data collected during and after mining and data collected at impact sites will be compared to data collected at control sites (control-impact).
- Monitoring of frog habitat according to the BACI design.
- Monitoring of upland swamps using shallow piezometers to gauge any changes in standing water levels and swamp groundwater quality (see Geoterra 2012d).
- Monitoring of water levels in Cataract Creek and tributaries (see Geoterra 2012d).

The BMP will be updated to include Longwalls 1 – 3 and 6 – 11. Monitoring for threatened species identified as having a moderate to high likelihood of occurring in the Study Area, and as vulnerable to the impacts of subsidence will be undertaken. Monitoring will be undertaken at annual intervals in appropriate seasonal timeframes for the detection of each individual species.

An adaptive management plan will be developed to use the monitoring program to detect the need for adjustment to the mining operations so that the subsidence predictions are not exceeded and subsidence impacts creating a risk of negative environmental consequences do not occur in upland swamps, streams and rocky habitats associated with cliffs and steep slopes.

Further measures to mitigate potential small scale affects of subsidence can be utilised as follows:

- If rock fracturing does occur and is confirmed to be a result of mining, remediation will be implemented as soon as possible, via a method to be determined in consultation with relevant stakeholders. All remediation works undertaken will be controlled and implemented in accordance with a BMP.
- If rock fracturing occurs leading to loss of surface water these areas will be prioritised for remediation, and extraction will be ceased in areas with similar fracture risks.

- If significant rock cracking occurs in vegetated areas and is confirmed to be a result of mining, then measures such as temporary fencing will be implemented. This will ensure that fauna (including humans) are not injured or trapped.
- Prior to any remediation works, advice will be sought from an ecologist regarding the potential impacts of such remediation works to plant and animal populations within the area.

A Biodiversity Offset Strategy would be developed if triggers, outlined in the Conditions of Approval and detailed in the Biodiversity Management Plan, are exceeded.

4.2 Aquatic Ecology

The potential impacts of longwall mining on the aquatic ecology of the Study Area have largely been mitigated through the design of the proposed longwall layout and will be further managed through an adaptive mine plan, ongoing monitoring of subsidence, water quality, aquatic habitat, macro invertebrates and fish.

A monitoring plan consistent with the monitoring plan outlined in the BMP for Longwalls 4 and 5 (Biosis 2012a) will be adopted and expanded for the Preferred Project. Monitoring of water quality, aquatic habitat, macro invertebrates and fish during the same seasons as used for the baseline study will continue. There will be additional surveys of aquatic habitats and biota if fractures of the stream bed and associated loss of water from pools occur, fish or yabby kills are noted during routine surface monitoring or if significant changes in pH, dissolved oxygen, turbidity or metal concentrations are detected during routine surface monitoring.

If significant effects on aquatic habitats and/or biota are detected during subsidence monitoring it may be necessary to reduce further impacts and environmental consequences by adopting one of the following strategies:

- Modifying mine layout to further reduce potential subsidence impacts.
- Increasing the setback of the longwall being extracted and future longwalls from the affected watercourse.

A Biodiversity Offset Strategy would be developed if triggers, outlined in the Conditions of Approval and detailed in the Biodiversity Management Plan, are exceeded.

4.3 Upland Swamps

The BMP will include an upland swamp monitoring plan to determine, as far as possible, the historic impacts on swamps and establish a comprehensive monitoring regime for water, ecology and geotechnical elements of swamp communities. Key elements of the monitoring plan will include:

- 3D subsidence surveys to gather detailed data on subsidence levels.
- Shallow piezometers to monitor changes in water levels and quality in upland swamps.
- A network of weirs to monitor base flow from upland swamps and inflows into Cataract Creek.
- Monitoring to get detailed data on climatic conditions.
- Detailed vegetation monitoring, as outlined above.

The aim of the upland swamp monitoring plan will be to determine whether subsidence associated with longwall mining results in impacts to the ecological functioning of upland swamps. The plan will be developed in consultation with relevant stakeholders.

The existing shallow piezometers installed within the upland swamps in the Study Area will be monitored to gauge any changes in standing water levels and swamp groundwater quality over the active mining area and all key water quality parameters on a regular basis for the duration and an appropriate time following mining.

A monitoring program will be designed and implemented to:

- Assess the swamp hydrology;
- Provide advance warning of potential breaches of subsidence predictions;
- Detection of adverse impacts on a swamp and underlying strata hydrology; and
- Characterise the relationship between swamp/s and their role in recharging the regional groundwater systems.

Water levels will be measured from a network of shallow piezometers in potentially impacted swamps and reference sites, before and after mining. Evaporation and rainfall data will also be collected. Should the standing water level or groundwater quality be unacceptably affected due to subsidence, WCL will investigate methods in liaison with the OEH and SCA and ameliorate as required.

At least one appropriately purged and collected, stored and transported groundwater sample will be collected from each swamp piezometer pre and post undermining to enable ongoing assessment of any subsidence related changes in groundwater quality.

Any visual observation of surface impacts such as cracking of rock outcrops, erosion, slumping or changes in flow patters within the swamp that are detected during regular monitoring will be reported and a plan to remediate or repair the impact will be determined in liaison with OEH and SCA.

Adaptive management measures will be utilised in the context of ongoing mining in the Wonga East area. Adaptive management based on groundwater levels is not rapid enough to prevent potential impacts to swamps as groundwater is a trailing indicator. If a swamp is impacted Wollongong Coal will review the mine plan in liaison with relevant stakeholders to determine options to prevent recurrence of impacts to future swamps affected by subsidence.

A Biodiversity Offset Strategy would be developed if triggers, outlined in the Conditions of Approval and detailed in the Biodiversity Management Plan, are exceeded.

5. Response to Submissions

This section provides a response to submissions received on the Underground Expansion Project (UEP) Preferred Project Report (PPR).

A total of six submissions related to biodiversity were received from:

- Department of Primary Industries (Fisheries NSW)
- Office of Environment and Heritage (OEH)
- Sydney Catchment Authority (SCA)
- Wollongong City Council (WCC)
- Bruce Hebblewhite (on behalf of the Department of Planning and Infrastructure (DP&I))
- Evans & Peck (on behalf of DP&I)

The submissions indicate that a number of issues raised in the initial response to submissions on the Environmental Assessment (EA) have been addressed, including:

- Underestimation of subsidence impacts and consequent level of impact to upland swamps.
- Monitoring of upland swamps.
- Impacts to upland swamps of special significance CCUS1, CCUS5, CCUS10, CRUS2, CRUS3 and BCUS.
- Undermining of Cataract Creek and consequent impacts to threatened species.
- Impact to threatened fish species, including survey techniques and effort.
- Potential impacts to threatened frog species.

Table 22 provides a summary of submissions received in relation to the PPR along with who raised them, and provides responses to these submissions.

Table 22: Summary of submissions and responses to these submissions

Submission	Response
Upland Swamps	
Mining under swamps of special significance (WCC, DP&I, Evans & Peck, OEH, SCA)	The PPR proposes to mine beneath upland swamps of 'special significance' CCUS4 (wholly) and CCUS5, CCUS10 and CRUS1 (partially). Of these, CCUS5, CCUS10 and CRUS1 are considered to be at negligible risk of impact. CCUS4 is considered to be at a high risk of impact. Evans & Peck in its analysis of risk of impact to upland swamps has concluded that the risk of impact to all upland swamps is low to minor, and has downgraded the risk of impact for BCUS4 and CCUS4 to Minor while upgrading the risk of impact to CCUS21 from Low to Minor.

Submission	Response
	It has been noted that monitoring by BHP Billiton Illawarra Coal (BHPBIC) and OEH has demonstrated that mining has resulted in fracturing of bedrock beneath upland swamps and consequent loss of the perched aquifer, loss of water flow at the base of the swamp and loss of soil moisture. Such impacts have been posited to *'alter the ecological function of the upland swamp and a high likelihood of eventual loss of vegetation communities and habitat that characterize upland swamps'* (OEH submission on the PPR). Section 3.3.3 provides an assessment of the historic impacts to upland swamps in the Wonga East area from mining of the Bulli and Balgownie seams. The data from this assessment indicates that at least some of the upland swamps in the Wonga East area have experienced levels of subsidence considered likely to have resulted in fracturing of bedrock and a risk of negative environmental outcome. A previous report by Biosis (2013) concluded that data from piezometers located in some of these upland swamps show regression of groundwater consistent with a 'fractured' swamp (e.g. CCUS3, CCUS6 and CRUS1), whilst others do not (e.g. CCUS2, CCUS4 and CCUS5). A subsequent review undertaken by Evans & Peck, on behalf of DP&I, concluded that the water retention characteristics of upland swamps had not been affected by past mining and that the majority of upland swamps in this area have maintained a perched groundwater system and do not show any evidence of cracking (see below for further information). It is the professional opinion of Biosis that there is currently insufficient data available to draw the conclusion that fracturing of bedrock beneath an upland swamp leads to a high likelihood of eventual loss of the vegetation communities and habitat that characterise upland swamps. The paucity of suitable monitoring data from past mining illustrates the difficulty in determining the nature and extent of past impacts. Previous conditions of approval for longwall mining projects

Submission	Response
	in the Southern Coalfield have set a performance measure of *"negligible impacts"* to upland swamps of special significance. Biosis (2013) concludes that CCUS4 is the only upland swamp of 'special significance' at risk of a more than negligible impact. A detailed upland swamp network monitoring program is currently being developed. This monitoring program will assist WCL in determining whether impacts are negligible, as well as providing information on primary and secondary effects of longwall mining on upland swamps. The Biodiversity Management Plan, currently being developed, will outline how Wollongong Coal proposes to achieve these aims and what corrective actions will be undertaken should greater than negligible impacts to CCUS4 occur.
Subsidence predictions exceed those that are predicted to result in fracturing of bedrock beneath upland swamps **(DP&I, Evans & Peck, OEH, SCA)**	The subsidence criteria adopted in the Bulli Seam Operations Planning and Assessment Commission (PAC) report (DoP 2010) and by OEH in their Draft Upland Swamp Environmental Impact Assessment Guidelines (2012) are a '*threshold for investigation – not a conclusion that the swamp will be impacted or suffer consequences*' (DoP 2010, p. 120). The PPR report for Biodiversity (Biosis 2013) sets out how this further investigation has been undertaken, and provides a comprehensive assessment of upland swamps. Based on the historical analysis of upland swamps it is clear that fracturing of bedrock beneath upland swamps does not necessarily result in the loss of the swamp. This is supported by the review undertaken by Evans & Peck, which concluded that the water retention characteristics of upland swamps had not been affected by past mining, except, potentially, for CCUS3 and CCUS6. Evans & Peck conclude that the majority of upland swamps in this area have maintained a perched groundwater system and do not show any evidence of cracking, despite past mining (with the possible exception of CCUS3 and CCUS6). With regard to CCUS3 and CCUS6, Geoterra, in their response to submissions on the PPR, notes that other factors, such as higher soil porosity, lower humic content, location of the piezometer in the

Submission	Response
	swamp, lower catchment area, discontinuous swamp soil extent and a greater proportion of outcropping / subcropping sandstone lead to more rapid water level lowering in these two swamps. The scale of impacts from past mining is currently unknown due to a paucity of monitoring data from past mining activities. However, large scale loss of upland swamps in the study area has not resulted from past mining, and some upland swamps, such as CCUS4, show healthy vegetation communities and significant baseflow. The proposed upland swamp network monitoring program currently being developed will provide additional information on the scale of primary and secondary impacts. Any impacts above those outlined in the Conditions of Approval will be offset under the biodiversity offset strategy to be developed.
Loss of base flow from upland swamps and consequent impacts to Cataract Creek and Cataract River **(OEH, DP&I, Evans & Peck, SCA)**	See Geoterra and GES (2014). Predictions arising from this report are included in Sections 3.1.4, 3.2.3 and 3.3.4. It is worth noting that Evans & Peck concluded that only one out of six upland swamps with piezometer data "*exhibits behaviour consistent with the hypothesized significant contribution to baseflow from upland swamps in general*". Evans & Peck conclude that upland swamps CCUS3 and CCUS6 would not be classified as upland swamps from a hydrological perspective. Biosis and Geoterra agree with this assessment due to the absence of a significant perched groundwater table and significant contribution to baseflow. However, as these two upland swamps meet the floristic characteristics of the Coastal Upland Swamps EEC they have been included in this assessment. There is currently minimal robust data on impacts to baseflow resulting from fracturing of bedrock beneath upland swamps. To date, the only study the authors are aware of looking at this issue is being undertaken by OEH, with baseflow measured at the exit point of an upland swamp in the Dendrobium

Submission	Response
	area. WCL is proposing an upland swamp network monitoring program that will assess changes in baseflow from upland swamps as well as a holistic view of catchment process to look at inflows from upland swamps into Cataract Creek.
Lack of analysis of subsidence effects from past mining on upland swamps, particularly CCUS4. (OEH, DP&I, Evans & Peck)	Section 3.3.3 provides a summary of historic impacts to upland swamps from previous mining activity. Mining of the Balgownie seam has resulted in compressive and tensile strains and tilts that exceed criteria used to determine risk of negative environmental consequences to upland swamps (DoP 2010, OEH 2012). CCUS4 contains patches of MU43 Tea-tree Thicket and MU44c Cyperoid Heath, both of which are reliant on permanent and semi-permanent water logging. Further, piezometer data from CCUS4 shows significant groundwater contact for prolonged periods following rainfall. This data appears to illustrate that CCUS4 has undergone negligible levels of impact from past mining activities. However, other swamps that have previously been mined beneath in this area show rapid regression of groundwater levels following rainfall, which may indicate fracturing of bedrock beneath these swamps (see previous comments on other factors that may influence piezometer regression rates). Despite this, the vegetation in these areas is consistent with upland swamps, albeit often drier representation of swamp communities. In the absence of historic monitoring data it is difficult to make any conclusions on what impacts if any, have occurred.
Over reliance on flow accumulation in risk assessment for upland swamps. (OEH)	Comments from OEH on over reliance on flow accumulation to assess risk to upland swamps is noted. However, the assessment of historic impacts to upland swamps in Wonga East from past mining see Section 3.3.3 of Biosis 2013) indicates that the fracturing of bedrock beneath swamps alone does not result in catastrophic loss of upland swamps. We are of the view that the upland swamp impact assessment includes additional geomorphic,

Submission	Response
	hydrologic and pedological criteria that facilitate a more robust assessment of potential impacts. However, we would welcome the opportunity to work with OEH to refine these criteria if they feel the assessments are still weighted towards flow accumulation impacts.
Threatened Species	
Potential impacts to threatened frogs. (WCC, OEH)	Impacts to threatened frogs are discussed in Section 3.1.4. Biosis has now completed two years of targeted surveys for the Giant Burrowing Frog, Littlejohn's Tree Frog and Stuttering Frog as a part of the ecological monitoring program for Wonga East. These species have not been recorded within the subsidence impact zone during these targeted surveys. These species are now considered unlikely to be present within the Wonga East area and are therefore unlikely to be impacted by the proposed extraction of coal in this area. Upland swamps do not provide suitable habitat for the Stuttering Frog.
Impacts to Cataract Creek, including loss of inflow and increase in iron seepage. Cataract Creek provides habitat Macquarie Perch and Trout Cod, particularly spawning habitat and refugia for juveniles . (OEH)	See Geoterra and GES (2014). Predictions arising from this report are included in Sections 3.1.4, 3.2.3 and 3.3.4. The groundwater model indicates that the average daily stream flow from Cataract Creek to Cataract Reservoir is 11.2 ML/d, of which 3.5 ML/d is baseflow. The model predicts a 0.013 ML/d (0.12%) loss of stream baseflow following mining. This level of change is unlikely to be detectable and unlikely to result in observable changes to flow regimes in Cataract Creek. There are currently significant levels of iron flocculent in Cataract Creek due to the hematitic / sideritic nature of the Bald Hill Claystone and potentially past mining of the Bulli and Balgownie seams. It is anticipated that there will be no discernible change in iron levels in Cataract Creek. Additional surveys have been undertaken for threatened fish species (Biosis 2013c). Fisheries NSW in their submission on the PPR stated that the

Submission	Response
	issues they previously raised have been addressed.
Impacts to habitat for the Giant Dragonfly. (OEH)	Additional surveys for the Giant Dragonfly have been undertaken and are discussed in Section 3.1.4 and below. The PPR incorrectly stated that areas of Tea-tree Thicket, particularly in upland swamp CRUS1, provide likely habitat for this species. Preferred habitat identified by OEH (2013c) includes open vegetation with free-standing water. In the PPR report for biodiversity (Biosis 2013c), CCUS4 was identified as suitable habitat for this species. Potential breeding habitat for the Giant Dragonfly can be identified based on the hydrogeomorphology, rainfall range and soils (Baird 2012). Breeding habitat is presumed to be associated with groundwater dependent habitat with some associated development of organic-rich or peaty soils. Swamp types with a negative water balance and prolonged periods of surface drying, or characterised by permanent or prolonged seasonal inundation, are not considered to provide potential breeding habitat for this species. Based on this information, Biosis has undertaken a review of potential habitat within the Wonga East area and identified upland swamps CCUS1, CCUS4, CCUS5, CCUS10, CRUS1 and BCUS4 as potential habitat for this species based on presence of communities reliant on presence of groundwater and potential for organic-rich soils. Additional surveys of these areas were undertaken in December 2013 to February 2014. These additional surveys focused on identifying significant breeding habitat through surveys for exuviae of the Giant Dragonfly, as it is breeding habitat for this species that is likely to be susceptible to impacts from subsidence and consequent changes in soil moisture. Exuviae were located in upland swamps CCUS4, CRUS1 and BCUS4. In all upland swamps exuviae were located in areas with deep, organic soils. In CCUS4 and BCUS4 this was at the downstream

Submission	Response
	extent of these swamps, where there was an accumulation of groundwater and open vegetation. In CRUS1 this was in pockets of groundwater dependent Tea-tree Thicket with an open overstorey, created by underlying geology. Of the locations where exuviae were observed only CCUS4 will be directly mined beneath. The potential for other locations listed above to support breeding habitat for this species cannot be discounted; however other locations will not be directly undermined.

6. Conclusions

Changes to the project, as outlined in Section 2 have resulted in a significant reduction in predicted impacts to terrestrial and aquatic biodiversity and upland swamps. A summary of the reduced impact predictions is provided below:

- Removal of Wonga West from the program has resulted in reduced impacts to cliffs, providing habitat for threatened bats, rocky outcrops, providing habitat for threatened flora species and the Broad-headed Snake, and habitat for threatened frogs. The risk assessment for each of these groups of species now indicates a low risk of potential impact.
- The revision of the mine plan to avoid undermining of Cataract Creek has resulted in a reduced risk of impact to Macquarie Perch, Murray Cod and Silver Perch, as well as habitat for the threatened Adam's Emerald Dragonfly.
- The revision of the mine plan has resulted in a reduction in risk for several upland swamps, including CRUS2, CRUS3 and CCUS5, and will result in low risk of impact for all upland swamps except BCUS4 and CCUS4.

Impacts to the biodiversity values in the Wonga East area overall is considered to be low. Whilst there remains a high risk of localised impact to habitat for the Giant Dragonfly in upland swamp CCUS4, as well as a moderate to high risk of impact to two upland swamps (BCUS4 and CCUS4) including one upland swamps of 'special significance' (CCUS4), these impacts are not considered likely to result in a significant effect on these threatened species or communities such that the long term viability of a local population of any threatened species or community will be reduced.

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Appendix H

UNDERGROUND EXPANSION PROJECT: RESPONSE TO SUBMISSIONS ON THE PREFERRED PROJECT REPORT – HERITAGE

27 March 2014

David Clarkson
Group Environment and Approvals Manager
Wollongong Coal Ltd
PO Box 281
FAIRY MEADOW NSW 2519

Dear David

Underground Expansion Project: Response to Submissions on the Preferred Project Report - Heritage

Our Ref: Matter 16646

The purpose of this letter is to provide a response to submissions received on the Preferred Project Report (PPR) for Wollongong Coal Ltd's (WCL) Underground Expansion Project (UEP).

A total of two submissions related to heritage were received from:

- Wollongong City Council (WCC); and,
- Heritage Council of NSW.

WCC identified that previous Aboriginal heritage issues had been addressed and did not raise any new heritage issues.

The Heritage Council has queried a WCL statement, made in the PPR, in regards to commitments to heritage made in the Statement of Commitments (SoC). In the PPR, WCL has stated that the SoC contained in the EA has been "*eclipsed by activities for the Preliminary Works Project Part 3A approval (MP 10-0046)*" and provide a summary of activities undertaken according to the Conditions of Approval for the Preliminary Works Project against these SoC.

WCL is not concluding that the Statement of Commitments is unnecessary; rather that the activities associated with these SoC are either completed or on-going. Table 1 below provides an update on activities associated with the SoC, including whether they are complete or ongoing.

Table 1: Status of activities associated with the Statement of Commitments

Statement of Commitment	Status	Notes
A Conservation Management Plan will be prepared for the Project. The plan will reflect the future need of the site as a continuing mine and include procedures to follow for the discovery of unanticipated 'Relics'.	Completed	The final versions of the Heritage Management Plan (HMP; Biosis 2012b) and Conservation Management Plan (CMP; Biosis 2013a) were submitted to DP&I in October 2012 and February 2013 respectively. Procedures for the discovery of unanticipated 'Relics" have been detailed in the CMP and HMP.

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Statement of Commitment	Status	Notes
No items identified as having heritage value or contributing to the heritage value of the site will be demolished as part of this project.	Ongoing	The CMP (Biosis 2013a) and HMP (Biosis 2012b) identify those items within the Russell Vale Colliery that have heritage value or contribute to heritage value. Heritage items need to be managed in accordance with the CMP (Biosis 2013a) and HMP (Biosis 2012b) requirements. This will be an ongoing task managed by Wollongong Coal.
A photographic recording of the 1887 portal and the site will be undertaken and copies will be lodged with the appropriate local and state repositories.	Completed	An archival recording of the Russell Vale Colliery (Biosis 2013b) was undertaken between 2011 and 2013, including photographic recordings of the 1887 portal and other site features to Heritage Archival Recording standards. Copies of the Archival Recording were lodged with NSW State Library and Wollongong City Library in August 2013.
A photographic recording of the site should be undertaken to Heritage Archival Recording standards, prior to commencement of construction for the Project, to provide a lasting record for the site prior to the new development. Copies of the recording should be lodged with the appropriate local and state repositories.	Completed	See above
Items of moveable heritage, including historical photos, plans, maps, records and the like will be documented, collated and catalogued. Items of moveable heritage will be retained at their current location on site and documented including historical photos, plans, maps and records to Heritage Archival Recording Standards. A conservator will provide advice regarding the long term storage of items to maximise their survival. When the item has been appropriately catalogued it will be donated to a suitable repository. Appropriate repositories will be identified prior to project works commencing.	Ongoing	A catalogue of heritage items has been be prepared; including historical documents as well as physical heritage elements, and has been included in the archival recording (Biosis 2013b). Historical documents are currently retained in Wollongong Coal archives on-site. If required, the Wollongong Library Local Studies Section has indicated it is prepared to be a repository for historical documents; however it is intended to keep documents on-site as a first preference. Conservator advice for other items of moveable heritage has been provided to Wollongong Coal and conservation actions are ongoing.
No secondary extraction will occur beneath or within 1 km of the Cataract Dam Wall.	Completed	There is 1.5 km exclusion zone for secondary extraction around the dam wall.

As can be seen, the vast majority of activities arising from the SoC have been completed. Only those activities associated with the conservation and management of heritage items are ongoing.

The Heritage Council also identified that it was unclear if issues previously raised by the OEH Heritage Branch with the previous version of the HMP (Biosis 2012a) had been addressed. Comments on the HMP were received from OEH Heritage Branch on 4 September 2012 and were addressed in Section 3.1 of the revised HMP (Biosis 2012b). The revised HMP was re-submitted to DP&I in October 2012.

Yours sincerely

Nathan Garvey
Resource Group Manager

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Appendix I

TRAFFIC & TRANSPORT IMPACT ASSESSMENT FOR REVISED PPR

Wollongong Coal Russell Vale Colliery

Traffic & Transport Impact Assessment for the Preferred Project

89914003

Prepared for
Wollongong Coal Ltd

April 2014

Document Information

Prepared for	Wollongong Coal Ltd
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Prepared for:
Wollongong Coal Ltd

Prepared by:
Cardno Pty Ltd (NSW/ACT)

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1 Introduction

Cardno has been engaged by Wollongong Coal Ltd (WCL) to undertake a Traffic and Transport Impact Assessment for the proposed WCL Underground Expansion Project Pt3A Preferred Project Report (PPR).

This study forms part of a larger assessment of the proposed changes to existing coal haulage operations from Russell Vale Colliery (previously NRE No. 1 Colliery) to the Port Kembla Coal Terminal (PKCT). Haulage operations are proposed 15 hours per day Monday to Friday, 7am to 10pm; and 10 hours per day Saturday and Sunday, 8am to 6pm, (referred to as 15/5-10/2 operations) delivering up to approximately 3 million tonnes per annum (Mtpa) of coal up over the five year Project life.

Cardno undertook a comprehensive Traffic Impact Assessment (TIA) in August 2010 as well as in subsequent addenda in September 2010, as part of the original NRE No.1 Colliery's Project Application (09_0013) Environmental Assessment (ERM, 2013) for the Underground Expansion Project (UEP). This study detailed key intersection performance, mid-block carriageway performance, crash review and route safety review. The assessment presented in this report should be read in conjunction with the previous TIA carried out by Cardno. Traffic impacts associated with the increased workforce associated with the UEP are assessed in the previous TIA. As no change to employee numbers is associated with the PPR when compared to the UEP EA, no further assessment has been provided in this document.

1.1 Project Background

In July 2010, Cardno undertook a TIA for WCL to form part of the UEP EA, the purpose of which was to seek approval (under Part 3A of the NSW Environmental Planning and Assessment Act 1979) to continue its coal mining operations for a Project life of 18 years and to increase the coal production of Russell Vale Colliery in the Southern Coalfield to a peak production of 3 Mtpa of ROM coal. The Russell Vale Colliery currently holds approval to extract up to 1 Mtpa of coal.

However, subsequent to community and agency submissions to the UEP EA, WCL has modified its Underground Expansion Project Part 3A application in the following manner:

1. The estimated Project life has been reduced to a maximum of 5 years.
2. The Wonga East longwall layout has been extensively modified to minimise impacts to identified significant features while recovering the maximum volume of coal reserves possible.
3. The Wonga Mains drive will not be extended to the north under the south arm of Cataract Reservoir through the known geological feature (in Bulli Seam).
4. The Wonga West longwalls will be removed from the application.
5. The Western Balgownie and Western Bulli seam first workings will be removed from this application.
6. No change to the Pit Top, 3 million tonnes per annum extraction rate or peak coal transport rates from the UEP EA.

As a result of this decision, the Department of Planning and Infrastructure (DP&I) requested that WCL submit a PPR incorporating the above changes to the UEP.

The key difference that pertains to the traffic impacts of the proposal is identified to be the change in project life period. The original proposal included a goal of achieving the production target of 3 Mtpa over a 10 to 18 year period. As such, the previous TIA was undertaken on the basis of a gradual increase in coal transport from 2009 to 2025 with peak production of 3 Mtpa reached around 2019.

However, with the PPR option, this ramp up of production is proposed to occur over a reduced project life span of 5 years. As such, this traffic and transport assessment will investigate the impacts associated with increasing the current production of 1 Mtpa to achieve a production and haulage target of 3 Mtpa over a 5 year period.

1.2 Scope of Work

Subsequent to the submission of the UEP EA, Wollongong City Council (WCC) and Roads and Maritime Services (RMS) provided comments and raised specific concerns which will be addressed in this assessment.

The following scope of works has been undertaken in this assessment, in response to the WCC and RMS comments, incorporating the proposed reduction in Project lifespan. Some comments provided by Council and the RMS which relate to impacts beyond the proposed 5 year Project life have not been addressed as they are no longer relevant to the Project. **Table 1-1** below details WCC and RMS comments and advises where each is addressed in this report.

Table 1-1 List of WCC and RMS Comments Addressed

Ref	Regulator	Issue	Where Addressed
1.	WCC	Council requests that traffic modelling be required for the next 5 years (2018) which deals with affected intersections and midblock performance, prior to the determination of the application.	This report
2.	WCC	Therefore, Council requests that the Department impose a condition of consent requiring that appropriate negotiations take place with both Wollongong City Council and the NSW Roads and Maritime Service concerning funding towards road maintenance works as a result of the additional trucks using local and regional roads between the site and the Port Kembla Coal Terminal.	See Wollongong Coal response
3.	RMS	RMS requests that the proponent provide information regarding the truck configurations to be used, including axle loadings and the additional equivalent standard axle loadings	This report

The scope of work undertaken and summarised in this report includes:

1. Review previous assessment undertaken to ensure validity of the all previous assumptions adopted in light of the PPR;
2. Apply relevant growth rates to traffic counts undertaken for the previous assessment to determine 2020 future base intersection and mid-block volumes;
3. Generate the future number of truck movements between Russell Vale Colliery and PKCT, based on the ‘3 Mtpa peak’ scenario over the 5 year Project life.
4. Undertake SIDRA assessment of the 2020 base and base plus Project (3 Mtpa peak) scenarios;
5. Undertake carriageway mid-block performance assessment for the 2020 base and base plus Project scenarios to determine the impacts of the proposal on carriageway mid-block traffic operations for each road section along the haulage route.
6. Compare the increase in the number of coal haulage trucks resulting from the Project with the design life of the pavement in Equivalent Standard Axles to determine the Project’s impact on the pavement along the designated haulage route. The haulage route includes:
   - Memorial Drive;
   - M1 Princes Highway (F6 Freeway);
   - Masters Road; and
   - Springhill Road.

2 Background and Existing Conditions

WCL currently owns and operates Russell Vale Colliery located in the Southern Coalfields of New South Wales, Australia. The mine spans over 6,545 hectares with reserves of over 300 million tonnes of coking coal. The mine is located approximately 14km north of the PKCT near Wollongong, New South Wales.

The Project proposes to continue to truck unwashed coal to PKCT via the existing haulage route for shipment to India. Some existing surface infrastructure will be upgraded, including coal handling and processing infrastructure.

PKCT is a major intermodal coal facility in southern New South Wales, located in the Inner Harbour of Port Kembla, near Wollongong. The facility transfers coal from rail and road to ship. Currently, approximately 1 Mtpa of coal is delivered to PKCT from Russell Vale Colliery using coal haulage trucks via the public roads between 7.30am and 8.30pm on Monday to Saturday.

Figure 2-1 below illustrates a map of the site locality.

Figure 2-1 Site Locality Map

2.2 Study Area

The Russell Vale Colliery is located off the Princes Highway, Russell Vale, opposite the intersection with Bellambi Lane, near Wollongong as shown on **Figure 2-1**. The study area includes the Russell Vale Colliery, PKCT and the major road haulage links between them.

The key public road haulage routes within the study area are:

> Bellambi Lane from Princes Highway to Memorial Drive.
> Memorial Drive/ M1 from Bellambi Lane to the Masters Road exit.
> Masters Road from M1 to Springhill Road.
> Springhill Road from Masters Road to Port Kembla Road.

The route overview is also shown on **Figure 2-2** below.

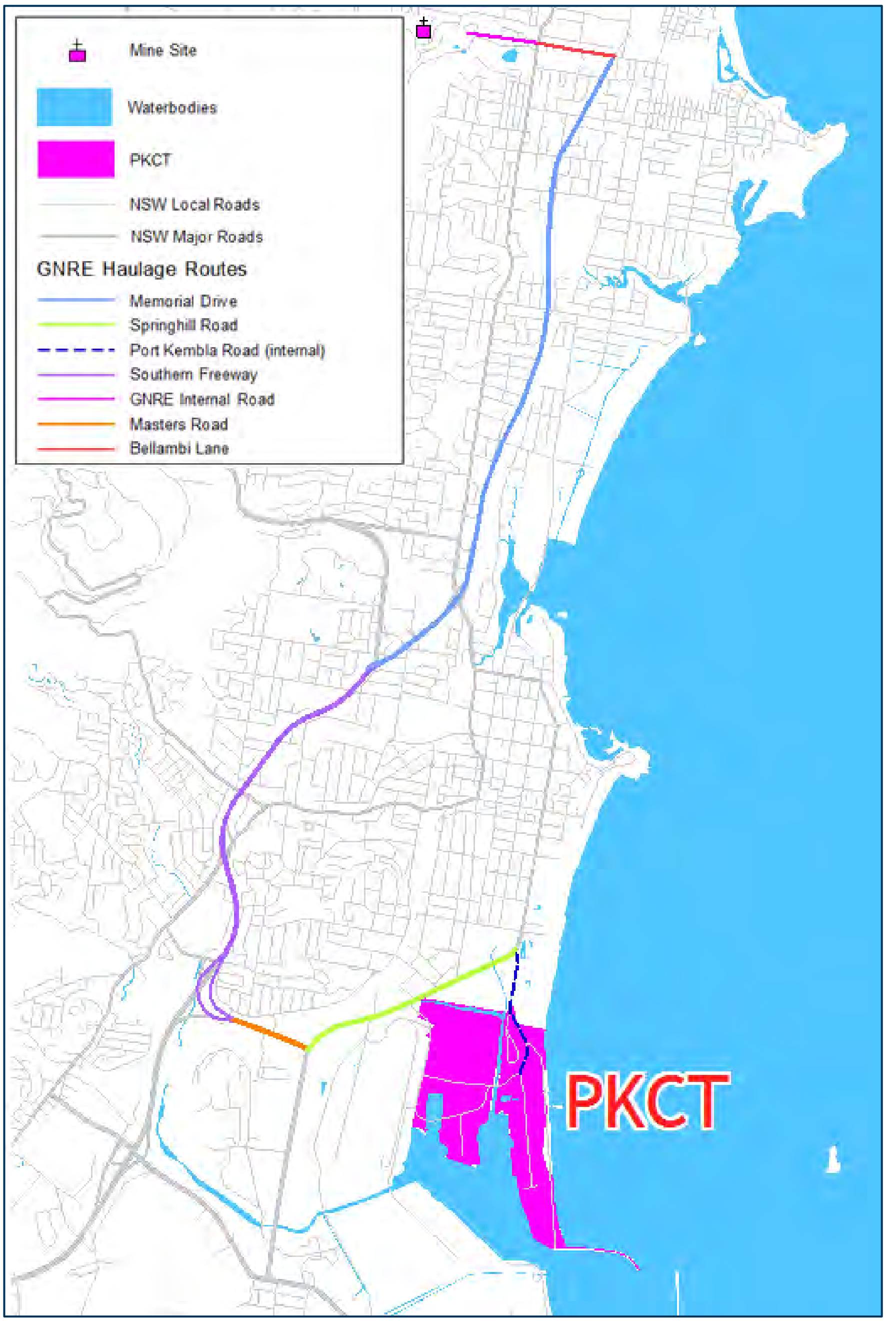


Figure 2-2 Site Location and Route Overview

2.3 Haulage Route Details

The coal haulage route between Russell Vale Colliery and the PKCT is a fixed route and in order to reach the PKCT site, the coal trucks from the mine site in Russell Vale will continue to:

1) Cross Princess Highway and enter Bellambi Lane from the Princess Highway/Bellambi Lane intersection;
2) Drive along Bellambi Lane and turn right on to Memorial Drive at Bellambi Lane/Memorial Drive intersection;
3) Drive south along Memorial Drive/ M1 and turn left onto Masters Road at the Masters Road exit;
4) Drive east along Masters Road and turn left onto Springhill Road at the Masters Road/Springhill Roald intersection; and
5) Drive north-east along Springhill Road and turn right onto Port Kembla Road at Springhill Road/Port Kembla Road intersection and reach the PKCT site.

The return trip from PKCT site to Russell Vale Colliery involves driving along the same route as outlined above, utilising the on ramp to the M1 from Masters Road.

2.4 Key Intersections Assessed

As per the haulage route details provided above, the performance of the following intersections have been assessed:

1) Bellambi Lane/Princess Highway intersection;
2) Bellambi Lane/Memorial Drive intersection;
3) Springhill Road/Masters Road intersection;
4) Springhill Road/Tom Thumb Road intersection; and
5) Springhill Road/Port Kembla Road intersection.

3 Existing Intersection Conditions and WCL Operations

3.1 Base Traffic Volumes from Previous Cardno Studies

The original comprehensive TIA was prepared by Cardno (in July 2010) using traffic count data obtained prior to the opening of the Northern Distributor (now Memorial Drive), and future traffic forecasts in this assessment were made based on assumptions of changes in traffic volume at key links expected following the opening of the Northern Distributor.

In September 2010, Cardno undertook additional works as an addendum to the previous comprehensive assessment. This addendum updated these future traffic forecasts, and subsequently identified the impacts of the UEP based on the then newly available, 2010 traffic data obtained following the opening of the new road link. The addendum assessment specifically considered the impacts on the Bellambi Lane and Northern Distributor haulage routes at key intersections and road links at the estimated 2019 future scenario.

From these previous studies carried out by Cardno, the traffic counts at the following key intersections were obtained;

- Springhill Road/Masters Road intersection (traffic counts undertaken in 2009);
- Springhill Road/Tom Thumb Road (traffic counts undertaken in 2009);
- Springhill Road/Port Kembla Road (traffic counts undertaken in 2009);
- Bellambi Lane/Northern Distributor (Memorial Drive) (traffic counts undertaken in 2010); and
- Bellambi Lane/Princess Highway (traffic counts undertaken in 2010).

3.2 Background Traffic Growth Rates

The traffic growth rates assumed, in the previous Cardno study, for each of the key routes are summarised in **Table 3-1** below. It is noted that for Bellambi Lane and the Northern Distributor, the percentage growth has been determined on the basis of Northern Distributor Extension modelling outcomes (as outlined in the previous Cardno TIA).

Table 3-1 Assumed Background Traffic Growth Rates (% per annum)

Name	Location	Basis	% Growth per Annum	
			Light Vehicles	Heavy Vehicles
Bellambi Lane[3]	Bellambi-E Of Old Princes Hwy	NDE Modelling	1.0%	1.0%
Memorial Drive	North Wollongong, south of Bellambi Lane	NDE Modelling	5.0%	5.0%
M1	Gwynneville, Gipps Rd overpass	AADT (2000-2006)[1]	2.9%	3.9%
Masters Road	Mt St Thomas, west of Springhill Rd	AADT (2000-2005)[2]	0.0%	0.0%
Springhill Road	Mt St Thomas, north of Masters Rd	AADT (2000-2005)[2]	0.0%	0.0%
Bellambi Lane[3]	Bellambi-E Of Old Princes Hwy	NDE Modelling	1.0%	1.0%

[1] Light Vehicle % growth assumed to be as per AADT 2000-2006, however heavy vehicle growth is assumed to be higher in the same ratio as the rates for the Sydney-Wollongong Corridor Strategy.
[2] AADT data showed fluctuating volumes with a general decline, a 0% growth was assumed instead.
[2] Growth rate applies from 2009.

The above identified growth rates have been applied to the original traffic counts obtained at each of the key intersections in order to establish the future base scenario for year 2020. The full results of this analysis is presented in **Appendix A** of this report.

3.3 Current WCL Operations

The existing WCL operations have been reviewed and incorporated into the analysis in order to establish a base trip generation scenario for comparison purposes. The operational hours of coal logistics between WCL and PKCT are as follows;

> Total of 6 days a week (Monday to Saturday) between 7:30am to 8:30pm (13 hours).

In order to establish the number of trucks that operate between WCL and PKCT each day and the fleet configuration, a logistics and haulage summary sheet was used from WCL. This summary sheet records the departure times of each truck from WCL and the gross weight of each truck (indicative of the type of truck used). The following table summarises the results obtained from a logistics summary sheet for a 5 day period between 17th to 22nd March 2014.

Table 3-2 Existing Fleet Configuration and Two-way Trips between WCL and PKCT

Date	Total Number of Trucks Working	Total Number of two-way Trips between WCL and PKCT		
		B-doubles	Truck and Dog	Semi-Trailers
17-Mar	15	79	17	64
18-Mar	15	71	26	43
19-Mar	14	76	24	44
21-Mar	16	85	17	68
22-Mar	17	38	6	59
Average (rounded up)	**16**	**70**	**18**	**56**

From the results presented above, it is evident that there are some variations, in each day, to the total number of trucks used, the overall fleet configuration and the number of two-way trips between WCL and PKCT. As such, the average values established above have been used, for the purposes of this analysis.

The following table presents a summary of the total number of two-way trips carried out each day by each type of truck. These values have subsequently been converted to Passenger Car Unit (PCU) equivalents for SIDRA analysis purposes.

Table 3-3 Number of Trips by Truck Type

Truck Type	Total Number of two-way Trips between WCL and PKCT	PCUs*
B-Double	70	210
Truck and Dog	18	54
Semi-Trailers	56	168
Total	**144**	**432**

*Passenger Car Units (PCUs) – These are units that enable an equivalence to be made between cars and heavy vehicles. In this case: Car = 1 PCU, Articulated Vehicles = 3 PCU's.

As per the results presented in the table above, the total of 144 two-way trips undertaken by the existing fleet translates to a total of 432 PCU two-way trips (per day). As such, on average, there are 432 PCU two-way trips between WCL and PKCT each day across the typical 13 hour day at WCL (7:30am to 8:30pm). This equates to a total of 34 two-way PCU trips per hour on average, i.e.: 17 PCU vehicles per hour (one-way) from 7:30am to 8:30pm between Monday to Saturday, each week.

3.4 Overview of Traffic Assessment

The RMS Guide to Traffic Generating Developments (Version 2.2, 2002) provides a guide in assessing level of service for various intersections. An extract of the guide is shown below in **Table 3-4** and highlights the key indicators in evaluating intersection performance.

Table 3-4 Level of Service Summary

LOS	Traffic Signal / Roundabout	Give Way / Stop Sign / T-Junction Control
A	Good operation	Good operation
B	Good operation, with acceptable delays and spare capacity	Acceptable delays and spare capacity
C	Satisfactory	Satisfactory, but accident study required
D	Operating near capacity	Near capacity and accident study required
E	At capacity; at signals, incidents will cause excessive delays	At capacity, requires other control mode
F	Unsatisfactory and requires additional capacity. Roundabouts require other control mode	Unsatisfactory and requires additional capacity. Roundabouts require other control mode

For signalised intersections, the overall level of service should be considered. For roundabouts and priority controlled intersections (sign control) individual lanes should be analysed.

The Average Vehicle Delay (AVD) provides a measure of performance, relating average delay to the level of service, and should be taken as a guide only. The average delay measures level of service based on delay per second per vehicle.

The *RMS Guide to Traffic Generating Developments* identifies the key criteria in assessing the level of service based on average delays and can be seen in **Table 3-5** below.

Table 3-5 Level of Service Average Vehicle Delay

LOS	Average Delay per Vehicle (sec/veh)
A	< 14
B	15 to 28
C	29 to 42
D	43 to 56
E	57 to 70
F	> 70

Another form of operational measurement is to assess the Degree of Saturation (DoS) of individual intersections. An intersection at DoS of up to 0.8 is considered satisfactory. Intersections are reaching capacity as the DoS approaches 0.9, with queue lengths increasing and extended delays.

3.5 Year 2020 – Future Base Scenario SIDRA Assessment Results

The background traffic growth rates established in the previous assessment (presented in Section 3.2) were applied to the intersection traffic counts. It is noted that the truck traffic volumes generated from the existing operations of WCL (17 PCUs) were removed from each of the movement, prior to the application of the growth rates (as WCL has been in operation during the periods the traffic counts were obtained). Subsequently, these truck traffic volumes were added on to the respective movements in order to establish the 2020 future baseline scenario.

The following table presents SIDRA modelling results for the key intersections assessed. Full SIDRA modelling outputs are presented in **Appendix B** of this report.

Table 3-6 SIDRA Intersection Performance Results for Year 2020 Base Scenario (1Mtpa Scenario)

Intersection	Control	2020 AM Peak			2020 PM Peak		
		Avg Delay (sec)	Queue Length (m)	LoS	Avg Delay (sec)	Queue Length (m)	LoS
Bellambi Lane/Princes Highway	Signalised	18.0	50.3	B	18.5	54.1	B
Bellambi Lane/Memorial Drive	Signalised	26.7	171.3	B	25.2	227.8	B
Masters Rd/ Springhill Rd	Signalised	30.8	274.7	C	32.0	139.7	C
Springhill Rd/ Tom Thumb Rd	Signalised	14.5	186.6	A	17.2	118.6	B
Springhill Rd/ Port Kembla Rd	Signalised	5.3	20.4	A	10.3	50.0	A

As per the performance results illustrated in the table above, it is evident that at 2020 base scenario, all the key intersections operate satisfactorily with minimal delays and satisfactory level of service during each peak hour period. The following sections describe, in detail, the operational performance of each intersection in 2020 base scenario.

3.5.2 Bellambi Lane/Princes Highway

This intersection operates at Level of Service (LoS) B with average delays of 18-19 seconds per vehicle, during both AM and PM peak hour periods. There are minimal delays on all movements during both peak periods. The maximum queue length in the AM peak was 50.3m on Princes Highway north for the through movement. The maximum queue length in the PM peak was 54.1m for the through movement from the Princes Highway south.

3.5.3 Bellambi Lane/Memorial Drive

This intersection operates at LoS B during both AM and PM peak periods with average delays of 27 seconds and 25 seconds per vehicle during the AM and PM peak periods respectively.

As detailed in **Appendix B** during the AM peak, the critical movement is the right turn from the Memorial Drive northbound approach on to Bellambi Lane with delays of 49 seconds. The PM peak critical movement is the right turn from the southbound approach of Memorial Drive, with delays of 59 seconds per vehicle. The maximum queue length was 171m on Northern distributor north for through movements during the AM peak and 228m on Memorial Drive south for through movements during the PM peak.

3.5.4 Springhill Road/Masters Road

This intersection operates at LoS C during both peak periods with average delays of 30- 32 seconds per vehicle during the AM and PM peak periods. As presented in **Appendix B** the critical movement during both peak periods is the right turn from Springhill Road north into Masters Road, with delays of 73 seconds and 52 seconds per vehicle during the AM and PM peak hours respectively. The maximum queue length observed during both peak periods were on Springhill Road south for the through movement, with 275m and 140m queues during AM and PM peaks respectively.

3.5.5 Springhill Road/Port Kembla Road

This intersection operates satisfactorily at LoS A and LoS B, during AM and PM peak hours respectively. There are minimal delays on all movements during both peak periods.

3.5.6 Springhill Road/Tom Thumb Road

This intersection operates satisfactorily with LoS A during both AM and PM peak hours. There are minimal delays and queuing on all movements during both peak periods.

4 Impacts of the Proposed Expansion of Operations on Intersection Level of Service

This section of the report provides an assessment for traffic impacts, on key intersections, associated with changes to the delivery hours, fleet configuration and gross annual haulage of coal, by road from the Russell Vale Colliery to PKCT for 2015 (base year with current 1Mtpa mine operations) and for the future year of 2020 (future base year with 1Mtpa existing mine operations) and 2020 (with proposed expansion to 3Mtpa) scenarios.

4.1 Details of the Proposed Expansion of Operations

Russel Vale Colliery currently produces approximately 1 Mtpa and is proposing to further develop the mine in phases to the production target of 3 Mtpa over a 5 year period. The proposed expansion is anticipated to commence in 2015 and the production levels will be gradually ramped up to reach the target of 3Mtpa by 2020.

The existing operations at Russell Vale Colliery at 13 hours haulage period over 6 days every week (Monday to Saturday) is proposed to change to 15 hours per day Monday to Friday, 7am to 10pm, and 10 hours per day Saturday and Sunday, 8am to 6pm, (referred to as 15/5-10/2 operations) delivering approximately 3Mtpa.

Currently, the fleet at WCL includes a mix of B-Doubles, Truck and Dogs and Semi-trailers. However, by 2020, the fleet at WCL is expected to be entirely comprised of B-Double vehicles with a net capacity of 38 tonnes of product coal.

4.2 Traffic Generation from the Proposed Operations

The total traffic generation from the proposed expansion of operations at WCL can be calculated as follows;

Table 4-1 Anticipated Traffic Generation from the Proposed Expansion in Operations at WCL

Item	Quantity	Comments
Total operating hours per week	95	15/5-10/2 operations
Weeks per year	50	In line with assumptions adopted in the previous study
Total operating hours per year	4,750	
Total coal haulage per annum	3,000,000 tonnes	Proposed expansion
Average coal haulage per hour	631.6	tonnes/hour
Vehicle capacity (tonnes)	38 tonnes	All B-Double vehicles
Total vehicles per hour (one-way)	17	
Total PCUs (post-expansion) per hour (one-way)	50	Passenger Car Units (1 AV = 3 PCU's)
Total PCUs (existing operations) per hour (one-way)	17	
Net additional PCUs (post-expansion) per hour (one way)	33	

The above determined number of net additional PCUs (33 vehicles per hour in each direction between WCL and PKCT) were added to the movements that lie along the haulage route, at each intersection assessed.

4.3 SIDRA Intersection Assessment for Year 2020 - Post Expansion Operations

The table below presents the SIDRA modelling results for the key intersections assessed to determine the operations after the proposed expansion in operations at WCL. The full SIDRA results for each of these intersections can be found in **Appendix C** of this report.

Table 4-2 SIDRA Intersection Performance Results for Year 2020 Post Expansion Scenario

Intersection	Control	2020 AM Peak			2020 PM Peak		
		Avg Delay (sec)	Queue Length (m)	LoS	Avg Delay (sec)	Queue Length (m)	LoS
Bellambi Lane/Princes Highway	Signalised	18.2	50.3	B	18.8	54.1	B
Bellambi Lane/Memorial Drive	Signalised	26.7	171.3	B	25.2	227.6	B
Masters Rd/ Springhill Rd	Signalised	32.1	286.8	C	32.4	139.7	C
Springhill Rd/ Tom Thumb Rd	Signalised	15.0	193.7	B	17.8	124.3	B
Springhill Rd/ Port Kembla Rd	Signalised	6.8	22.6	A	11.1	50.0	A

As per the performance results illustrated in the table above, it is evident that at 2020 post-expansion scenario, all the key intersections continue to operate satisfactorily with minimal delays and satisfactory level of service during each peak hour period. The following sections describe, in detail, the operational performance of each intersection in 2020 post-expansion scenario.

4.3.2 Bellambi Lane/Princes Highway

This intersection operates at LoS B with average delays of 18-19 seconds per vehicle, during both AM and PM peak hour periods – in line with the baseline performance. The delays are minimal on all movements during both peak periods and the maximum queue lengths occur along the same movements identified in the baseline scenario.

4.3.3 Bellambi Lane/Northern Distributor

This intersection operates at LoS B during both AM and PM peak periods – in line with the LoS of the baseline scenario performance. It is noted that the average delays and the queue lengths are only marginally increased compared to the baseline scenario, for both peak periods.

4.3.4 Springhill Road/Masters Road

This intersection operates at LoS C during both peak periods with average delays of 30- 32 seconds per vehicle during the AM and PM peak periods. The delays and queue lengths at this intersection have only marginally increased while the LoS is maintained at the same level when compared to the baseline scenario during both peak periods.

4.3.5 Springhill Road/Port Kembla Road

This intersection operates satisfactorily at LoS B, during both AM and PM peak hours. There are minimal delays and queuing on all movements during both peak periods. It is noted that the LoS of this intersection, during the AM peak, has weakened from LoS A in the baseline scenario to LoS B in the post-expansion scenario. This minor drop in LoS is attributable to the marginal increase in average delay associated with the increased traffic levels arising from the proposed expansion of the coal mining operations. However, this intersection is still operating at a satisfactory LoS with minimal delays and queuing.

4.3.6 Springhill Road/Tom Thumb Road

This intersection operates satisfactorily with LoS A during both AM and PM peak hours. There are minimal delays and queuing on all movements during both peak periods. The average delay and queuing has only marginally increased due to the traffic impacts arising from the subject proposal.

4.4 Conclusion

On the basis of the assessment undertaken, the impact of hauling coal at up to 3 Mtpa in 2020 is not considered to have any significant impact on the operation of the intersections along the haulage route. All intersections operate at an acceptable level of service with only marginal difference to one intersection from the 2020 base case.

5 Impacts of the Proposed Expansion of Operations on Midblock Carriageway Level of Service

As a part of this assessment, the traffic impacts, arising from the proposed expansion in WCL mining operations, on mid-block carriageway LoS along each key mid-block section of the haulage route has been assessed.

As a mid-block measure, LoS is a qualitative description of the operational conditions on a road and their perception by a driver. The capacity of major streets within an urban area can be based on an assessment of their operating LoS. LoS is defined by AUSTROADS (1988) as a qualitative measure of the effects of a number of features, which include speed and travel time, traffic interruptions, freedom to manoeuvre, safety, driving comfort and convenience, and operating costs. LoS are designated from ‘A’ to ‘F’ from best (free flow conditions) to worst (forced flow with stop start operation, long queues and delays) as defined in **Table 5-1**.

5.1 Mid-block Capacity of Urban Roads

The typical capacity of urban lanes with interrupted flow is provided in **Table 5-1** for each LoS, as defined in the RTA Guide to Traffic Generating Developments. These capacities may increase when priority is given to the major traffic flow at intersections or if there is flaring at intersections to accommodate more traffic. The spacing of intersections will differ with the hierarchy and function of the road.

Table 5-1 Mid-block Level of Service and Capacity

LoS	Description	Hourly flow (vehicles)	
		1 Lane	2 Lanes
A	**Free flow** - A condition of free flow in which individual drivers are virtually unaffected by the presence of others in the traffic stream. Freedom to select desired speeds and to manoeuvre within the traffic stream is extremely high, and the general level of comfort and convenience provided is excellent.	200	900
B	**Stable flow** (**slight delays**) - In the zone of stable flow and drivers still have the reasonable freedom to select their desired speed and to manoeuvre within the traffic stream, although the general level of comfort and convenience is a little less than with LOS A.	380	1400
C	**Stable flow (acceptable delays)** - Also in the zone of stable flow, but most drivers are restricted to some extent in their freedom to select their desired speed and to manoeuvre within the traffic stream. The general level of comfort and convenience declines noticeably at this level.	600	1800
D	**Approaching unstable flow (tolerable delays) -** Close to the limit of stable flow and is approaching unstable flow. All drivers are severely restricted in their freedom to select their desired speed and to manoeuvre within the traffic stream. The general level of comfort and convenience is poor, and small increases in traffic flow will generally cause operational problems.	900	2200
E	**Unstable flow (congestion; intolerable delays) -** Occurs when traffic volumes are at or close to capacity, and there is virtually no freedom to select desired speeds or to manoeuvre within the traffic stream. Flow is unstable and minor disturbances within the traffic stream will cause break-down.	1400	2800
F	**Forced flow (jammed)**	>1400	>2800

Source: RTA Guide to Traffic Generating Developments

A service volume, as defined by AUSTROADS (1988), is the maximum number of vehicles that can pass over a given section of roadway in one direction during one hour while operating conditions are maintained at a specified LoS. It is suggested that ideally arterial and sub-arterial roads should not exceed service volumes at LoS 'C'. At this level, whilst most drivers are restricted in their freedom to manoeuvre, operating speeds are still reasonable and acceptable delays experienced. However, in urban situations, arterial and sub-arterial roads operating at LoS 'D' are still considered adequate. It is acceptable to provide road capacity at LoS 'D' in the peak hour since overprovision of road capacity is not conducive to promoting alternative transport modes to the car. The LoS for uninterrupted flow conditions along urban roads is identified in **Table 5-2**.

Table 5-2 Uninterrupted Flow Conditions along Urban Roads Level of Service *

Description	LEVEL OF SERVICE					
	A	B	C	D	E	F
2 Lane Undivided (2U)	760	880	1000	1130	1260	Forced Flows
2 Lane with Clearways and limited access (2CL)	1010	1170	1330	1500	1680	
4 Lane Undivided (13m) (4U)	1260	1470	1680	1890	2100	
4 Lane Undivided with Clearways (4UC)	1510	1760	2010	2270	2520	
4 Lane Divided with Clearways (4DC)	1600	1860	2130	2400	2660	
4 Lane Divided with Clearways, limited access / intersections(4DCL)	2250	2620	3000	3380	3740	
6 Lane Undivided (6U)	2020	2350	2690	3020	3360	
6 Lane Divided with Clearway (6DC)	2440	2840	3250	3660	4060	
6 Lane Divided with Clearways, limited access / intersections (6DCL)	3375	3930	4500	5070	5610	

* One Way Hourly Volumes

5.2 Mid-block Traffic Impacts from the Proposal

The peak hour projected carriageway traffic volumes for future year 2020 has been established as a part of the intersection assessment. The additional traffic volumes generated by the proposal has been added to the mid-block base traffic volumes along the road haulage routes in order to determine the mid-block carriageway Level of Service (LoS) in 2020 for the post-expansion scenario.

The following tables present the mid-block carriageway LoS performance, during each peak period, for the 2020 baseline scenario and 2020 post-expansion scenario. The full mid-block carriageway performance analysis results are presented in **Appendix D**.

Table 5-3 Mid-block Level of Service for 2020 Baseline Scenario

Road	From/ To	AM Peak		PM Peak	
		WCL To PKCT	PKCT to WCL	WCL To PKCT	PKCT to WCL
Bellambi Ln	Princes Hwy to Memorial Drive	A	A	A	A
Memorial Drive	Bellambi Ln to Railway St	C	B	B	C
Masters Rd	M1 to Springhill Rd	A	A	A	A
Springhill Rd	Masters Rd to Port Kembla Rd	A	A	A	A

Table 5-4 Mid-block Level of Service for 2020 Baseline with Expansion Scenario

Road	From/ To	AM Peak		PM Peak	
		WCL To PKCT	PKCT to WCL	WCL To PKCT	PKCT to WCL
Bellambi Ln	Princes Hwy to Memorial Drive	A	A	A	A
Memorial Drive	Bellambi Ln to Railway St	C	B	B	C
Masters Rd	Southern Fwy to Springhill Rd	A	A	A	A
Springhill Rd	Masters Rd to Port Kembla Rd	A	A	A	A

5.3 Conclusion

From the results presented in the tables above, it is noted that there is no change in the mid-block level of service along the haulage routes during the weekday AM peak hour and PM peak hour under the 2020 year post-expansion scenario when compared to the 2020 baseline scenario. As such, the Project is predicted to result in negligible impacts on the mid-block carriageway performance of the road section along the haulage route.

6 Pavement Design Life Assessment for Haulage Route

As a part of this investigation, the impact of the Project on the pavement design life of RMS roads has been assessed. RMS were approached to provide information about the design life of the pavements in question however this information was not available to enable direct calculation of impacts. As a result an estimation has been undertaken in line with the approached summarised below;

1) Obtain from RMS the Annual Average Daily Traffic (AADT) volumes and the percentage heavy vehicles (%HV) for each key road segments within the haulage route;
2) Determine the initial daily Equivalent Standard Axle's (ESAs – the number of standard axle loads which are equivalent in damaging effect on a pavement to a given vehicle or axle loading) as per the following formula from Austroads Guide to Pavement Design 2004;

   Initial Daily ESAs = AADT x F^1 x DIR^2 x %HV

   Note: (1) The Factor F was assumed to be 1.9 across all roads, representing an Urban Road designed for a large volume movement of people and goods;

   (2) It should be noted that the AADT values obtained by RMS are indicative of one-way volumes. Therefore, the directional split (DIR) was assumed to be 1.0.
3) The percentage growth rates presented in **Table 3-1** of this report has been used to establish the cumulative growth factor (CGF). Also, for the purpose of establishing the CGF, a design life of 25 years was assumed for Masters Road and Springhill Road sections, given these roads are designed to carry vehicles in urban arterial conditions. A design life of 40 years has been assumed for Memorial Drive and M1 as these roads are designed to carry vehicles in freeway conditions and a 40 year design life is consistent with current RMS design requirements for roads of this type. The final CGF was determined using the values outlined in Table 7.4 of Austroads Guide to Pavement Design (2004);
4) Establish the design ESAs for each road section along the haulage route by using the following formula;

   ESA (design) = Initial Daily ESA x CGF x 365

Using the above outlined approach, the ESA (design) was estimated for each road section as follows;

Table 6-1 Estimated Design ESAs for each Road Segment

Road	AADT (one-way 2014)	% HV	F - Factor	DIR	Growth Rate	Initial Daily ESAs	Cumulative Growth Factor	Design ESAs
Memorial Drive	17,011	5%	1.90	1	5%	1,616	124.90	125,658,103
M1 Gwynneville	40,742	16%	1.90	1	3%	12,386	75.40	500,502,440
Masters Road	17,362	10%	1.90	1	0%	3,299	25.00	30,348,776
Springhill Road	22,491	10%	1.90	1	0%	4,273	25.00	39,314,268

Subsequently, the above estimated design ESAs were compared against the ESAs arising from both existing and proposed mining operations. The following tables outline the assessment undertaken to establish the ESAs from existing and proposed operations.

Table 6-2 Existing Operations ESAs

	Existing Operations
Existing approved extraction rate per year	1 Mtpa
Weighted average payload based on current fleet	33.22 tonnes
Total number of trucks per year (one-way)	30,103
ESA/truck	7.16* Weighted average of current fleet ESAs (see note below)
ESA's per year (one-way)	215,537
Number of years in proposal	5
Total ESA's from current operations (over 5 years at the existing ESA rate)	1,077,685

Note: The current fleet configuration on average is comprised of 48.6% B-doubles, 12.5% Truck and Dogs and 38.9% Semi-Trailers. *The ESA values for each type of truck are based on the values presented in www.atatruck.net.au (Australian Trucking Association).

Based on the existing operation ESAs identified in the table above, the following table summarises the net additional ESAs that will be imposed on the road sections, along the towards PKCT haulage route, over the next 5 years.

Table 6-3 Proposed Operations ESAs

	Future Operations
Proposed haulage rate per year	3 Mtpa
Payload	38 tonnes
Total trucks per year (one-way)	78,947
ESA/truck	7.71*
ESA's per year (one-way)	608,684
Number of years in proposal	5
Total ESA's from operations (based on uniform ramp up of operations from between 1Mtpa to 3Mtpa over 5 years)	(215,537+608,684) x 0.5 x 5 = 2,060,553
Net additional ESAs due to uniform expansion over 5 years	**2,060,553 – 1,077,685 = 982,868**

*The ESA values for each type of truck are based on the values presented in www.atatruck.net.au (Australian Trucking Association).

As per the net additional ESA levels identified in **Table 6-3** above, these ESAs have been calculated as a percentage of the design ESA of each road pavement along the coal haulage route. These results are summarised in **Table 6-4** below.

Table 6-4 Summary of Additional ESAs from Proposed Operations as a Percentage of Design ESAs

Road	Design ESA: Baseline Scenario	Net Additional ESAs due to the Proposal	Additional ESAs from the Proposal as a % of Design ESA
Memorial Drive	125,658,103	**982,868**	0.78%
M1 Gwynneville	500,502,440		0.20%
Masters Road	30,348,776		3.24%
Springhill Road	39,314,268		2.50%

6.2 Assumptions

There are some significant assumptions in the above calculations, which contribute to the results obtained. These assumptions result as a consequence of incomplete information being available from the RMS regarding the pavement original design life in ESA and include:

- Original design life in years of the pavement in years;
- Predicated heavy vehicle composition of the pavement during design;
- Predicted traffic volume and growth during design;
- F- Factor – being the average number of ESA's per heavy vehicle. The adopted value of 1.9 on the basis of Functional Classification would appear low based on observation of the composition of vehicles across the network under examination; and
- How traffic has tracked in reality against the predictions made when the pavement was first built.

The assessment methodology has estimated factors in order to be able to complete the calculation, however any deviation away from the assumed values can have a marked impact on the results obtained, in particular F-Factor. As such, the results can only be described as indicative.

It is further noted that the calculations undertaken are only relevant for the trip towards PKCT. In the return direction, haulage vehicles are travelling empty and as such the number of ESA per vehicle in the unloaded condition is much lower. As a result, the impacts on pavement design life in the return direction will also be much lower.

6.3 Conclusion

As per the results presented in **Table 6-4**, it is evident that the additional haulage pavement loadings have the most significant contribution to pavement life on Masters Road and Springhill Road, where they will account for an estimated maximum of 3.24% and 2.50% of the design life of the pavement respectively. For the remaining road sections, the additional ESAs from the proposal remain below 1% of the design ESAs.

As a result of the above, it can be concluded that the operation of the additional haulage activity will have a minor increase in the rate of wear or requirement for pavement remediation on pavements along Masters Road and Springhill Road, and a negligible impact on the pavements of the M1 and Memorial Drive.

It should be noted that the assumptions made in quantifying the value of design life used up by the proposal mean that the results are indicative only.

7 Conclusions

This study assesses the proposed changes to existing operations at WCL's Russell Vale Colliery, which includes increasing the coal extraction levels at the Colliery from existing 1 Mtpa up to 3 Mtpa over a 5 year period. As a part of this proposal, it is envisaged to increase the current operational hours (between 7:30am to 8:30pm, Monday to Saturday) of 78 hours a week up to a total of 95 hours a week (15 hours per day Monday to Friday, 7am to 10pm, and 10 hours per day Saturday and Sunday, 8am to 6pm).

As such, this traffic and transport assessment investigated the traffic impacts associated with increasing the current production of 1 Mtpa to achieve a production target of 3 Mtpa.

The key findings of this study are as follows;

> The existing coal haulage operations between WCL and PKCT generate truck movements equivalent to approximately 17 PCU movements (each way) during each hour between 7:30am to 8:30pm, Monday to Saturday;

> The future base 2020 scenario (with WCL haulage as usual) indicates that the key intersections along the haulage route will continue to operate satisfactorily;

> The Project will generate a total of 50 PCU equivalent truck movements per hour;

> Based on the intersection modelling outputs, the hauling operations of up to 3 Mtpa of coal in 2020 is not considered to have any significant impact on the operation of the intersections along the haulage route. All intersections operate at an acceptable LoS, and with only marginal difference to the 2020 base case;

> It is noted that there is no change in the mid-block LoS along the haulage routes during the weekday AM peak hour and PM peak hour under the 2020 year post-expansion scenario when compared to the 2020 baseline scenario. As such, the Project results in negligible impacts on the mid-block carriageway performance of the road section along the haulage route;

> Pavement life reduction as a result of the proposal has estimated to vary from between 3.24% on Masters Road to 0.2% on the M1 in the towards PKCT direction, however the estimation of significant variables in the calculation mean that the results are considered indicative.

Overall the assessment has shown that expansion of operations to cover 3 Mtpa of coal haulage will have acceptable impacts on the road network, and as a result the proposal is supported from a traffic perspective.

Appendix A

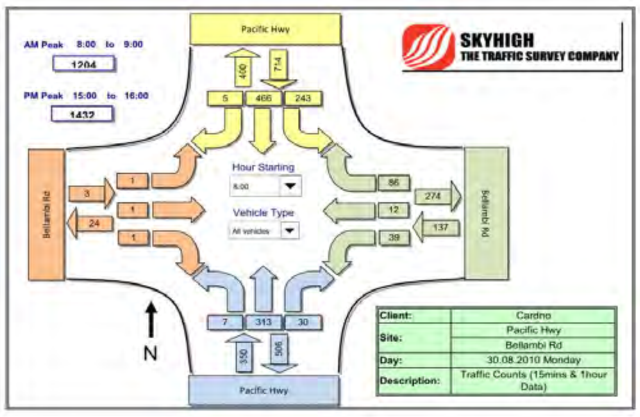
Mid-block Carriageway Performance Analysis

Legend

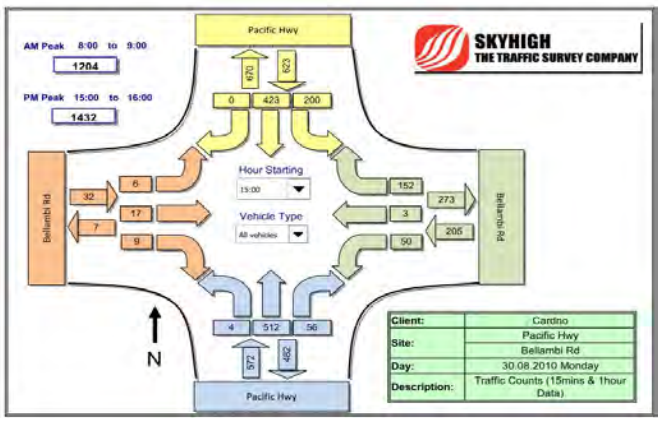
Midblock Traffic Volumes	(yellow)
Approaches to which a Growth Factor has been Applied	(green)
Movements that include NRE Trucks	(red)

2010 - Bellambi Lane/Princess Highway - Intersection Traffic Counts

AM Peak



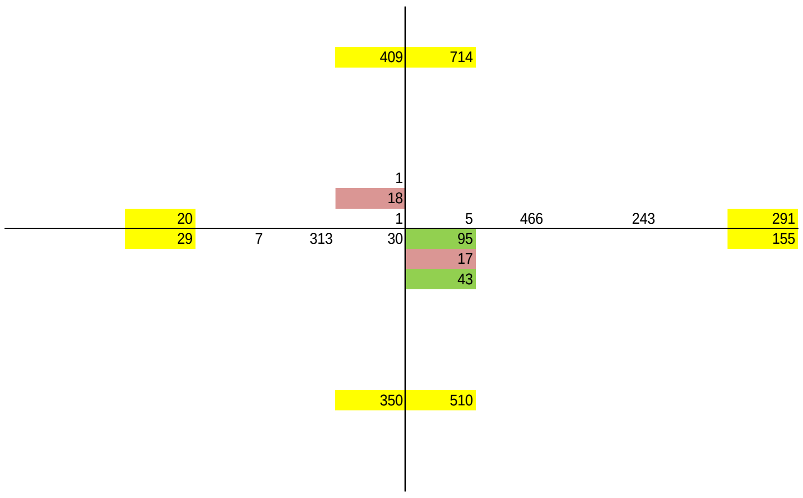
PM Peak

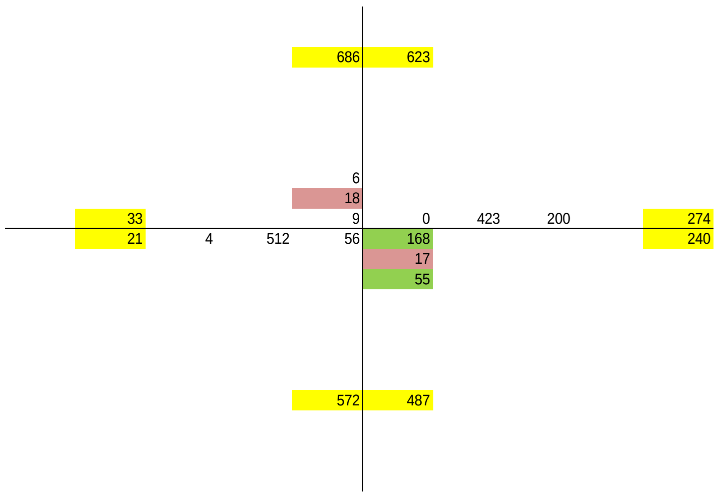


Existing truck movements in PCUs 17 One-way

Scenario 1 - Future Base

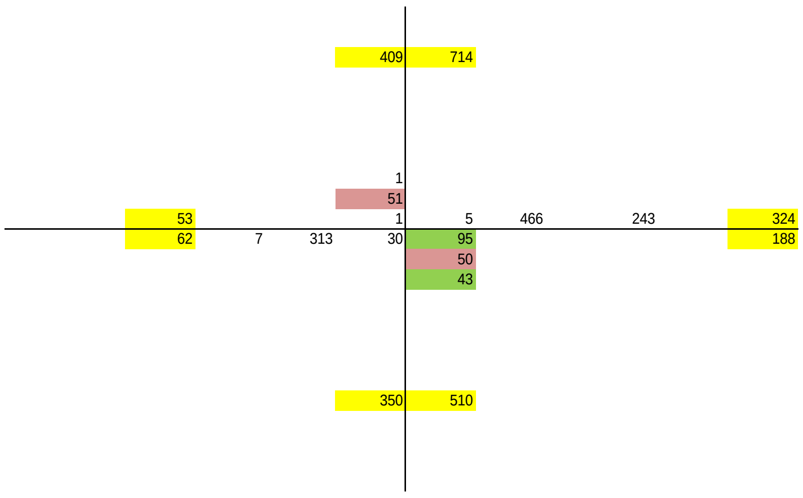
Year	2020
Years from Count	10
Growth on Bellambi Lane - East	1%
Growth on ND - south of Bellambi Lane	5%

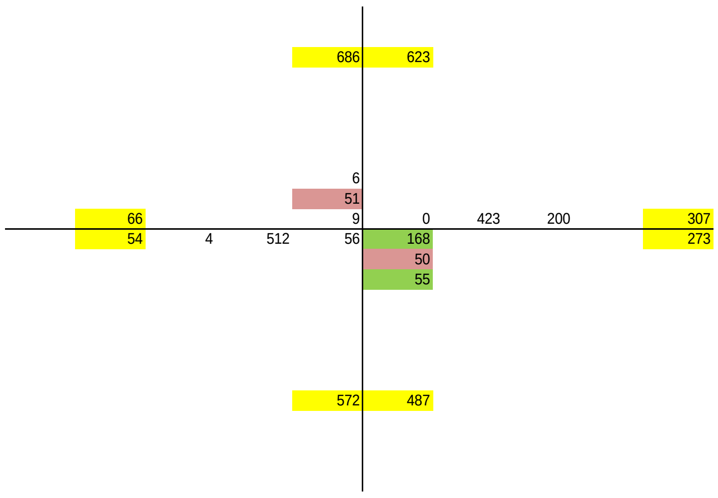




Scenario 2 - Future Base + Expansion

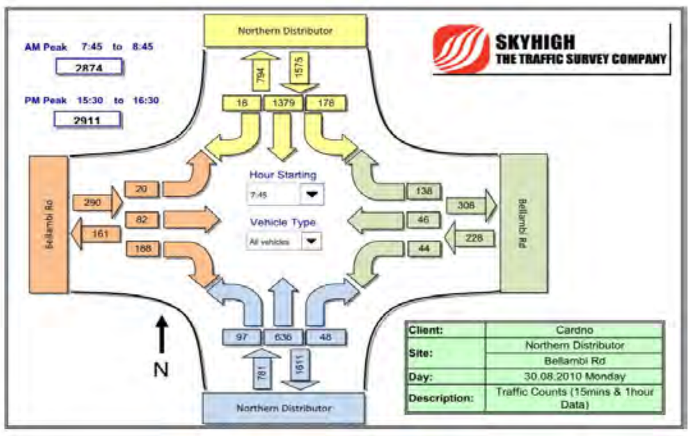
Year	2020	Number of truck movements after expansion, in PCUs	50 one-way
Years from Count	10	Existing truck movements in PCUS	17 one-way
Growth on Bellambi Lane - East	1%	Net additional truck movements	33 one-way
Growth on ND - south of Bellambi Lane	5%		



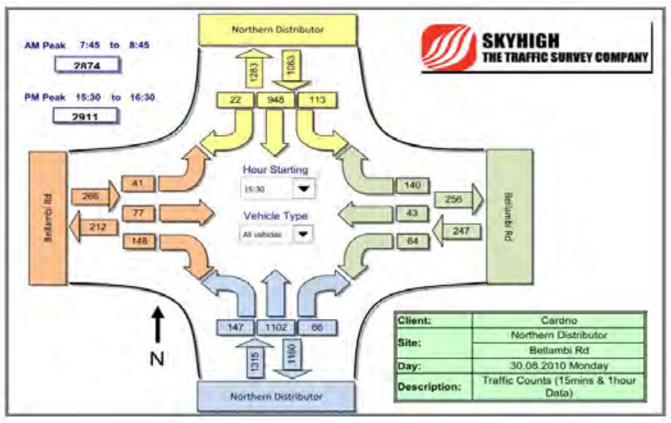


2010 - Bellambi Lane/Northern Distributor - Intersection Traffic Counts

AM Peak



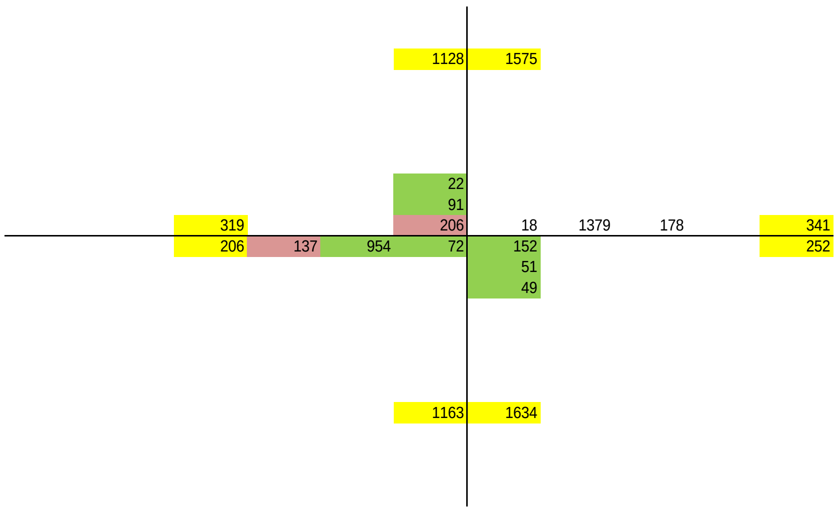
PM Peak

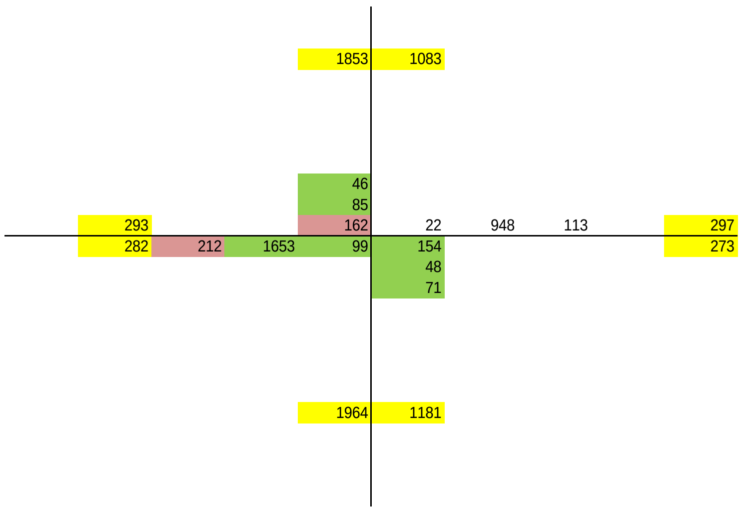


Existing truck movements in PCUs 17 One-way

Scenario 1 - Future Base

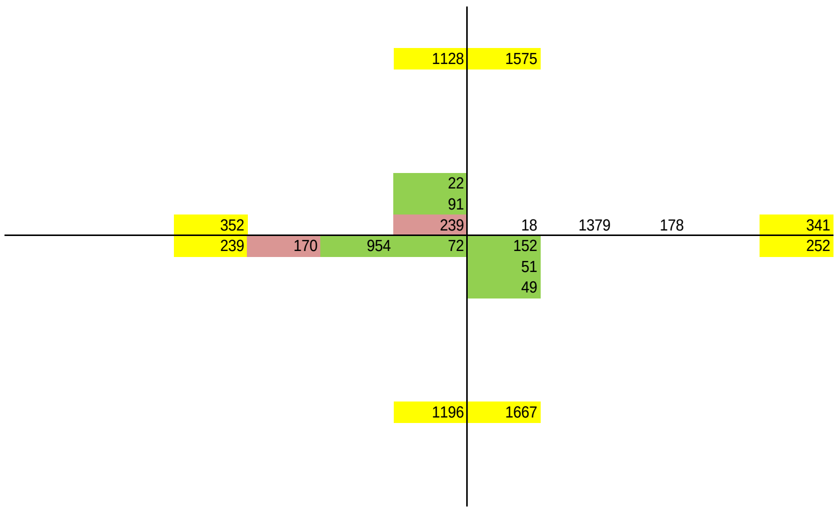
Year	2020
Years from Count	10
Growth on Bellambi Lane - East	1%
Growth on ND - south of Bellambi Lar	5%

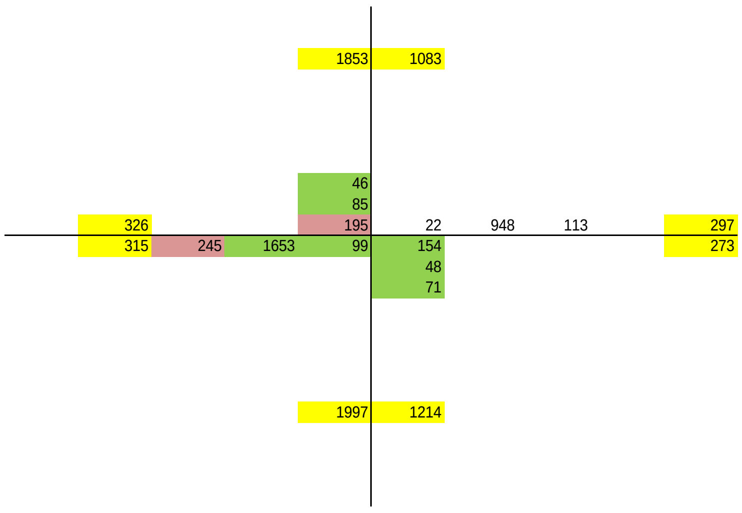




Scenario 2 - Future Base + Expansion

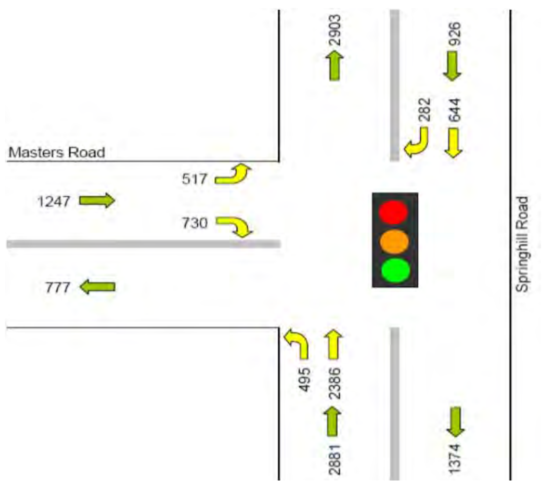
Year	2020	Number of truck movements after expansion, in PCUs	50
Years from Count	10	Existing truck movements in PCUS	17
Growth on Bellambi Lane - East	1%	Net additional truck movements	33
Growth on ND - south of Bellambi Lar	5%		



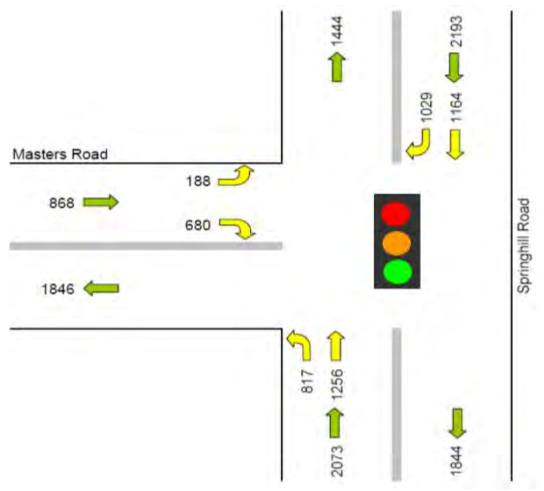


2009 - Springhill Road/Masters Road - Intersection Traffic Counts

AM Peak



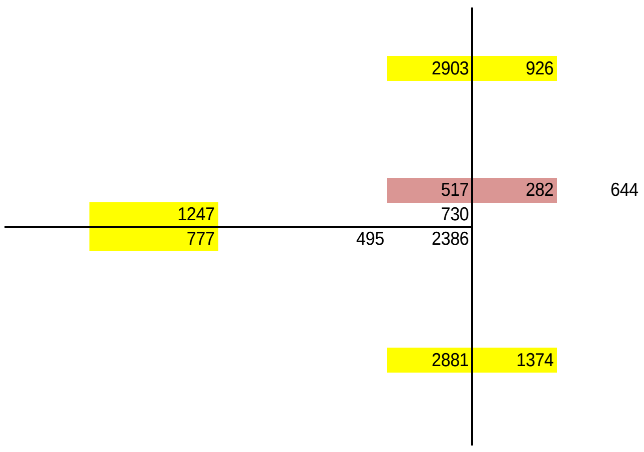
PM Peak

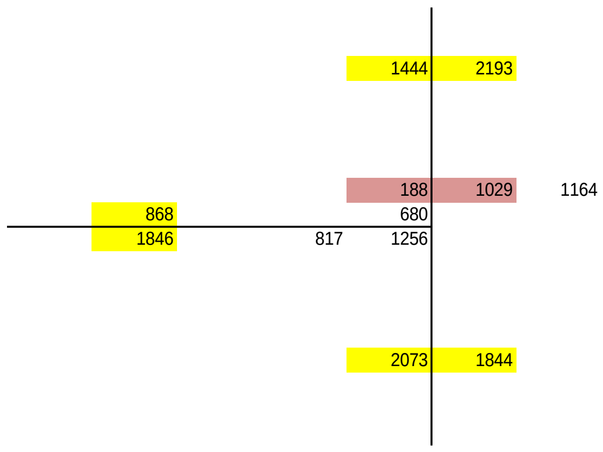


Existing truck movements in PCUs 17 One way

Scenario 1 - Future Base

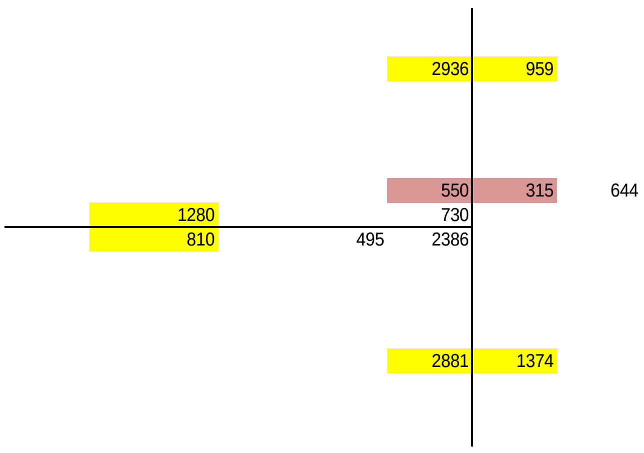
Year	2020
Years from Count	12
Growth on Masters Rd	0%
Growth on Springhill Rd	0%

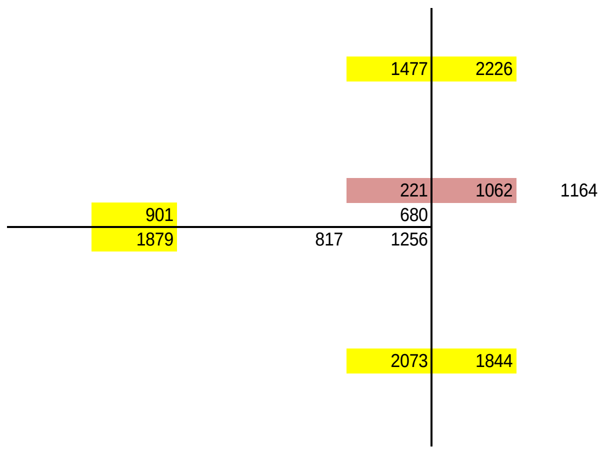




Scenario 2 - Future Base + Expansion

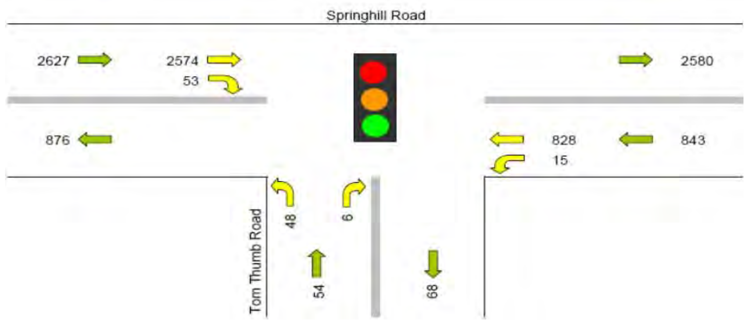
Year	2020	Number of truck movements after expansion, in PCUs	50
Years from Count	12	Existing truck movements in PCUS	17
Growth on Masters Rd	0%	Net additional truck movements	33
Growth on Springhill Rd	0%		





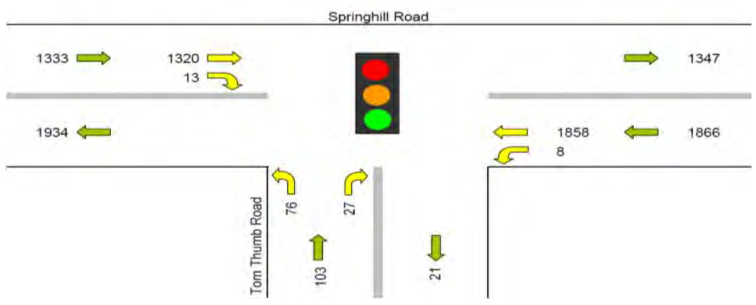
2009 - Springhill Road/Tom Thumb Road - Intersection Traffic Counts

AM Peak



Existing truck movements in PCUs 17 One way

PM Peak



Scenario 1 - Future Base

Year	2020
Years from Count	12
Growth on Tom Thumb Rd	0%
Growth on Springhill Rd	0%

AM Peak:

		2574		
2627		53		2580
876	48	6	828	843
			15	
		54	68	

PM Peak:

		1320		
1333		13		1347
1934	76	27	1858	1866
			8	
		103	21	

Scenario 2 - Future Base + Expansion

Year	2020	Number of truck movements after expansion, in PCUs	50
Years from Count	12	Existing truck movements in PCUS	17
Growth on Tom Thumb Rd	0%	Net additional truck movements	33
Growth on Springhill Rd	0%		

AM Peak:

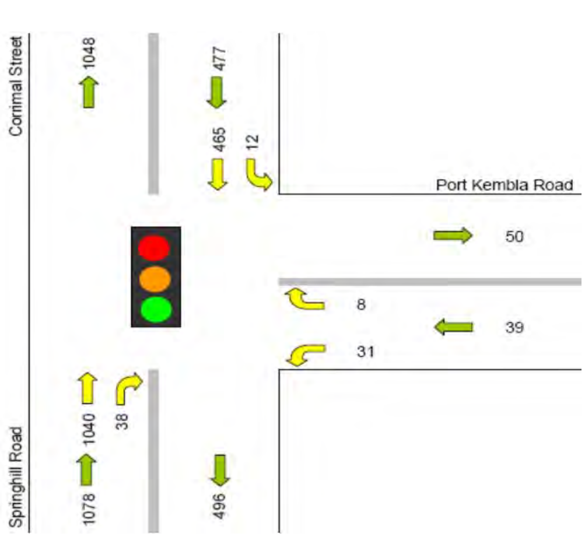
		2607		
2660		53		2613
909	48	6	861	876
			15	
		54	68	

PM Peak:

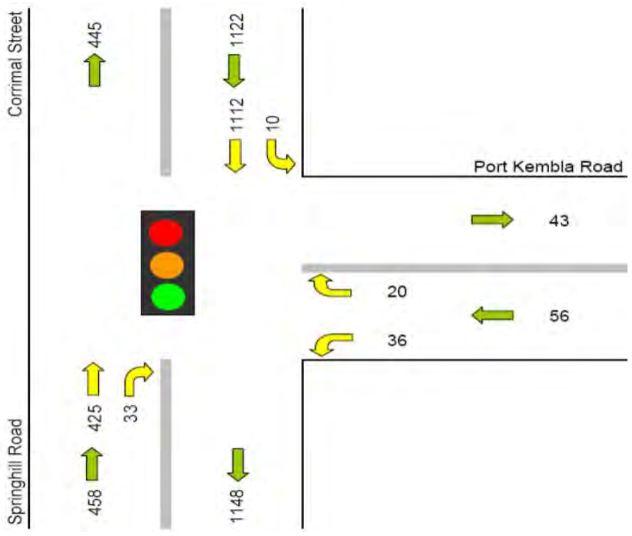
		1353		
1366		13		1380
1967	76	27	1891	1899
			8	
		103	21	

2009 - Springhill Road/Port Kembla Road - Intersection Traffic Counts

AM Peak



PM Peak



Existing truck movements in PCUs 17 Each Way

Scenario 1 - Future Base

Year	2020
Years from Count	12
Growth on Port Kembla Rd	0%
Growth on Springhill Rd	0%

	1048	477		
		465	12	50
1040	38	8		39
		31		
	1078	496		

	445	1122		
		1112	10	43
425	33	20		56
		36		
	458	1148		

Scenario 2 - Future Base + Expansion

Year	2020	Number of truck movements after expansion, in PCUs	50
Years from Count	12	Existing truck movements in PCUS	17
Growth on Port Kembla Rd	0%	Net additional truck movements	33
Growth on Springhill Rd	0%		

	1048	477		
		465	12	83
1040	71	8		72
		64		
	1111	529		

	445	1122		
		1112	10	76
425	66	20		89
		69		
	491	1181		

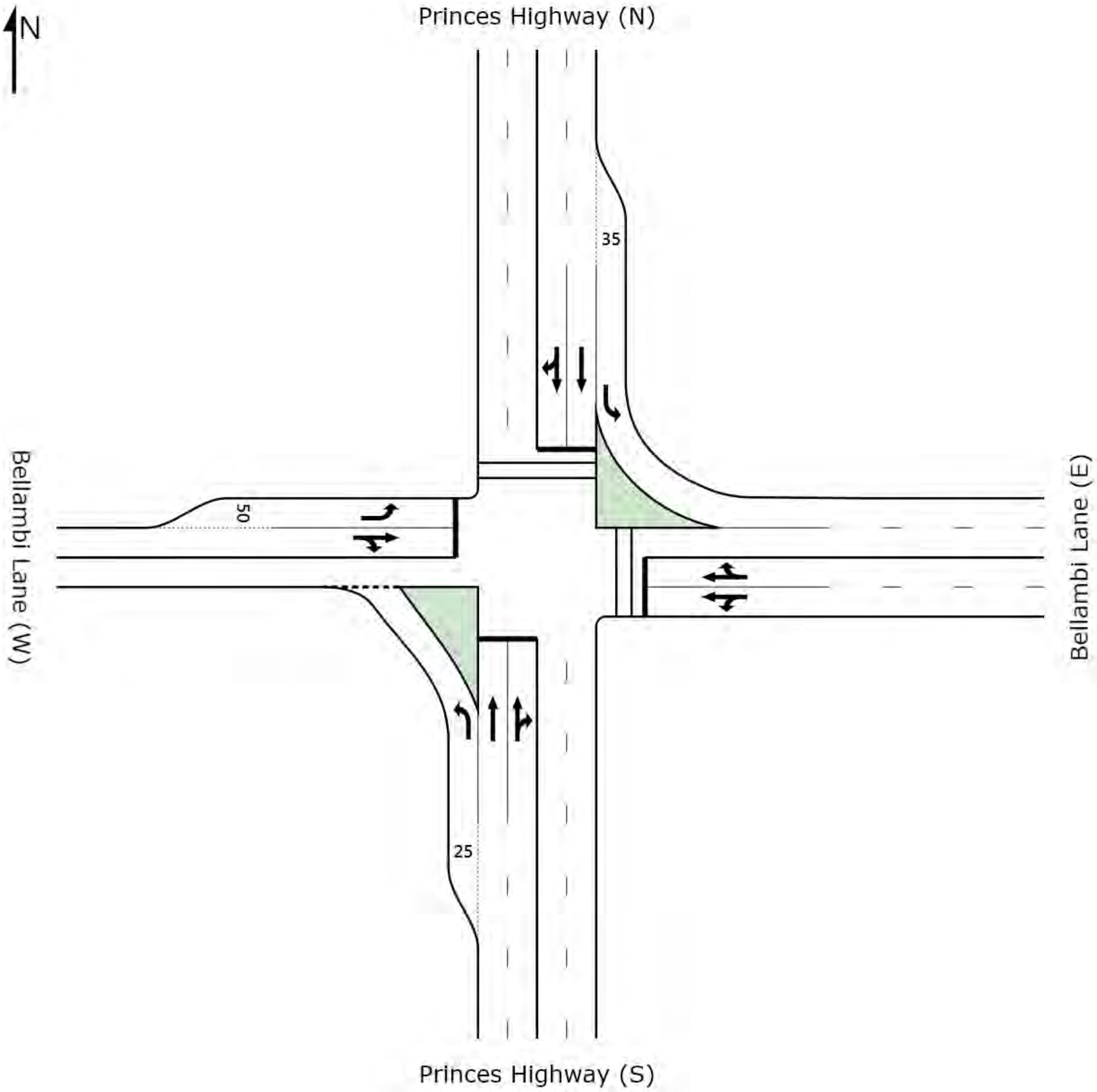
Appendix B

2020 Future Baseline – SIDRA Analysis Results

Cardno
Shaping the Future

2020 Baseline Scenario

Bellambi Lane/Princess Highway



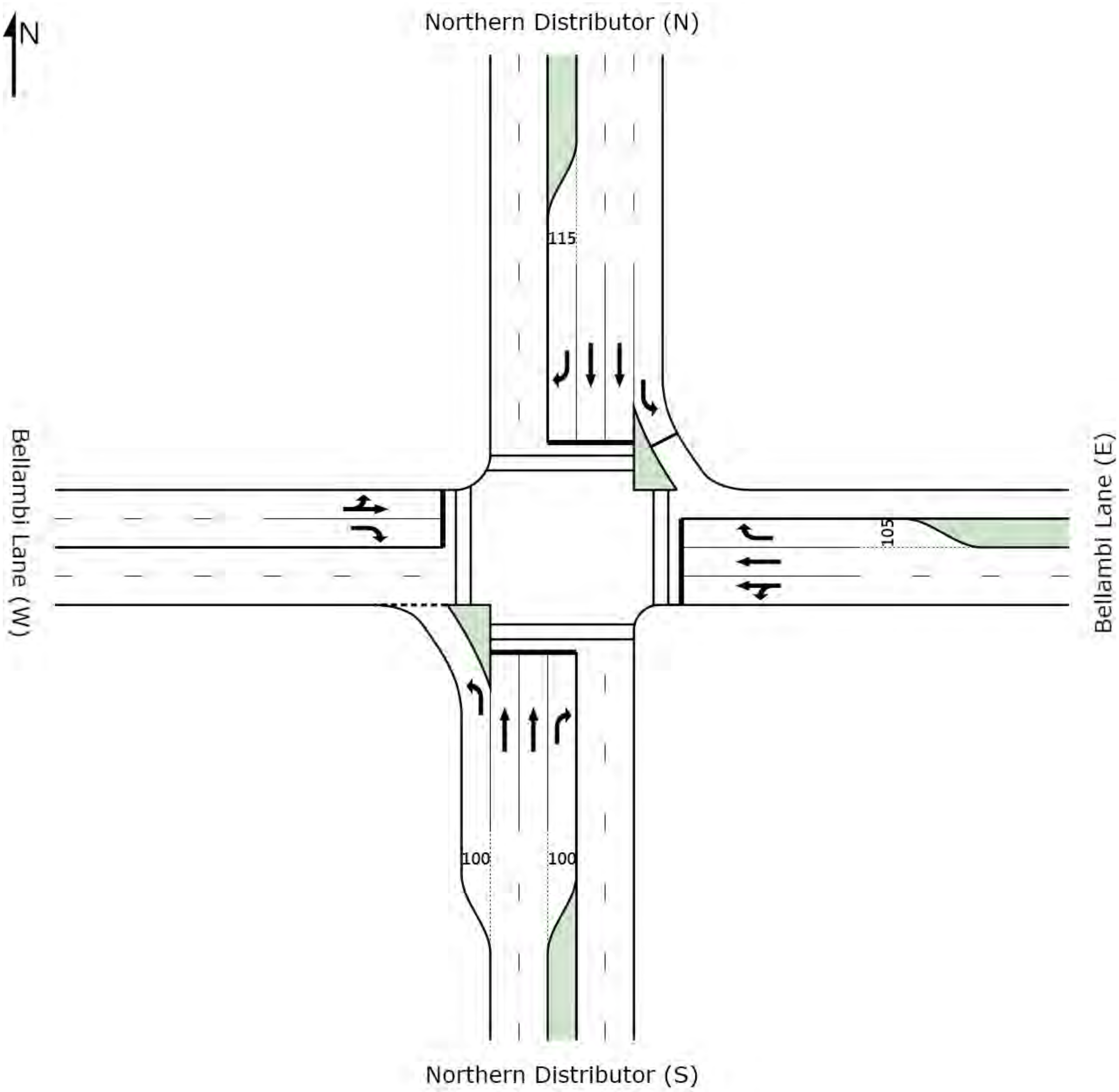
AM Peak

Movement Performance - Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Princes Highway (S)											
1	L	7	28.6	0.009	7.3	LOS A	0.0	0.2	0.18	0.57	48.6
2	T	313	7.3	0.242	14.4	LOS A	4.2	31.4	0.70	0.57	40.7
3	R	30	10.0	0.242	23.9	LOS B	3.5	26.0	0.73	0.86	37.9
Approach		350	8.0	0.242	15.1	LOS B	4.2	31.4	0.69	0.59	40.6
East: Bellambi Lane (E)											
4	L	43	12.8	0.044	15.7	LOS B	0.6	5.0	0.46	0.71	42.3
5	T	17	8.3	0.220	18.5	LOS B	2.6	19.3	0.76	0.66	36.0
6	R	95	8.1	0.220	23.8	LOS B	2.6	19.3	0.76	0.77	36.6
Approach		155	9.5	0.220	21.0	LOS B	2.6	19.3	0.68	0.74	38.0
North: Princes Highway (N)											
7	L	243	2.5	0.133	7.7	X	X	X	X	0.60	49.8
8	T	466	1.9	0.480	24.3	LOS B	7.1	50.3	0.90	0.74	34.1
9	R	5	0.0	0.480	31.6	LOS C	6.9	49.3	0.90	0.86	32.4
Approach		714	2.1	0.480	18.7	LOS B	7.1	50.3	0.59	0.70	38.2
West: Bellambi Lane (W)											
10	L	1	0.0	0.003	28.0	LOS B	0.0	0.2	0.79	0.59	27.2
11	T	18	0.0	0.044	22.9	LOS B	0.5	3.6	0.81	0.57	27.4
12	R	1	0.0	0.044	28.6	LOS C	0.5	3.6	0.81	0.71	27.4
Approach		20	0.0	0.044	23.4	LOS B	0.5	3.6	0.81	0.58	27.4
All Vehicles		1239	4.7	0.480	18.0	LOS B	7.1	50.3	0.63	0.67	38.6

PM Peak

Movement Performance - Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Princes Highway (S)											
1	L	4	25.0	0.005	7.2	LOS A	0.0	0.1	0.18	0.56	48.6
2	T	512	2.5	0.390	15.5	LOS B	7.6	54.1	0.75	0.63	39.7
3	R	56	0.0	0.390	24.7	LOS B	6.1	43.8	0.78	0.86	37.2
Approach		572	2.4	0.390	16.3	LOS B	7.6	54.1	0.75	0.65	39.5
East: Bellambi Lane (E)											
4	L	55	2.0	0.070	17.4	LOS B	1.1	8.0	0.53	0.74	40.8
5	T	17	33.3	0.348	15.9	LOS B	4.3	31.8	0.66	0.60	38.1
6	R	168	5.3	0.348	24.6	LOS B	4.3	31.8	0.80	0.79	35.9
Approach		240	6.5	0.348	22.3	LOS B	4.3	31.8	0.73	0.77	37.1
North: Princes Highway (N)											
7	L	200	2.5	0.110	7.7	X	X	X	X	0.60	49.8
8	T	423	2.1	0.430	24.0	LOS B	6.2	44.3	0.88	0.73	34.4
9	R	1	0.0	0.430	31.2	LOS C	6.2	44.1	0.88	0.86	32.6
Approach		624	2.2	0.430	18.7	LOS B	6.2	44.3	0.60	0.69	38.2
West: Bellambi Lane (W)											
10	L	6	0.0	0.017	28.3	LOS B	0.2	1.1	0.80	0.65	27.1
11	T	18	11.8	0.075	23.3	LOS B	0.7	5.7	0.81	0.60	27.1
12	R	9	11.1	0.075	29.3	LOS C	0.7	5.7	0.81	0.72	27.1
Approach		33	9.4	0.075	25.9	LOS B	0.7	5.7	0.81	0.64	27.1
All Vehicles		1469	3.2	0.430	18.5	LOS B	7.6	54.1	0.68	0.69	38.2

Bellambi Lane/Memorial Drive



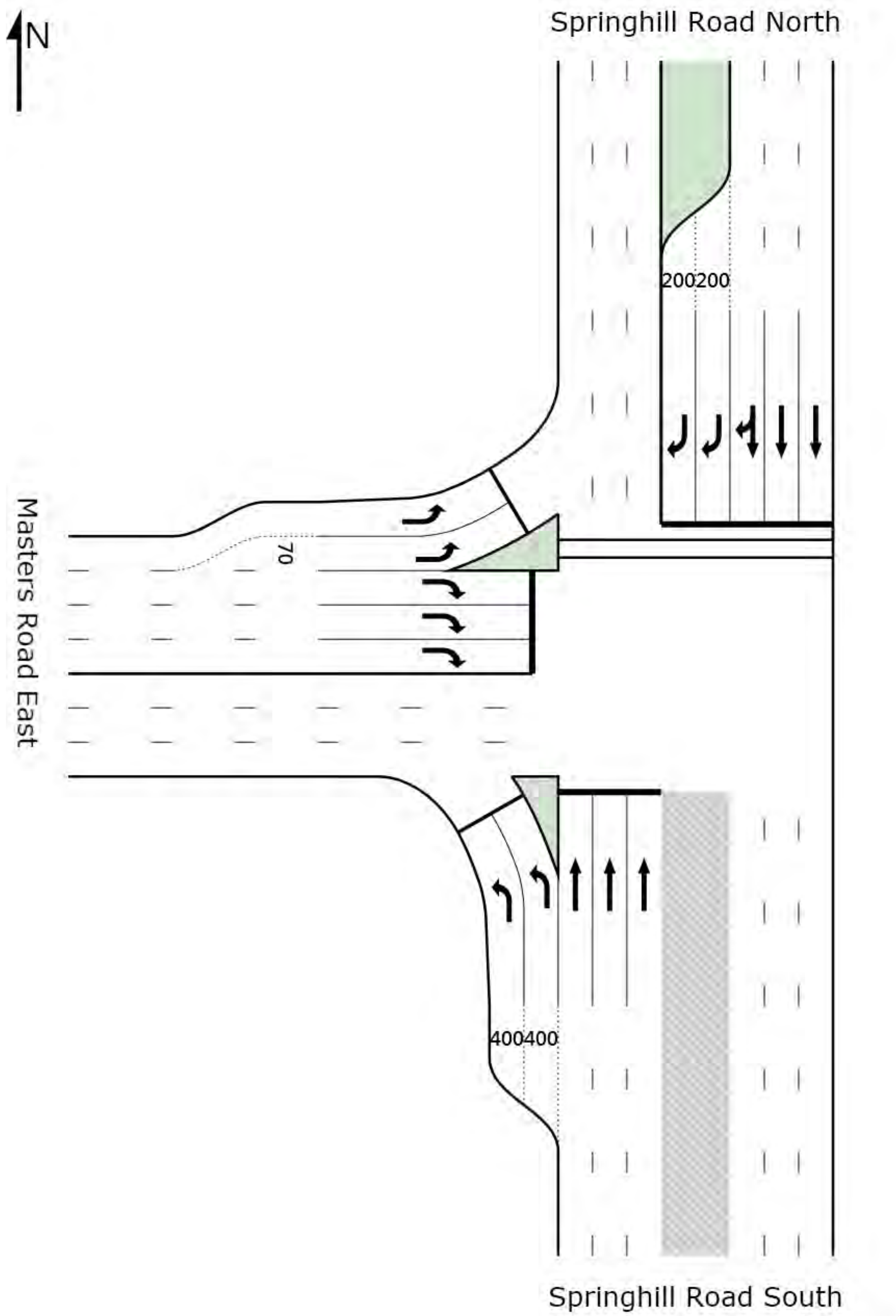
AM Peak

Movement Performance - Vehicles												
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Northern Distributor (S)											
1	L	137	5.2	0.103	10.6	LOS A	0.5	3.7	0.19	0.69	56.2
2	T	954	6.3	0.815	35.0	LOS C	19.3	142.3	0.99	0.95	34.6
3	R	72	12.5	0.620	48.5	LOS D	3.0	23.1	0.97	0.84	28.6
Approach		1163	6.5	0.815	33.0	LOS C	19.3	142.3	0.89	0.91	35.7
East: Bellambi Lane (E)											
4	L	49	11.4	0.120	35.9	LOS C	1.5	11.7	0.82	0.75	33.0
5	T	51	8.7	0.116	26.1	LOS B	1.6	11.9	0.82	0.62	33.4
6	R	152	2.2	0.354	28.0	LOS B	4.3	30.9	0.83	0.77	34.0
Approach		252	5.3	0.354	29.1	LOS C	4.3	30.9	0.83	0.74	33.6
North: Northern Distributor (N)											
7	L	178	2.2	0.188	15.7	LOS B	3.1	22.3	0.56	0.73	42.0
8	T	1379	3.0	0.779	21.4	LOS B	23.9	171.3	0.91	0.85	37.3
9	R	18	27.8	0.086	37.6	LOS C	0.6	5.2	0.88	0.71	29.9
Approach		1575	3.2	0.779	20.9	LOS B	23.9	171.3	0.87	0.83	37.6
West: Bellambi Lane (W)											
10	L	22	20.0	0.255	38.4	LOS C	3.2	24.4	0.85	0.87	30.6
11	T	91	6.1	0.255	29.5	LOS C	3.2	24.4	0.85	0.72	31.3
12	R	206	2.1	0.448	30.7	LOS C	6.1	43.3	0.83	0.80	37.2
Approach		319	4.5	0.448	30.9	LOS C	6.1	43.3	0.84	0.78	34.8
All Vehicles		3309	4.6	0.815	26.7	LOS B	23.9	171.3	0.87	0.85	36.4

PM Peak

Movement Performance - Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Northern Distributor (S)											
1	L	212	6.1	0.159	10.6	LOS A	0.9	6.4	0.17	0.69	56.3
2	T	1653	1.1	0.817	24.6	LOS B	32.2	227.6	0.90	0.88	41.4
3	R	99	3.0	0.305	29.8	LOS C	3.1	22.1	0.77	0.80	37.7
Approach		1964	1.7	0.817	23.3	LOS B	32.2	227.6	0.82	0.86	42.4
East: Bellambi Lane (E)											
4	L	71	3.1	0.141	26.2	LOS B	1.8	13.2	0.78	0.75	37.7
5	T	48	0.0	0.117	31.2	LOS C	1.7	12.0	0.84	0.64	30.9
6	R	154	0.7	0.433	33.7	LOS C	5.3	37.3	0.89	0.78	31.2
Approach		273	1.2	0.433	31.3	LOS C	5.3	37.3	0.86	0.75	32.7
North: Northern Distributor (N)											
7	L	113	5.3	0.156	16.6	LOS B	1.9	13.9	0.63	0.73	41.5
8	T	948	3.2	0.638	24.2	LOS B	17.0	122.1	0.87	0.76	35.9
9	R	22	18.2	0.283	59.0	LOS E	1.0	8.4	1.00	0.69	23.0
Approach		1083	3.7	0.638	24.1	LOS B	17.0	122.1	0.85	0.76	36.0
West: Bellambi Lane (W)											
10	L	46	7.3	0.333	41.5	LOS C	5.0	36.1	0.89	0.81	29.0
11	T	85	2.6	0.333	33.1	LOS C	5.0	36.1	0.89	0.72	29.4
12	R	162	3.4	0.400	35.5	LOS C	5.6	40.5	0.85	0.78	34.4
Approach		293	3.8	0.400	35.8	LOS C	5.6	40.5	0.87	0.77	31.9
All Vehicles		3613	2.4	0.817	25.2	LOS B	32.2	227.6	0.83	0.81	38.4

Masters Road/Springhill Road



AM Peak

Movement Performance - Vehicles

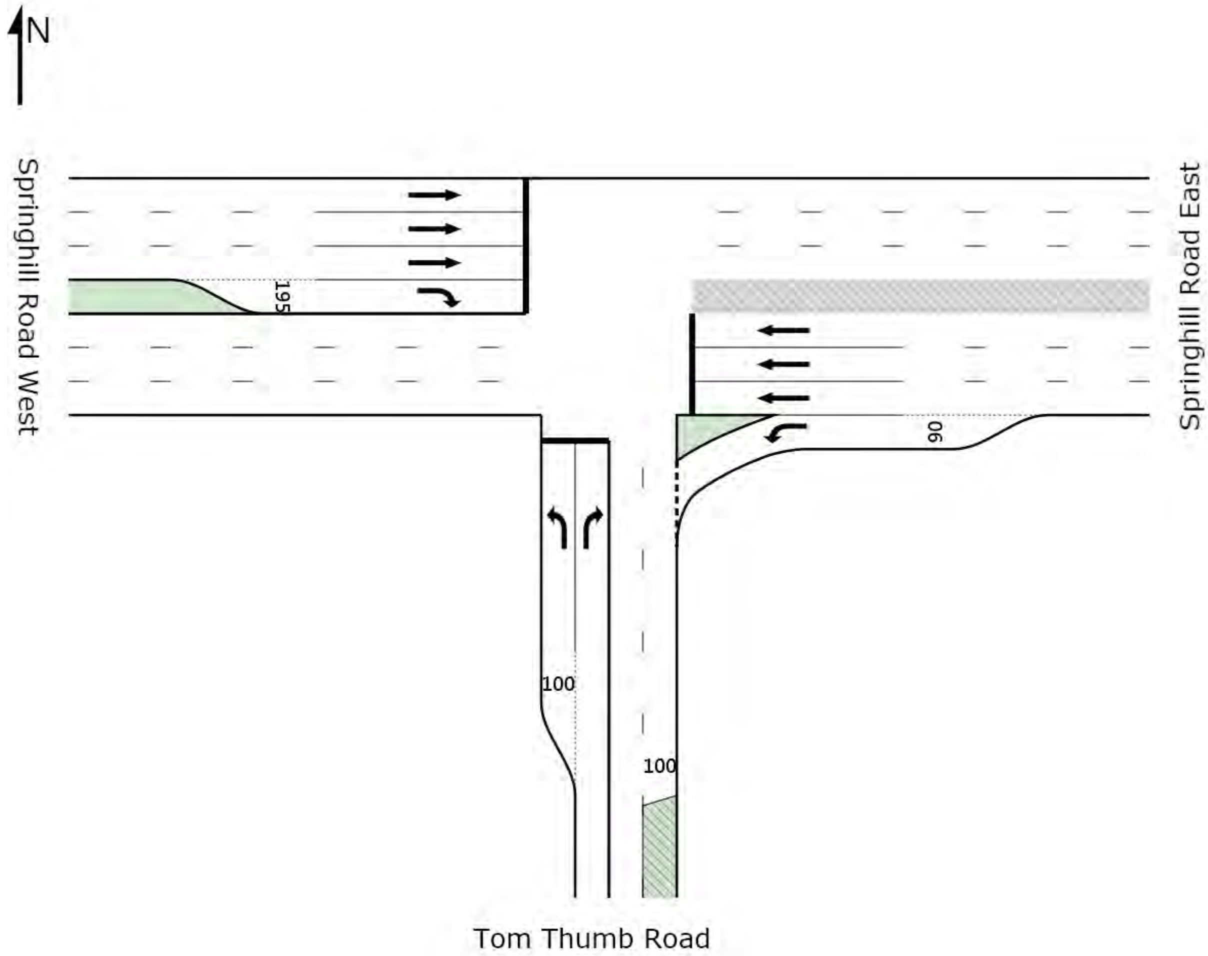
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Springhill Road South											
1	L	495	11.3	0.178	14.0	LOS A	2.9	22.2	0.24	0.73	55.6
2	T	2386	4.8	0.826	26.9	LOS B	37.7	274.7	0.92	0.87	39.9
Approach		2881	6.0	0.826	24.7	LOS B	37.7	274.7	0.80	0.84	42.0
North: Springhill Road North											
8	T	644	12.8	0.277	8.9	LOS A	7.3	56.9	0.46	0.40	59.0
9	R	282	34.2	0.770	73.0	LOS F	5.5	49.9	1.00	0.88	24.0
Approach		926	19.3	0.770	28.4	LOS B	7.3	56.9	0.63	0.55	41.0
West: Masters Road East											
10	L	517	17.3	0.532	39.2	LOS C	14.0	112.5	0.80	0.82	35.6
12	R	730	12.8	0.583	51.6	LOS D	11.7	90.6	0.93	0.83	30.0
Approach		1247	14.7	0.583	46.5	LOS D	14.0	112.5	0.88	0.83	32.1
All Vehicles		5054	10.6	0.826	30.8	LOS C	37.7	274.7	0.79	0.79	38.9

PM Peak

Movement Performance - Vehicles

Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Springhill Road South											
1	L	817	5.1	0.360	19.6	LOS B	8.4	61.6	0.51	0.79	49.1
2	T	1256	3.7	0.825	39.2	LOS C	19.3	139.7	1.00	0.96	33.2
Approach		2073	4.3	0.825	31.5	LOS C	19.3	139.7	0.81	0.89	38.0
North: Springhill Road North											
8	T	1164	4.7	0.543	13.0	LOS A	15.9	115.6	0.67	0.60	52.6
9	R	1029	3.1	0.809	51.7	LOS D	15.8	113.8	1.00	0.92	29.8
Approach		2193	4.0	0.809	31.2	LOS C	15.9	115.6	0.83	0.75	38.8
West: Masters Road East											
10	L	188	18.8	0.123	20.1	LOS B	2.3	18.4	0.45	0.74	49.3
12	R	680	14.4	0.449	39.6	LOS C	8.2	64.2	0.86	0.82	35.2
Approach		868	15.3	0.449	35.4	LOS C	8.2	64.2	0.77	0.80	37.6
All Vehicles		5134	6.0	0.825	32.0	LOS C	19.3	139.7	0.81	0.82	38.3

Springhill Road/Tom Thumb Road



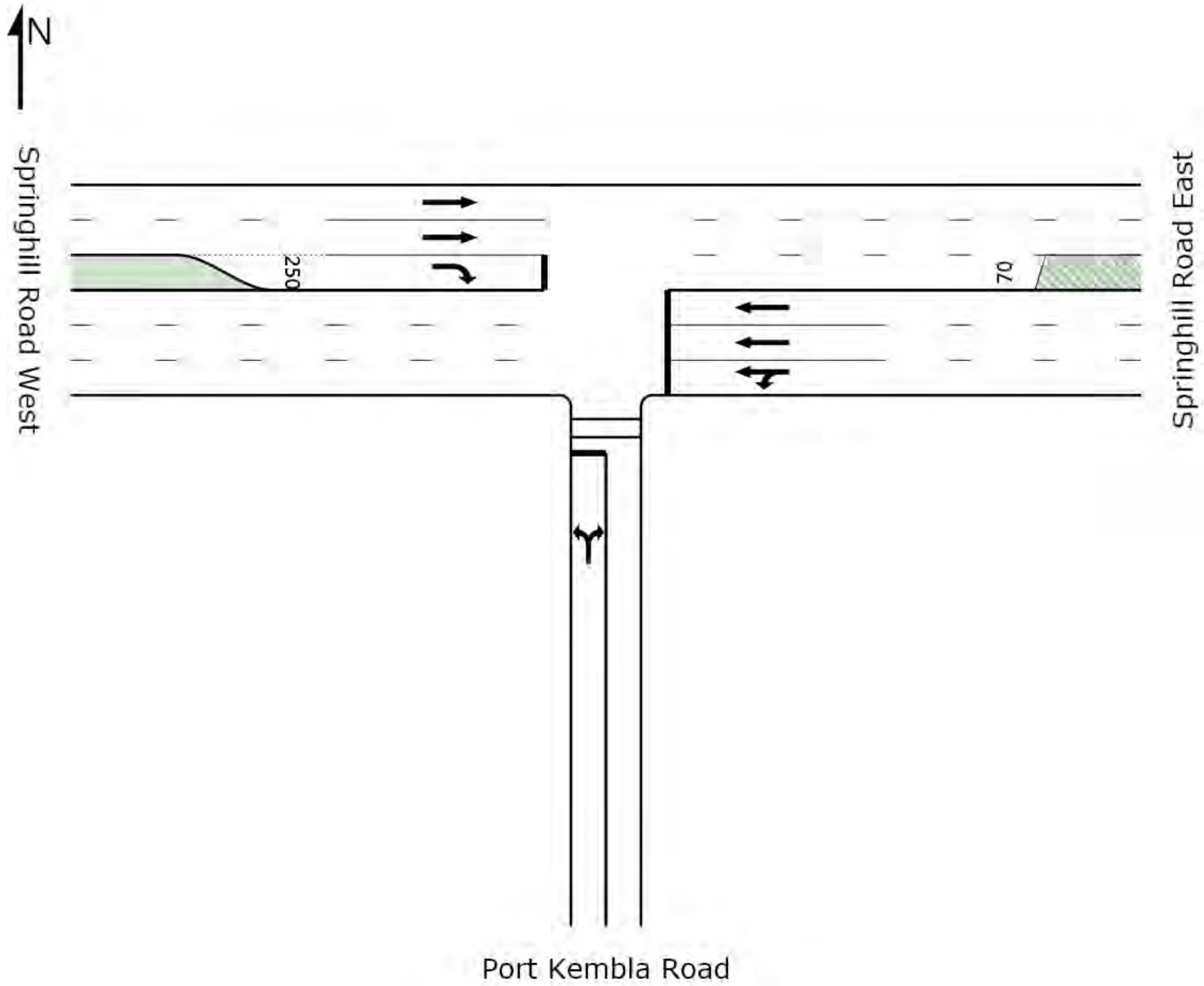
AM Peak

Movement Performance - Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Tom Thumb Road											
1	L	48	36.4	0.127	31.6	LOS C	1.3	11.9	0.80	0.74	32.7
3	R	6	33.3	0.047	42.7	LOS D	0.2	1.8	0.94	0.66	28.0
Approach		54	36.1	0.127	32.8	LOS C	1.3	11.9	0.82	0.73	32.1
East: Springhill Road East											
4	L	15	0.0	0.010	8.1	LOS A	0.0	0.3	0.18	0.62	48.8
5	T	828	16.1	0.274	8.2	LOS A	4.8	38.1	0.54	0.46	47.0
Approach		843	15.8	0.274	8.2	LOS A	4.8	38.1	0.53	0.47	47.0
West: Springhill Road West											
11	T	2574	6.1	0.801	15.5	LOS B	25.3	186.6	0.85	0.83	39.7
12	R	53	26.3	0.396	44.6	LOS D	1.9	16.1	0.98	0.75	27.3
Approach		2627	6.5	0.801	16.1	LOS B	25.3	186.6	0.86	0.83	39.4
All Vehicles		3524	9.2	0.801	14.5	LOS A	25.3	186.6	0.78	0.74	40.8

PM Peak

Movement Performance - Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Tom Thumb Road											
1	L	76	9.7	0.122	20.3	LOS B	1.3	9.6	0.70	0.75	38.7
3	R	27	3.7	0.124	30.7	LOS C	0.6	4.5	0.92	0.71	32.6
Approach		103	8.1	0.124	23.0	LOS B	1.3	9.6	0.76	0.74	36.9
East: Springhill Road East											
4	L	8	25.0	0.007	9.0	LOS A	0.0	0.2	0.25	0.62	48.4
5	T	1858	4.9	0.819	19.7	LOS B	16.3	118.6	0.96	0.98	36.7
Approach		1866	4.9	0.819	19.7	LOS B	16.3	118.6	0.95	0.98	36.7
West: Springhill Road West											
11	T	1320	6.5	0.588	13.0	LOS A	8.7	64.1	0.84	0.72	41.7
12	R	13	13.9	0.064	30.9	LOS C	0.3	2.3	0.91	0.68	32.7
Approach		1333	6.6	0.588	13.2	LOS A	8.7	64.1	0.84	0.72	41.6
All Vehicles		3302	5.7	0.819	17.2	LOS B	16.3	118.6	0.90	0.87	38.5

Springhill Road/Port Kembla Road



AM Peak

Movement Performance - Vehicles												
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Port Kembla Road											
1	L	31	87.0	0.120	28.6	LOS C	0.7	8.6	0.78	0.75	38.7
3	R	8	25.0	0.120	25.6	LOS B	0.7	8.6	0.78	0.74	38.7
Approach		39	74.2	0.120	28.0	LOS B	0.7	8.6	0.78	0.74	38.7
East: Springhill Road East											
4	L	12	0.0	0.235	22.4	LOS B	2.8	20.4	0.74	1.00	48.1
5	T	465	6.0	0.235	12.3	LOS A	2.8	20.4	0.74	0.60	52.9
Approach		477	5.9	0.235	12.6	LOS A	2.8	20.4	0.74	0.61	52.8
West: Springhill Road West											
11	T	1040	3.2	0.272	0.0	X	X	X	X	0.00	79.9
12	R	38	87.3	0.208	35.4	LOS C	0.9	10.8	0.90	0.74	36.5
Approach		1078	6.1	0.272	1.3	LOS A	0.9	10.8	0.03	0.03	77.1
All Vehicles		1594	7.7	0.272	5.3	LOS A	2.8	20.4	0.26	0.22	66.3

PM Peak

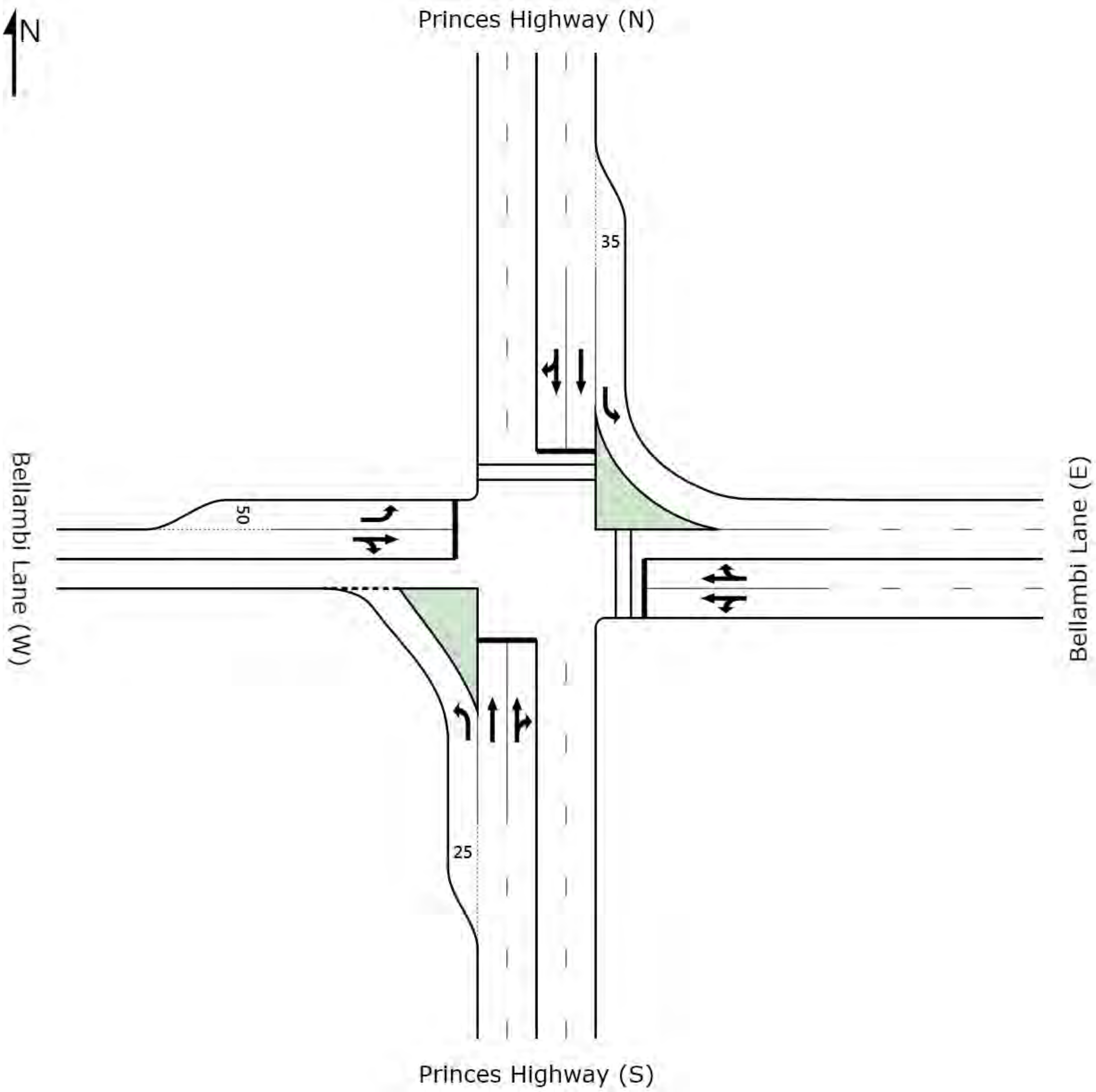
Movement Performance - Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Port Kembla Road											
1	L	36	58.1	0.196	30.2	LOS C	1.2	11.1	0.85	0.76	37.0
3	R	20	3.6	0.196	27.6	LOS B	1.2	11.1	0.85	0.75	37.0
Approach		56	38.6	0.196	29.2	LOS C	1.2	11.1	0.85	0.76	37.0
East: Springhill Road East											
4	L	10	20.0	0.488	23.3	LOS B	7.0	50.0	0.79	1.05	49.0
5	T	1112	2.6	0.488	12.3	LOS A	7.0	50.0	0.79	0.68	52.7
Approach		1122	2.7	0.488	12.4	LOS A	7.0	50.0	0.79	0.68	52.7
West: Springhill Road West											
11	T	425	8.4	0.115	0.0	X	X	X	X	0.00	80.0
12	R	33	88.3	0.241	37.9	LOS C	0.8	10.0	0.94	0.74	35.0
Approach		458	14.2	0.241	2.7	LOS A	0.8	10.0	0.07	0.05	73.9
All Vehicles		1636	7.2	0.488	10.3	LOS A	7.0	50.0	0.59	0.51	56.4

Appendix C

2020 Future Baseline plus Expansion Traffic –
SIDRA Analysis Results

2020 Baseline plus Proposed Expansion Traffic

Bellambi Lane/Princess Highway



AM Peak

Movement Performance - Vehicles

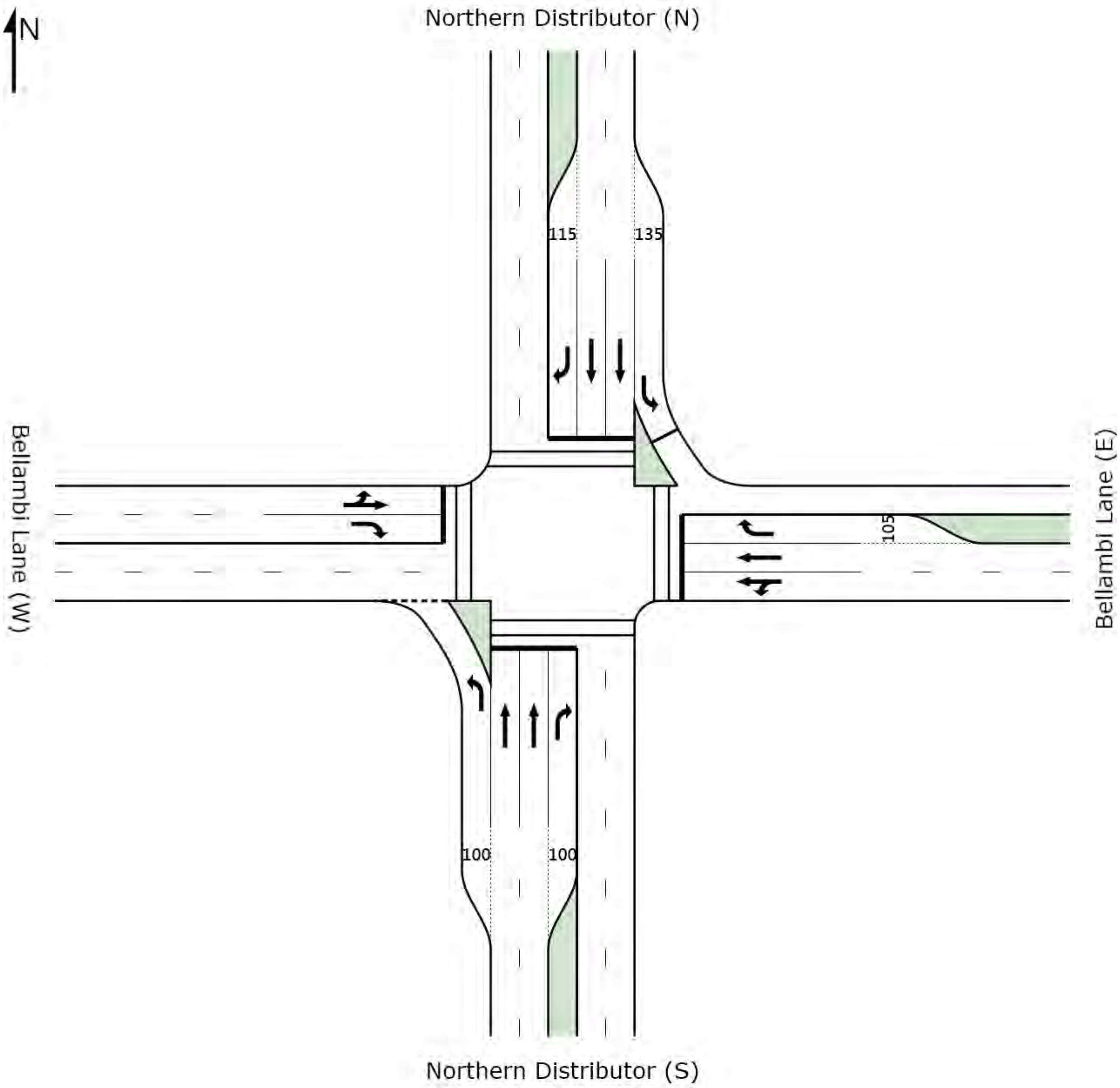
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Princes Highway (S)											
1	L	7	28.6	0.010	7.3	LOS A	0.0	0.2	0.18	0.57	48.6
2	T	313	7.3	0.242	14.4	LOS A	4.2	31.4	0.70	0.57	40.7
3	R	30	10.0	0.242	23.9	LOS B	3.5	26.0	0.73	0.86	37.9
Approach		350	8.0	0.242	15.1	LOS B	4.2	31.4	0.69	0.59	40.6
East: Bellambi Lane (E)											
4	L	43	12.8	0.054	17.2	LOS B	0.8	6.1	0.51	0.73	41.2
5	T	48	8.3	0.268	18.1	LOS B	3.2	24.3	0.75	0.65	36.6
6	R	95	8.1	0.268	24.1	LOS B	3.2	24.3	0.78	0.79	36.6
Approach		186	9.3	0.268	21.0	LOS B	3.2	24.3	0.71	0.74	37.6
North: Princes Highway (N)											
7	L	243	2.5	0.133	7.7	X	X	X	X	0.60	49.8
8	T	466	1.9	0.480	24.3	LOS B	7.1	50.3	0.90	0.74	34.1
9	R	5	0.0	0.480	31.6	LOS C	6.9	49.3	0.90	0.86	32.4
Approach		714	2.1	0.480	18.7	LOS B	7.1	50.3	0.59	0.70	38.2
West: Bellambi Lane (W)											
10	L	1	0.0	0.003	28.0	LOS B	0.0	0.2	0.79	0.59	27.2
11	T	49	0.0	0.113	23.4	LOS B	1.4	9.6	0.83	0.62	27.2
12	R	1	0.0	0.113	29.1	LOS C	1.4	9.6	0.83	0.75	27.2
Approach		51	0.0	0.113	23.6	LOS B	1.4	9.6	0.82	0.62	27.2
All Vehicles		1301	4.6	0.480	18.2	LOS B	7.1	50.3	0.64	0.67	38.1

PM Peak

Movement Performance - Vehicles

Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Princes Highway (S)											
1	L	4	25.0	0.005	7.2	LOS A	0.0	0.1	0.18	0.56	48.6
2	T	512	2.5	0.390	15.5	LOS B	7.6	54.1	0.75	0.63	39.7
3	R	56	0.0	0.390	24.7	LOS B	6.1	43.8	0.78	0.86	37.2
Approach		572	2.4	0.390	16.3	LOS B	7.6	54.1	0.75	0.65	39.5
East: Bellambi Lane (E)											
4	L	55	2.0	0.082	18.6	LOS B	1.3	9.6	0.56	0.75	40.0
5	T	48	33.3	0.410	18.0	LOS B	5.0	38.3	0.74	0.66	36.6
6	R	168	5.3	0.410	25.1	LOS B	5.0	38.3	0.83	0.80	35.8
Approach		271	9.6	0.410	22.5	LOS B	5.0	38.3	0.76	0.77	36.7
North: Princes Highway (N)											
7	L	200	2.5	0.110	7.7	X	X	X	X	0.60	49.8
8	T	423	2.1	0.430	24.0	LOS B	6.2	44.3	0.88	0.73	34.4
9	R	1	0.0	0.430	31.2	LOS C	6.2	44.1	0.88	0.86	32.6
Approach		624	2.2	0.430	18.7	LOS B	6.2	44.3	0.60	0.69	38.2
West: Bellambi Lane (W)											
10	L	6	0.0	0.017	28.3	LOS B	0.2	1.1	0.80	0.65	27.1
11	T	49	11.8	0.152	23.8	LOS B	1.6	12.5	0.83	0.64	27.0
12	R	9	11.1	0.152	29.8	LOS C	1.6	12.5	0.83	0.75	27.0
Approach		64	10.6	0.152	25.1	LOS B	1.6	12.5	0.83	0.66	27.0
All Vehicles		1531	4.0	0.430	18.8	LOS B	7.6	54.1	0.69	0.69	37.8

Bellambi Lane/Memorial Drive



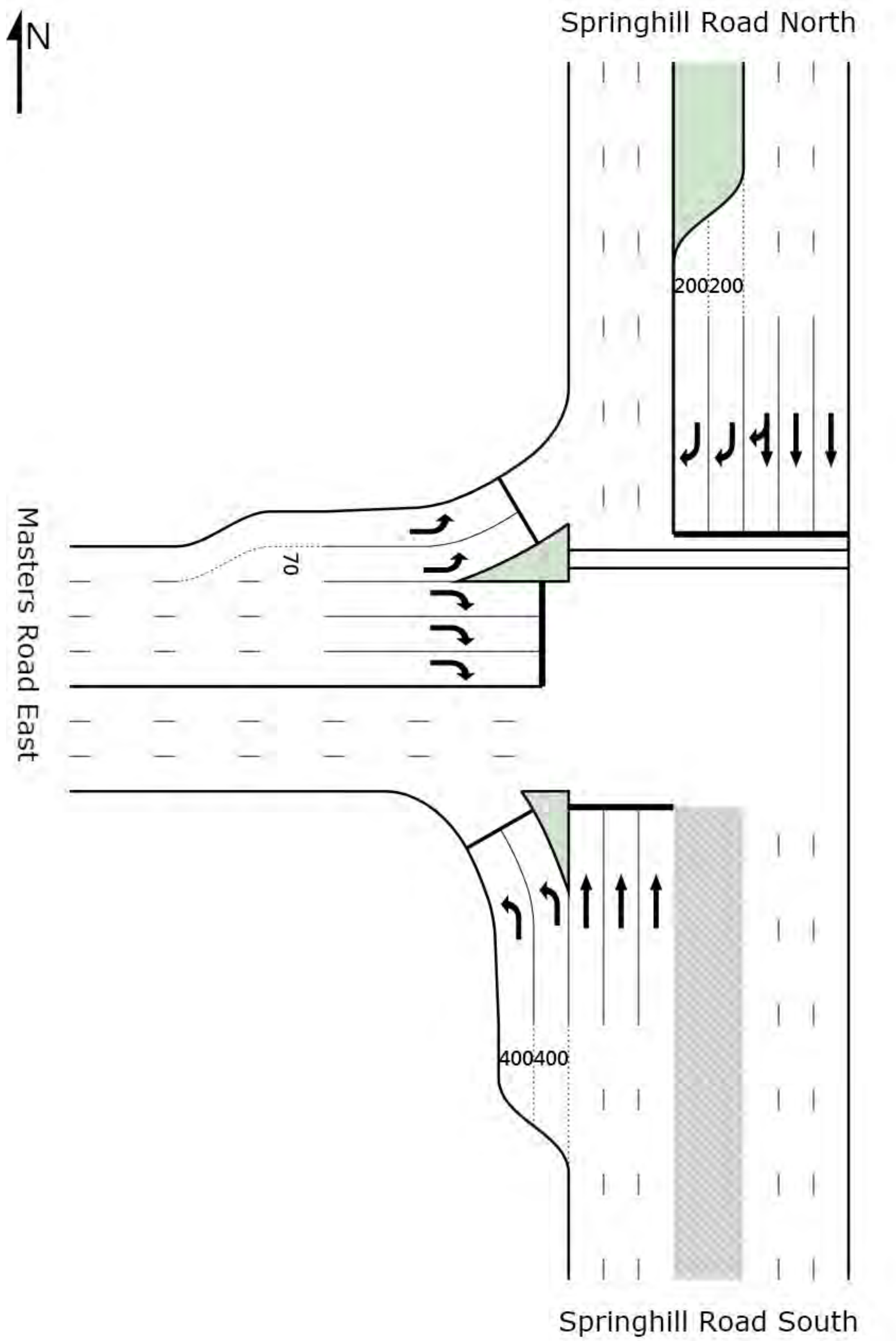
AM Peak

Movement Performance - Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Northern Distributor (S)											
1	L	168	5.2	0.126	10.6	LOS A	0.6	4.6	0.19	0.69	56.2
2	T	954	6.3	0.815	35.0	LOS C	19.3	142.3	0.99	0.95	34.6
3	R	72	12.5	0.620	48.5	LOS D	3.0	23.1	0.97	0.84	28.6
Approach		1194	6.5	0.815	32.4	LOS C	19.3	142.3	0.87	0.91	36.1
East: Bellambi Lane (E)											
4	L	49	11.4	0.120	35.9	LOS C	1.5	11.7	0.82	0.75	33.0
5	T	51	8.7	0.116	26.1	LOS B	1.6	11.9	0.82	0.62	33.4
6	R	152	2.2	0.354	28.0	LOS B	4.3	30.9	0.83	0.77	34.0
Approach		252	5.3	0.354	29.1	LOS C	4.3	30.9	0.83	0.74	33.6
North: Northern Distributor (N)											
7	L	178	2.2	0.188	15.7	LOS B	3.1	22.3	0.56	0.73	42.0
8	T	1379	3.0	0.779	21.4	LOS B	23.9	171.3	0.91	0.85	37.3
9	R	18	27.8	0.086	37.6	LOS C	0.6	5.2	0.88	0.71	29.9
Approach		1575	3.2	0.779	20.9	LOS B	23.9	171.3	0.87	0.83	37.6
West: Bellambi Lane (W)											
10	L	22	20.0	0.255	38.4	LOS C	3.2	24.4	0.85	0.87	30.6
11	T	91	6.1	0.255	29.5	LOS C	3.2	24.4	0.85	0.72	31.3
12	R	237	2.1	0.516	32.0	LOS C	7.0	50.0	0.86	0.84	36.4
Approach		350	4.3	0.516	31.7	LOS C	7.0	50.0	0.85	0.81	34.5
All Vehicles		3371	4.6	0.815	26.7	LOS B	23.9	171.3	0.86	0.85	36.5

PM Peak

Movement Performance - Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Northern Distributor (S)											
1	L	243	6.1	0.182	10.6	LOS A	1.0	7.5	0.18	0.69	56.3
2	T	1653	1.1	0.817	24.6	LOS B	32.2	227.6	0.90	0.88	41.4
3	R	99	3.0	0.305	29.8	LOS C	3.1	22.1	0.77	0.80	37.7
Approach		1995	1.8	0.817	23.1	LOS B	32.2	227.6	0.81	0.85	42.6
East: Bellambi Lane (E)											
4	L	71	3.1	0.141	26.2	LOS B	1.8	13.2	0.78	0.75	37.7
5	T	48	0.0	0.117	31.2	LOS C	1.7	12.0	0.84	0.64	30.9
6	R	154	0.7	0.433	33.7	LOS C	5.3	37.3	0.89	0.78	31.2
Approach		273	1.2	0.433	31.3	LOS C	5.3	37.3	0.86	0.75	32.7
North: Northern Distributor (N)											
7	L	113	5.3	0.156	16.6	LOS B	1.9	13.9	0.63	0.73	41.5
8	T	948	3.2	0.638	24.2	LOS B	17.0	122.1	0.87	0.76	35.9
9	R	22	18.2	0.283	59.0	LOS E	1.0	8.4	1.00	0.69	23.0
Approach		1083	3.7	0.638	24.1	LOS B	17.0	122.1	0.85	0.76	36.0
West: Bellambi Lane (W)											
10	L	46	7.3	0.333	41.5	LOS C	5.0	36.1	0.89	0.81	29.0
11	T	85	2.6	0.333	33.1	LOS C	5.0	36.1	0.89	0.72	29.4
12	R	193	3.4	0.477	37.0	LOS C	6.7	48.5	0.87	0.82	33.6
Approach		324	3.7	0.477	36.6	LOS C	6.7	48.5	0.88	0.79	31.7
All Vehicles		3675	2.5	0.817	25.2	LOS B	32.2	227.6	0.83	0.81	38.4

Masters Road/Springhill Road



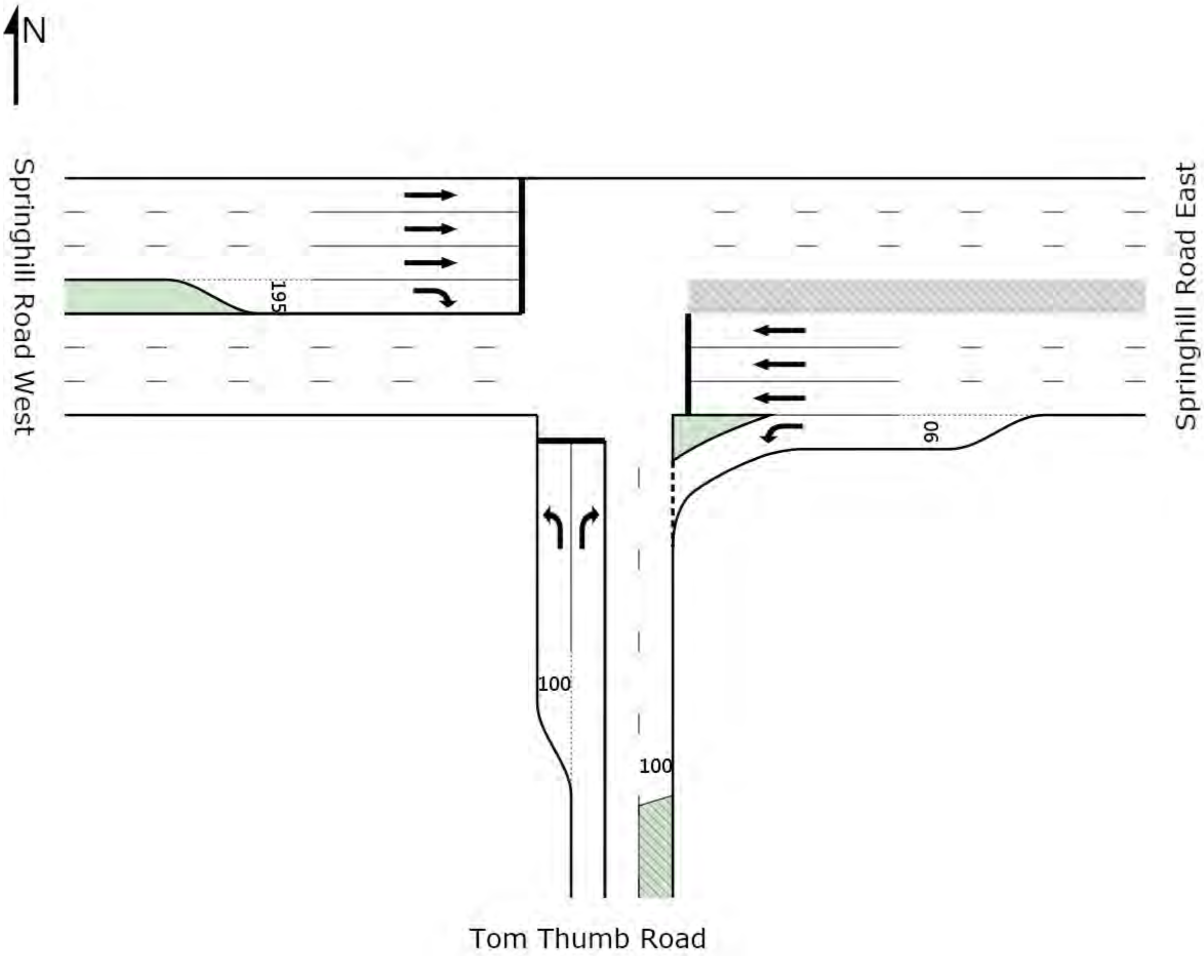
AM Peak

Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
Movement Performance - Vehicles											
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Springhill Road South											
1	L	495	11.3	0.180	14.3	LOS A	3.0	23.3	0.25	0.73	55.3
2	T	2386	4.8	0.841	29.3	LOS C	39.3	286.8	0.93	0.90	38.4
Approach		2881	6.0	0.841	26.7	LOS B	39.3	286.8	0.82	0.87	40.5
North: Springhill Road North											
8	T	644	12.8	0.277	8.9	LOS A	7.3	56.9	0.46	0.40	59.0
9	R	313	34.2	0.769	72.1	LOS F	6.1	55.0	1.00	0.88	24.3
Approach		957	19.8	0.769	29.6	LOS C	7.3	56.9	0.64	0.56	40.3
West: Masters Road East											
10	L	548	17.3	0.553	38.8	LOS C	14.9	119.9	0.80	0.82	35.8
12	R	730	12.8	0.583	51.6	LOS D	11.7	90.6	0.93	0.83	30.0
Approach		1278	14.7	0.583	46.1	LOS D	14.9	119.9	0.88	0.83	32.3
All Vehicles		5116	10.7	0.841	32.1	LOS C	39.3	286.8	0.80	0.80	38.1

PM Peak

Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
Movement Performance - Vehicles											
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Springhill Road South											
1	L	817	5.1	0.360	19.6	LOS B	8.4	61.6	0.51	0.79	49.1
2	T	1256	3.7	0.825	39.2	LOS C	19.3	139.7	1.00	0.96	33.2
Approach		2073	4.3	0.825	31.5	LOS C	19.3	139.7	0.81	0.89	38.0
North: Springhill Road North											
8	T	1164	4.7	0.543	13.0	LOS A	15.9	115.6	0.67	0.60	52.6
9	R	1060	3.1	0.834	53.5	LOS D	16.8	120.7	1.00	0.94	29.2
Approach		2224	3.9	0.834	32.3	LOS C	16.8	120.7	0.83	0.76	38.1
West: Masters Road East											
10	L	219	18.8	0.144	20.2	LOS B	2.7	21.8	0.46	0.75	49.2
12	R	680	14.4	0.449	39.6	LOS C	8.2	64.2	0.86	0.82	35.2
Approach		899	15.4	0.449	34.9	LOS C	8.2	64.2	0.76	0.80	37.9
All Vehicles		5196	6.1	0.834	32.4	LOS C	19.3	139.7	0.81	0.82	38.0

Springhill Road/Tom Thumb Road



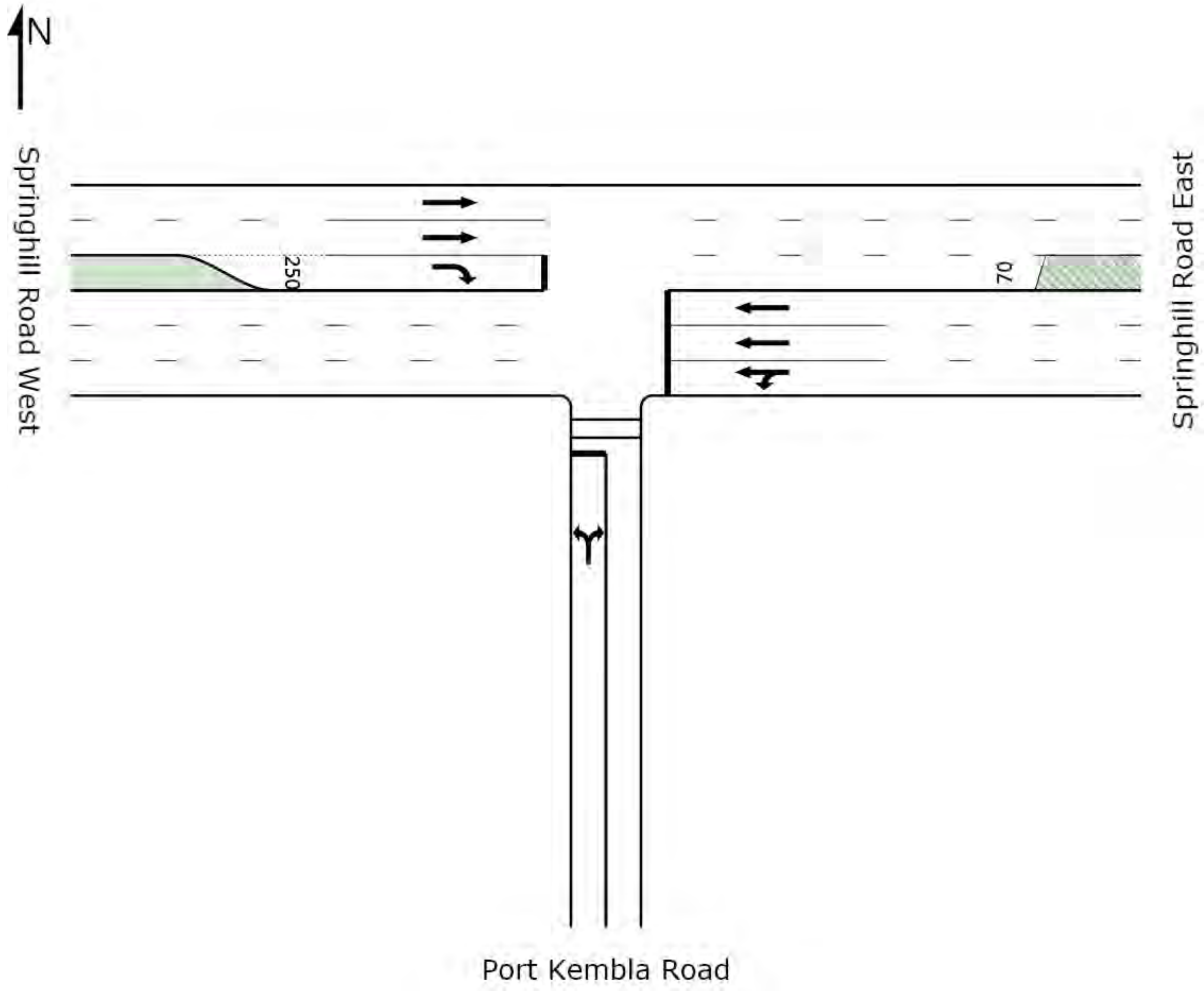
AM Peak

Movement Performance - Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Tom Thumb Road											
1	L	48	36.4	0.127	31.6	LOS C	1.3	11.9	0.80	0.74	32.7
3	R	6	33.3	0.047	42.7	LOS D	0.2	1.8	0.94	0.66	28.0
Approach		54	36.1	0.127	32.8	LOS C	1.3	11.9	0.82	0.73	32.1
East: Springhill Road East											
4	L	15	0.0	0.010	8.1	LOS A	0.0	0.3	0.18	0.62	48.8
5	T	859	16.1	0.284	8.3	LOS A	5.0	39.8	0.55	0.47	46.9
Approach		874	15.8	0.284	8.2	LOS A	5.0	39.8	0.54	0.47	46.9
West: Springhill Road West											
11	T	2605	6.1	0.810	16.3	LOS B	26.3	193.7	0.86	0.85	39.2
12	R	53	26.3	0.396	44.6	LOS D	1.9	16.1	0.98	0.75	27.3
Approach		2658	6.5	0.810	16.8	LOS B	26.3	193.7	0.87	0.85	38.9
All Vehicles		3586	9.2	0.810	15.0	LOS B	26.3	193.7	0.79	0.75	40.4

PM Peak

Movement Performance - Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Tom Thumb Road											
1	L	76	9.7	0.122	20.3	LOS B	1.3	9.6	0.70	0.75	38.7
3	R	27	3.7	0.124	30.7	LOS C	0.6	4.5	0.92	0.71	32.6
Approach		103	8.1	0.124	23.0	LOS B	1.3	9.6	0.76	0.74	36.9
East: Springhill Road East											
4	L	8	25.0	0.007	9.0	LOS A	0.0	0.2	0.25	0.62	48.4
5	T	1889	4.9	0.833	20.7	LOS B	17.0	124.3	0.96	1.01	36.1
Approach		1897	4.9	0.833	20.7	LOS B	17.0	124.3	0.96	1.01	36.1
West: Springhill Road West											
11	T	1351	6.5	0.602	13.1	LOS A	8.9	66.0	0.84	0.73	41.6
12	R	13	13.9	0.064	30.9	LOS C	0.3	2.3	0.91	0.68	32.7
Approach		1364	6.6	0.602	13.3	LOS A	8.9	66.0	0.84	0.73	41.5
All Vehicles		3364	5.7	0.833	17.8	LOS B	17.0	124.3	0.91	0.89	38.1

Springhill Road/Port Kembla Road



AM Peak

Movement Performance - Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue		Prop. Queued	Effective Stop Rate	Average Speed
							Vehicles	Distance			
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Port Kembla Road											
1	L	62	87.0	0.171	25.7	LOS B	1.2	14.4	0.71	0.76	40.6
3	R	8	25.0	0.171	22.6	LOS B	1.2	14.4	0.71	0.76	40.6
Approach		70	79.9	0.171	25.3	LOS B	1.2	14.4	0.71	0.76	40.6
East: Springhill Road East											
4	L	12	0.0	0.283	24.9	LOS B	3.1	22.5	0.80	0.95	46.0
5	T	465	6.0	0.283	14.9	LOS B	3.1	22.6	0.80	0.65	49.9
Approach		477	5.9	0.283	15.1	LOS B	3.1	22.6	0.80	0.66	49.8
West: Springhill Road West											
11	T	1040	3.2	0.272	0.0	X	X	X	X	0.00	79.9
12	R	69	87.3	0.274	32.7	LOS C	1.5	18.5	0.87	0.77	38.2
Approach		1109	8.4	0.274	2.1	LOS A	1.5	18.5	0.05	0.05	75.4
All Vehicles		1656	10.7	0.283	6.8	LOS A	3.1	22.6	0.30	0.25	63.6

PM Peak

Movement Performance - Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue		Prop. Queued	Effective Stop Rate	Average Speed
							Vehicles	Distance			
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Port Kembla Road											
1	L	67	58.1	0.262	28.7	LOS C	1.8	17.4	0.83	0.78	37.8
3	R	20	3.6	0.262	26.1	LOS B	1.8	17.4	0.83	0.77	37.8
Approach		87	45.6	0.262	28.1	LOS B	1.8	17.4	0.83	0.77	37.8
East: Springhill Road East											
4	L	10	20.0	0.488	23.3	LOS B	7.0	50.0	0.79	1.05	49.0
5	T	1112	2.6	0.488	12.3	LOS A	7.0	50.0	0.79	0.68	52.7
Approach		1122	2.7	0.488	12.4	LOS A	7.0	50.0	0.79	0.68	52.7
West: Springhill Road West											
11	T	425	8.4	0.115	0.0	X	X	X	X	0.00	80.0
12	R	64	88.3	0.468	38.9	LOS C	1.6	20.3	0.97	0.77	34.5
Approach		489	18.9	0.468	5.1	LOS A	1.6	20.3	0.13	0.10	69.3
All Vehicles		1698	9.6	0.488	11.1	LOS A	7.0	50.0	0.60	0.52	55.4

Appendix D

Mid-block Carriageway Performance Analysis
Results

Average Weekday - AM Peak

Peak: AM
Day: AWD

GEOGRAPHY / CATEGORY / PHYSICAL CHARACTERISTICS

Street	between	and	Public/Private	Urban/Rural	Carriageway Type	URB to PKCT	URB from PKCT	Road Section Distances (km) to PKCT	Road Section Distances (km) from PKCT	Road Section Distances (km) avg	Speed (km/h) Limit	Speed (km/h) Design	No. of Lanes to PKCT	No. of Lanes from PKCT	Terrain	% Sight Distance <450m to PKCT	% Sight Distance <450m from PKCT	Lane Widths (m)	Shoulder Width	Sides obstructed	Road Type	Development Environment	Driver Population
Bellambi Ln	Princes Hwy	Northern Distributor	Public	Urban	URB	4UC	4UC	0.722	0.722	0.722	60	60	2	2	L	0%	0%	3.5	0.0				
Northern Distributor	Bellambi Ln	Railway St	Public	Urban	UML	-	-	1.413	1.420	1.416	80	80	2	2	L	60%	60%	3.5	2.0	2	D	S	C
Masters Rd	Southern Fwy	Springhill Rd	Public	Urban	URB	6DCL	6DCL	1.346	1.628	1.487	80	80	3	3	L	0%	0%	3.5	0.0				
Springhill Rd	Masters Rd	Port Kembla Rd	Public	Urban	URB	6DCL	6DCL	2.212	2.243	2.228	80	80	3	3	L	0%	0%	3.5	0.0				
Total								48.095	48.3	48.2													

LOOKUP CALCULATIONS

Street	v/c to PKCT A	B	C	D	E	v/c from PKCT A	B	C	D	E	f_d	f_w LoS A to D	f_w LoS E	E_t A	B	C	D	E
Bellambi Ln	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Distributor	0.00	0.45	0.60	0.76	1.00	0.00	0.45	0.60	0.76	1.00	-	0.985	0.985	2.0	1.7	1.7	1.7	1.7
Masters Rd	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Springhill Rd	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total																		

Street	f_{HV} 1/(1+P_t*(E_t-1)) to PKCT A	B	C	D	E	f_{HV} from PKCT A	B	C	D	E	f_e	f_p
Bellambi Ln	-	-	-	-	-	-	-	-	-	-	-	-
Northern Distributor	0.95	0.97	0.97	0.97	0.97	0.88	0.91	0.91	0.91	0.91	0.90	1.00
Masters Rd	-	-	-	-	-	-	-	-	-	-	-	-
Springhill Rd	-	-	-	-	-	-	-	-	-	-	-	-
Total												

LOOKUP CALCULATIONS (LoS Capacity) / VARIABLES / OUTPUT

Street	LoS Capacity Sfi* to PKCT	A	B	C	D	E	LoS Capacity Sfi* from PKCT	A	B	C	D	E	AM AWD S25 AM PEAK to PKCT Veh/hr	to PKCT % HV	From PKCT Veh/hr	From PKCT % HV	Both Veh/hr	Both flow	LoS to PKCT	LoS from PKCT
Bellambi Ln	0	1510	1760	2010	2270	2520	0	1510	1760	2010	2270	2520	319	11%	206	17%	525	61	A	A
Northern Distributor	0	*770*	1540	4169	4489	5906	0	*730*	1459	1945	2464	3191	1,634	5%	1,163	13%	2,797	58	C	B
Masters Rd	0	3375	3930	4500	5070	5610	0	3375	3930	4500	5070	5610	1,247	13%	777	17%	2,024	62	A	A
Springhill Rd	0	3375	3930	4500	5070	5610	0	3375	3930	4500	5070	5610	2,627	15%	876	7%	3,503	75	A	A
Total																				

*SF_i =	
U2L	2800*(v/c)*f_d*f_w*f_{HV}
UML	C_j*$(v/c)_i$*N*f_w*f_{HV}*f_e*f_p
FWY	C_j*$(v/c)_i$*N*f_w*f_{HV}*f_p
URB	???

Note
The following assumptions were made when calculating fw for Multi-Lane and Freeway:
3.5 metres lane width
Both sides obstruction

Average Weekday - PM Peak

Peak: PM
Day: AWD

GEOGRAPHY / CATEGORY / PHYSICAL CHARACTERISTICS

Location: Street	between	and	Public/Private	Urban/Rural	Carriageway Type	URB: to PKCT	URB: from PKCT	Road Section Distances (km): to PKCT	from PKCT	avg	Speed (km/h): Limit	Design	No. of Lanes: to PKCT	from PKCT	Terrain	% Sight Distance <450m: to PKCT	from PKCT	Lane Widths (m)	Shoulder Width	Sides obstructed	Road Type	Development Environment	Driver Population
Bellambi Ln	Princes Hwy	Northern Distributor	Public	Urban	URB	4UC	4UC	0.722	0.722	0.722	60	60	2	2	L	0%	0%	3.5	0.0				
Northern Distributor	Bellambi Ln	Railway St	Public	Urban	UML	-	-	1.413	1.420	1.416	80	80	2	2	L	60%	60%	3.5	2.0	2	D	S	C
Masters Rd	Southern Fwy	Springhill Rd	Public	Urban	URB	6DCL	6DCL	1.346	1.628	1.487	80	80	3	3	L	0%	0%	3.5	0.0				
Springhill Rd	Masters Rd	Port Kembla Rd	Public	Urban	URB	6DCL	6DCL	2.212	2.243	2.228	80	80	3	3	L	0%	0%	3.5	0.0				
Total								48.095	48.3	48.2													

LOOKUP CALCULATIONS

Street	v/c to PKCT A	B	C	D	E	v/c from PKCT A	B	C	D	E	f_d	f_w LoS A to D	E	E_t A	B	C	D	E	f_{HV} = $1/(1+P_t*(E_t-1))$ to PKCT A	B	C	D	E	f_{HV} from PKCT A	B	C	D	E	f_e	f_p
Bellambi Ln	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Distributor	0.00	0.45	0.60	0.76	1.00	0.00	0.45	0.60	0.76	1.00	-	0.985	0.985	2.0	1.7	1.7	1.7	1.7	0.96	0.97	0.97	0.97	0.97	0.95	0.97	0.97	0.97	0.97	0.90	1.00
Masters Rd	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Springhill Rd	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total																														

LOOKUP CALCULATIONS (cont.) / VARIABLES / OUTPUT

Street	LoS Capacity Sfi* to PKCT	A	B	C	D	E	from PKCT	A	B	C	D	E	PM AWD S25 PM PEAK to PKCT Veh/hr	% HV	From PKCT Veh/hr	% HV	Both Veh/hr	flow	LoS to PKCT	LoS from PKCT
Bellambi Ln	0	1510	1760	2010	2270	2520	0	1510	1760	2010	2270	2520	293	15%	282	13%	575	51	A	A
Northern Distributor	0	778	1555	4209	4532	5963	0	770	1540	2053	2601	3191	1,181	4%	1,964	5%	3,145	62	B	C
Masters Rd	0	3375	3930	4500	5070	5610	0	3375	3930	4500	5070	5610	868	13%	1,846	6%	2,714	68	A	A
Springhill Rd	0	3375	3930	4500	5070	5610	0	3375	3930	4500	5070	5610	1,333	4%	1,934	5%	3,267	59	A	A
Total																				

*SF_i =	
U2L	$2800*(v/c)*f_d*f_w*f_{HV}$
UML	$C_j*(v/c)_i*N*f_w*f_{HV}*f_e*f_p$
FWY	$C_j*(v/c)_i*N*f_w*f_{HV}*f_p$

Note
The following assumptions were made when calculating fw for Multi-Lane and Freeway:
3.5 metres lane width
Both sides obstruction

Average Weekday - AM Peak (with proposed expansion)

Peak: AM
Day: AWD

GEOGRAPHY / CATEGORY / PHYSICAL CHARACTERISTICS

Location: Street	between	and	Public/Private	Urban/Rural	Carriageway Type	URB: to PKCT	URB: from PKCT	Road Section Distances (km): to PKCT	Road Section Distances (km): from PKCT	Road Section Distances (km): avg	Speed (km/h): Limit	Speed (km/h): Design	No. of Lanes: to PKCT	No. of Lanes: from PKCT	Terrain	% Sight Distance <450m: to PKCT	% Sight Distance <450m: from PKCT	Lane Widths (m)	Shoulder Width	Sides obstructed	Road Type	Development Environment	Driver Population
Bellambi Ln	Princes Hwy	Northern Distributor	Public	Urban	URB	4UC	4UC	0.722	0.722	0.722	60	60	2	2	L	0%	0%	3.5	0.0				
Northern Distributor	Bellambi Ln	Railway St	Public	Urban	UML	-	-	1.413	1.420	1.416	80	80	2	2	L	60%	60%	3.5	2.0	2	D	S	C
Masters Rd	Southern Fwy	Springhill Rd	Public	Urban	URB	6DCL	6DCL	1.346	1.628	1.487	80	80	3	3	L	0%	0%	3.5	0.0				
Springhill Rd	Masters Rd	Port Kembla Rd	Public	Urban	URB	6DCL	6DCL	2.212	2.243	2.228	80	80	3	3	L	0%	0%	3.5	0.0				
Total								48.095	48.3	48.2													

LOOKUP CALCULATIONS

Street	v/c to PKCT: A	B	C	D	E	v/c from PKCT: A	B	C	D	E	f_d	f_w LoS: A to D	f_w LoS: E	E_t: A	B	C	D	E	f_{HV} = $1/(1+P_t*(E_t-1))$ to PKCT: A	B	C	D	E	f_{HV} from PKCT: A	B	C	D	E	f_e	f_p
Bellambi Ln	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Distributor	0.00	0.45	0.60	0.76	1.00	0.00	0.45	0.60	0.76	1.00	-	0.985	0.985	2.0	1.7	1.7	1.7	1.7	0.95	0.97	0.97	0.97	0.97	0.88	0.91	0.91	0.91	0.91	0.90	1.00
Masters Rd	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Springhill Rd	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total																														

LOOKUP CALCULATIONS (LoS Capacity) / VARIABLES / OUTPUT

Street	LoS Capacity Sfi* to PKCT:	A	B	C	D	E	LoS Capacity Sfi* from PKCT:	A	B	C	D	E	AM AWD S25 AM PEAK to PKCT: Veh/hr	% HV	From PKCT: Veh/hr	% HV	Both: Veh/hr	flow	LoS: to PKCT	LoS: from PKCT
Bellambi Ln	0	1510	1760	2010	2270	2520	0	1510	1760	2010	2270	2520	352	11%	239	17%	591	60	A	A
Northern Distributor	0	770	1540	4169	4489	5906	0	730	1459	1945	2464	3191	1,667	5%	1,196	13%	2,863	58	C	B
Masters Rd	0	3375	3930	4500	5070	5610	0	3375	3930	4500	5070	5610	1,280	13%	810	17%	2,090	61	A	A
Springhill Rd	0	3375	3930	4500	5070	5610	0	3375	3930	4500	5070	5610	2,660	15%	909	7%	3,569	75	A	A
Total																				

*SF_i =	
U2L	$2800*(v/c)*f_d*f_w*f_{HV}$
UML	$C_j*(v/c)_i*N*f_w*f_{HV}*f_e*f_p$
FWY	$C_j*(v/c)_i*N*f_w*f_{HV}*f_p$

Note
The following assumptions were made when calculating fw for Multi-Lane and Freeway:
3.5 metres lane width
Both sides obstruction

LoS

Average Weekday - PM Peak (with proposed expansion)

Scenario No. 25
Peak: PM
Day: AWD

GEOGRAPHY			CATEGORY					PHYSICAL CHARACTERISTICS															
Location			Public/Private	Urban/Rural	Carriageway Type	URB		Road Section Distances (km)			Speed (km/h)		No. of Lanes		Terrain	% Sight Distance <450m		Lane Widths (m)	Shoulder Width	Sides obstructed	Road Type	Development Environment	Driver Population
Street	between	and				to PKCT	from PKCT	to PKCT	from PKCT	avg	Limit	Design	to PKCT	from PKCT		to PKCT	from PKCT						
Bellambi Ln	Princes Hwy	Northern Distributor	Public	Urban	URB	4UC	4UC	0.722	0.722	0.722	60	60	2	2	L	0%	0%	3.5	0.0				
Northern Distributor	Bellambi Ln	Railway St	Public	Urban	UML	-	-	1.413	1.420	1.416	80	80	2	2	L	60%	60%	3.5	2.0	2	D	S	C
Masters Rd	Southern Fwy	Springhill Rd	Public	Urban	URB	6DCL	6DCL	1.346	1.628	1.487	80	80	3	3	L	0%	0%	3.5	0.0				
Springhill Rd	Masters Rd	Port Kembla Rd	Public	Urban	URB	6DCL	6DCL	2.212	2.243	2.228	80	80	3	3	L	0%	0%	3.5	0.0				
Total								48.095	48.3	48.2													

LOOKUP CALCULATIONS																														
	v/c										f_d	f_w		E_t					f_{HV} $1/(1+P_t*(E_t-1))$										f_e	f_p
	to PKCT					from PKCT						LoS							to PKCT					from PKCT						
Street	A	B	C	D	E	A	B	C	D	E		A to D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E		
Bellambi Ln	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Distributor	0.00	0.45	0.60	0.76	1.00	0.00	0.45	0.60	0.76	1.00	-	0.985	0.985	2.0	1.7	1.7	1.7	1.7	0.96	0.97	0.97	0.97	0.97	0.95	0.97	0.97	0.97	0.97	0.90	1.00
Masters Rd	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Springhill Rd	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total																														

	LOOKUP CALCULATIONS												VARIABLES						OUTPUT	
	LoS Capacity Sfi*												PM AWD S25 PM PEAK						LoS	
	to PKCT						from PKCT						to PKCT		From PKCT		Both			
Street		A	B	C	D	E		A	B	C	D	E	Veh/hr	% HV	Veh/hr	% HV	Veh/hr	flow	to PKCT	from PKCT
Bellambi Ln	0	1510	1760	2010	2270	2520	0	1510	1760	2010	2270	2520	326	15%	315	13%	641	51	A	A
Northern Distributor	0	778	1555	4209	4532	5963	0	770	1540	2053	2601	3191	1,214	4%	1,997	5%	3,211	62	B	C
Masters Rd	0	3375	3930	4500	5070	5610	0	3375	3930	4500	5070	5610	901	13%	1,879	6%	2,780	68	A	A
Springhill Rd	0	3375	3930	4500	5070	5610	0	3375	3930	4500	5070	5610	1,366	4%	1,967	5%	3,333	59	A	A
Total																				

$*SF_i =$	
U2L	$2800*(v/c)*f_d*f_w*f_{HV}$
UML	$C_j*(v/c)_i*N*f_w*f_{HV}*f_e*f_p$
FWY	$C_j*(v/c)_i*N*f_w*f_{HV}*f_p$

Appendix J

RMS COMMENTS ON TRAFFIC & TRANSPORT IMPACT ASSESSMENT

Our Ref: STH09/02236/10
Contact: Jayd Marsh – 4221 2561

Transport
Roads & Maritime Services

The General Manager
Department of Planning & Infrastructure
GPO Box 39
Sydney NSW 2001

Attention: Jessie Giblett

DEPARTMENT OF PLANNING & INFRASTRUCTURE – MAJOR PROJECT APPLICATION MP 09_0013 – NO.1 COLLIERY UNDERGROUND EXPANSION PROJECT – PPR & RTS

Dear Madam,

Reference is made to additional information received on 11 April 2014 regarding major project application MP09_0013 – No.1 Colliery Underground Expansion Project (UEP).

Roads and Maritime Services (RMS) has reviewed the submitted information and notes that there is an increase of approximately 33 Passenger Car Units (PCU's) per hour (one way). RMS does not consider that this increase in traffic generation would have a significant impact on the operation and performance of the main road network. Based on this, Roads and Maritime has no objections to the application in principle subject to any technical implications regarding subsidence being referred to the Wollongong Coal RMS Longwall Mining Technical Committee.

RMS highlights that Bellambi Lane is now a local road under the care and control of Wollongong City Council. On this basis RMS has not considered any noise implications associated with the modifications on sensitive receivers on, and near Bellambi Lane.

Upon the Department's determination of this matter, it would be appreciated if the Department could forward a copy of the Notice of Determination to RMS within the appellant period for advice and consideration.

Adam Berry
Network and Safety Manager
Network Management, Southern Region

2 8 MAY 2014

CC – The General Manager, Wollongong Council (via email)
- Dianne Munro, Hansen Bailey

Appendix K

GEOLOGICAL REPORT ON WONGA EAST AREA

GUJARAT NRE COKING COAL LTD
CORPORATE ADDRESS: CNR BELLAMBI LANE & PRINCESS HIGHWAY,
RUSSELL VALE. NSW 2517
ABN 77 111 928 762

GUJARAT NRE No. 1 COLLIERY

GEOLOGICAL REPORT ON THE WONGA EAST AREA

GUJARAT NRE COKING COAL LIMITED

Prepared By – NRE Technical Services Department

Date – May 2014

GEOLOGICAL REPORT on the WONGA EAST AREA

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1. INTRODUCTION

Gujarat NRE Coking Coal Ltd owns and operates the NRE No.1 Colliery at Russell Vale which is approximately 8 km north of Wollongong within the Illawarra district of NSW.

The Colliery Holding covers approximately 63 km^2 and topographically the majority of the area west of the escarpment is a plateau of relatively undulating countryside incised by westerly to northwesterly flowing creeks. The major creeks flow into the Cataract Reservoir and Cataract River systems.

The NRE No. 1 colliery was the former South Bulli Colliery and has a long history of operation extending over 120 years. During its history coal extraction has concentrated on the Bulli Seam, the upper most of the coal seams in the Illawarra Coal Measures. Mining in the Balgownie Seam, approximately10 metres below the Bulli Seam, occurred from 1968 to 1982 and also in the period from 2001 to 2003.

Gujarat NRE purchased the mine in 2004 and identified the unmined Wongawilli Seam, some 30 metres below the Bulli seam, as having potential to produce a high quality coking coal with a thermal coal by-product. Development from outcrop on the Illawarra escarpment commenced in 2008 with longwall mining using modern high capacity equipment beginning in 2012.

This report has been compiled to document the current level of knowledge and understanding of the geology of the current mining domain designated as the Wonga East Study Area. Within this area extensive extraction of the Bulli Seam has occurred and also the mining operations within the Balgownie Seam.

2. DEPOSIT GEOLOGY

2.1 Regional Geology

Gujarat NRE No.1 Colliery is located in the Southern Coalfield, which is the southern portion of the Permo-Triassic Sydney Basin, as shown in Figure 1, and contains the Illawarra Coal Measures of Late Permian Age. Overlying the Illawarra Coal Measures are sandstones, shales and mudstones of the Narrabeen Group, which in turn are overlain by the Hawkesbury Sandstone, a massive quartzose sandstone unit. The Wianamatta Group, stratigraphically above the Hawkesbury Sandstone, is the top most unit in the Southern Coalfield.

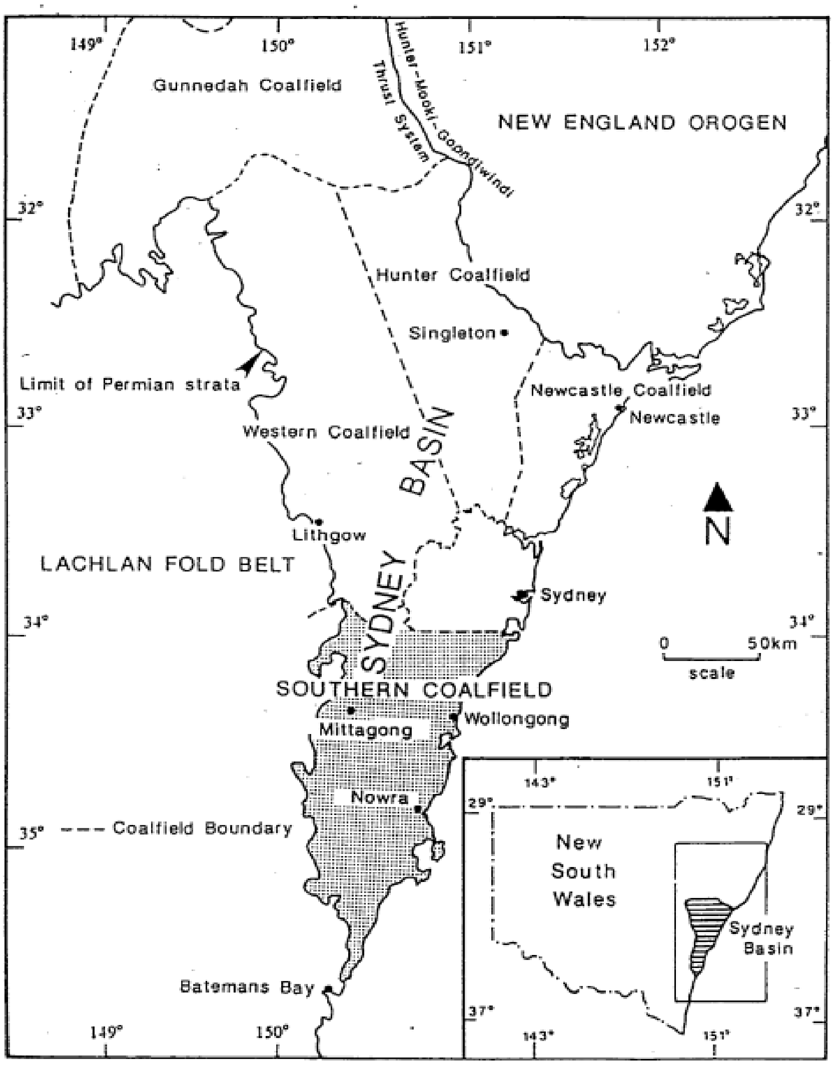


Figure 1 - Location of the Southern Coalfield

Within the Illawarra Coal Measures the Bulli Coal is the uppermost coal member and has been extensively mined across the Southern Coalfield. The Balgownie Coal, stratigraphically around 10 metres below the Bulli Coal has been mined by the longwall method at South Bulli Colliery and in the 2000's by bord and pillar operations (Gibson's Colliery). There are currently no mining operations in the Balgownie Seam within the Southern Coalfield. The Bulli to Wongawilli Coal interval varies from approximately 24 metres to around 35 metres. Although generally consistent in thickness across the Coalfield at 8 to 11 metres, the Wongawilli Seam deteriorates in quality to the north when compared to the southern part of the Coalfield where a basal section is mined at Gujarat's Wongawilli Colliery and BHPB Dendrobium Colliery.

At the broad scale the Southern Coalfield is dominated by a north plunging syncline with associated northwest trending synclines and anticlines, shown in Figure 2. The overall structure of the Coalfield is defined from the Bulli Coal but the major structural trends of the Bulli Coal are generally thought to be mirrored through the coal measure sequence.

Large displacement faults in the Coalfield consist primarily of normal faults with dips of between 70 to 85 degrees, trending NW or NNW and are the primary set. The exception to this rule is faults found in a NE trending coastal fault zone. West of this zone northeast faulting still occur but at a much wider spacing and as a secondary set (some of these are strike slip faults associated with dykes). The deformational history of the NW fault system is complex and the pattern is the sum of several events that appear to have starting after the Permian although there is evidence of growth faulting indicating structural activity during coal deposition.

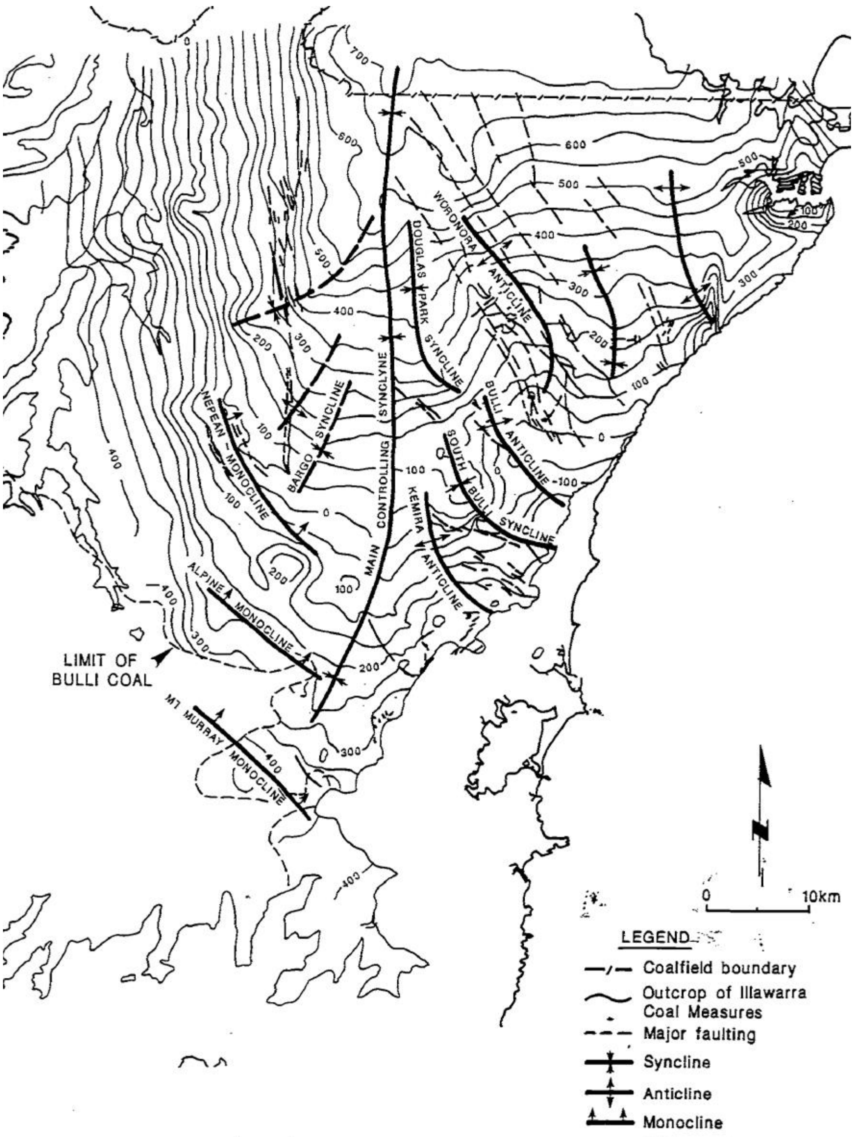


Figure 2 - Structural Elements of the Southern Coalfield

2.2 Stratigraphy

Figure 3 shows the stratigraphy of the Southern Coalfield and gives details of the coal seams present in the Illawarra Coal Measures.

AGE	GROUP	SUB-GRP	CODE	FORMATION & MEMBERS	
TRIASSIC	WIANAMATTA GROUP			BRINGELLY SHALE	
			WMSH	MINCHINBURY SANDSTONE	
				ASHFIELD SHALE	
				MITTAGONG FORMATION	
			HBSS	HAWKSBURY SANDSTONE	
	NARRABEEN GROUP	GOSFORD		NEWPORT FORMATION	
			GRFM	GARIE FORMATION	
		CLIFTON	BACS	BALD HILL CLAYSTONE	
			BGSS	BULGO SANDSTONE	
			SPCS	STANWELL PARK CLAYSTONE	
			SBSS	SCARBOROUGH SANDSTONE	
			WBCS	WOMBARRA CLAYSTONE	
			CCSS	COAL CLIFF SANDSTONE	
PERMIAN	ILLAWARRA COAL MEASURES	SYDNEY	BUSM	BULLI COAL	
			UNM1	LODDON SANDSTONE	
			BASM	BALGOWNIE COAL	
			LRSS	LAWRENCE SANDSTONE	
				BURRAGORANG CLAYSTONE	
			CHSM	ECKERSLEY FORMATION	CAPE HORN
			UNM2		UNNAMED MEMBER 2
					HARGRAVE COAL
					WORONORA COAL
					NOVICE SANDSTONE
			WW01-11	WONGAWILLI COAL	
			KBSS	KEMBLA SANDSTONE	
			ACSM	ALLANS CREEK FORMATION	AMERICAN CK. COAL
			APFM	DARKES FOREST SANDSTONE (APPIN FORMATION)	
				BARGO CLAYSTONE	HUNTLEY CLAYST.
					AUSTIMER SANDST.
			TGSM	TONGARRA COAL	
			WTFM	WILTON FORMATION	
				WOONONA COAL MEMBER	
				ERINS VALE FORMATION	
		CUMBERLAND		PHEASANTS NEST FORMATION	FIGTREE COAL
					UNANDERRA COAL
					BERKELEY LATITE
					MINNAMURRA LATITE
					CALDERWOOD LATITE
					FIVE ISLANDS LATITE
	SHOALHAVEN GROUP			BROUGHTON FORMATION	
				BERRY SILTSTONE	
				NOWRA SANDSTONE	
				WANDRAWANDIAN SILTSTONE	
				SNAPPER POINT FORMATION	
				PEBBLEY BEACH FORMATION	
	TALATERANG			CLYDE COAL MEASURES	
UNDIFFERENTIATED PALAEOZOIC (DEVONIAN, SILURIAN & ORDOVICIAN) ROCKS OF THE BASIN BASEMENT					
Information Sourced From - "Geological Survey Report No. GS1998/277 - R.S. Moffitt"					

Figure 3 - Generalised Stratigraphy of the Southern Coalfield

The following is a brief summary of the stratigraphic units of the Southern Coalfield within the NRE No.1 Colliery holding.

The Wianamatta Group is the uppermost unit in the stratigraphical sequence and is prominent in the north of the Coalfield. Within the lease area of NRE No.1 only two boreholes (SR16 and WB8) intersected the Wianamatta Shale. Its outcrop is restricted to a very small area in the ar western portion of the lease and well outside of the Wonga East area.

The Hawkesbury Sandstone outcrops over most parts of the Coalfield and consists of thickly bedded or massive quartzose sandstone (with grey shale lenses up to several metres thick) with an average thickness of 154m in the lease area.

Within NRE No.1 Colliery the full Narrabeen Group sequence is about 275m thick.

The Gosford Formation (consisting of the Newport Formation of interbedded grey shales and sandstones and the Garie Claystone, a generally hard, grey-brown “oolitic” clay stone) is about 12m thick across the lease area.

The Bald Hill Claystone displays characteristic brownish-red coloured “chocolate shale”, a physically weak but lithologically stable unit about 20m thick. The “chocolate shale” is an easily recognised marker horizon.

The Bulgo Sandstone, averaging 162m thick, consists of strong, thickly bedded, and medium to coarse-grained lithic sandstone with occasional beds of conglomerate or shale.

The Stanwell Park Claystone (thickness average 14m) consists of greenish-grey mudstones and sandstones. This “green shale” is very weak lithologically and frets easily on exposure.

The Scarborough Sandstone, averaging 36m in thickness, consists mainly of thickly bedded sandstone with shale and sandy shale lenses up to several metres thick.

Like the Stanwell Park Claystone the Wombarra Shale (thickness average 20m), consists of greenish-grey mudstones and sandstones. This “green shale” is also very weak lithologically and is prone to fretting on exposure.

The Coal Cliff Sandstone averages 10m in thickness. In the coastal region of the Coalfield the Coal Cliff Sandstone is strong quartzose sandstone. Westward, away from the coast, dominance of the sandstone diminishes and in many areas the original roof strata of the Bulli Seam, a shale / mudstone unit, (which can become laminated in places) is prominent.

The Illawarra Coal Measures consist of interbedded shales, mudstones, lithic sandstones and coal seams of which ten named seams are identified and occur in the Coalfield.

2.2.1 Coal Seams

2.2.1.1 Bulli

The Bulli Seam is the most extensively worked coal seam in the Southern Coalfield, from outcrop mines on the coastal margins to current inland mines of BPB Billiton and Xstrata Coal. The seam produces a high quality hard coking coal (usually needing beneficiating to a coking and energy fraction) to obtain a marketable low ash coking coal. Resources of the Bulli Seam exist in the western portion of NRE No.1 Colliery. Average thickness is 2.2m and thickness variations across the Wonga East Study Area are shown on Figure 4.

2.2.1.2 Balgownie

The Balgownie Seam generally consists of medium to high ash coal with a transitional basal section of varying proportions of carbonaceous shale, mudstone and coal. Seam thickness averages 1.2m (varies from 0.2m to 1.7m) and thickness variations across the Study Area are shown on Figure 5.

Across the colliery the interval separating the Balgownie Coal from the overlying Bulli Coal (Loddon Sandstone) averages 9.5m (varies from approximately 5.2m to 13.8m). Figure 6 shows the thickness variations of the Loddon Sandstone in the Study Area.

2.2.1.3 Cape Horn

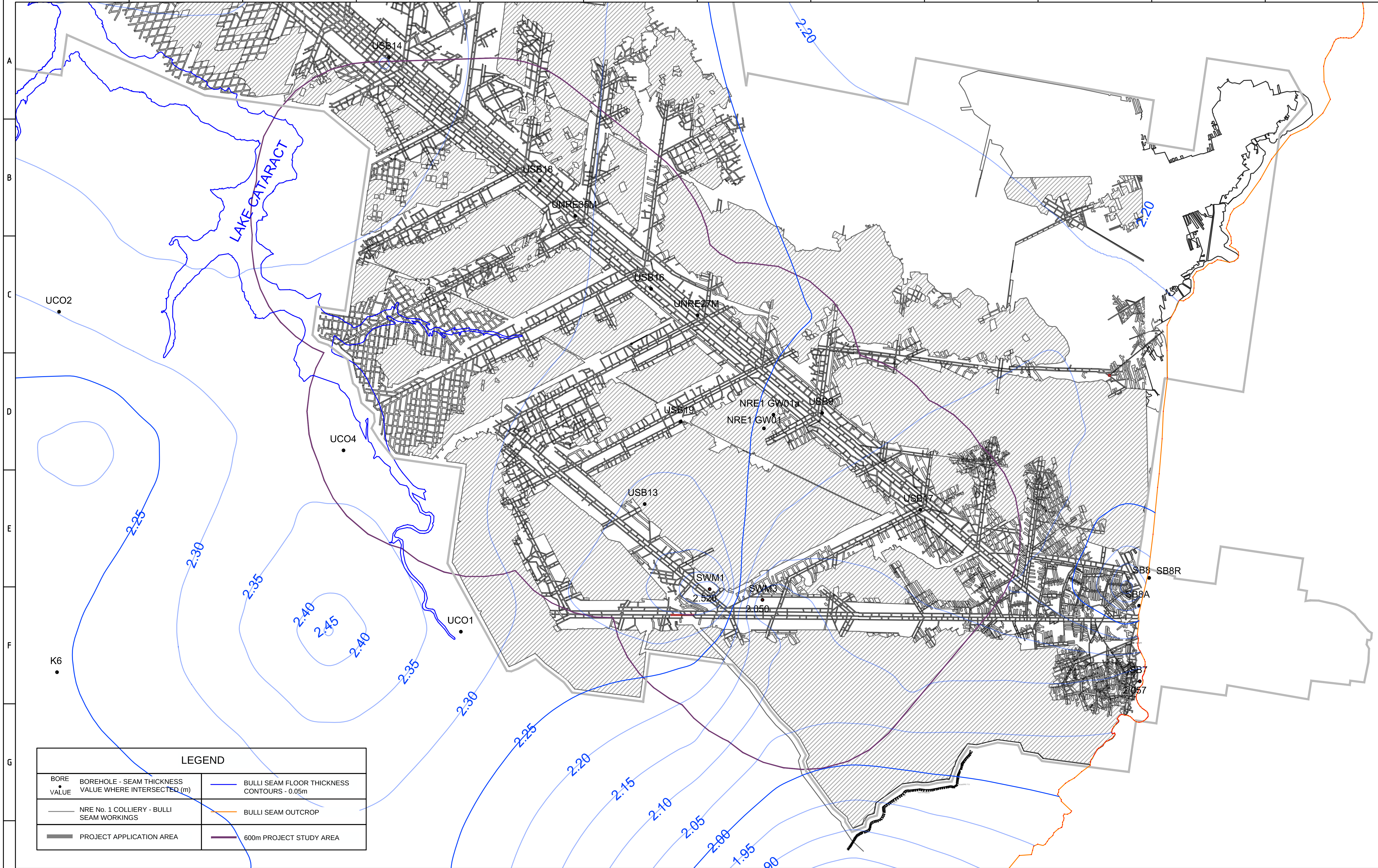
The Cape Horn Seam is uneconomic with thickness typically varying between 0.06m and 0.8m and varying in composition from carbonaceous shale to bright coal. It occurs about 9.5m below the Balgownie Coal and identification is facilitated by the occurrence of the overlying Lawrence Sandstone Member.

2.2.1.4 Hargrave

This seam is separated from the overlying Cape Horn Seam by about 2.5m of shale or mudstone and is not economic, varying in thickness from 0.1m to 0.50m and in composition from bright coal to carbonaceous shale.

2.2.1.5 Wongawilli

The Wongawilli Seam varies in thickness from 7.7m to 11.9m across the Colliery and consists of interbedded bands of brown mudstone or grey shales and coal plies.



REV	DESCRIPTION	DATE	DRN	CKD	REV	DESCRIPTION	DATE	DRN	CKD

NRE No. 1 Colliery

GUJARAT NRE Coking Coal Pty Ltd

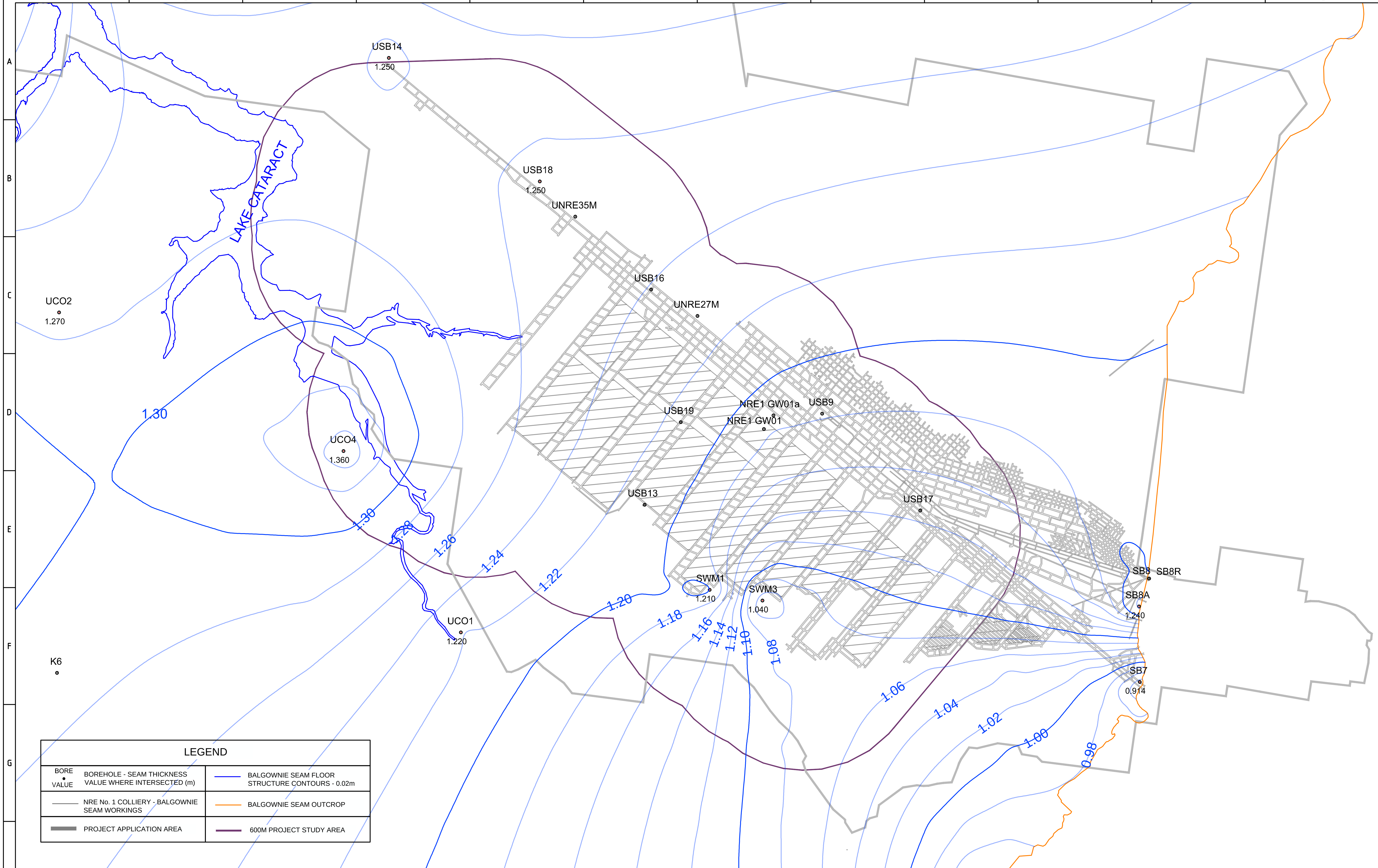
Princess Highway & Bellmabi Lane, Russell Vale, NSW. 2517
ABN 28 111 244 896

	Name	Date
DRN	RC	30.07.13
CKD		
APP	BC	
SCALE	1:15000	

Title
NRE No. 1 COLLIERY - PART 3A APPLICATION PPR
BULLI SEAM THICKNESS
AREA - WONGA EAST

DRAWING NUMBER FIGURE 4

REV 0



REV	DESCRIPTION	DATE	DRN	CKD	REV	DESCRIPTION	DATE	DRN	CKD

NRE No. 1 Colliery

GUJARAT NRE Coking Coal Pty Ltd

Princess Highway & Bellmabi Lane, Russell Vale, NSW. 2517

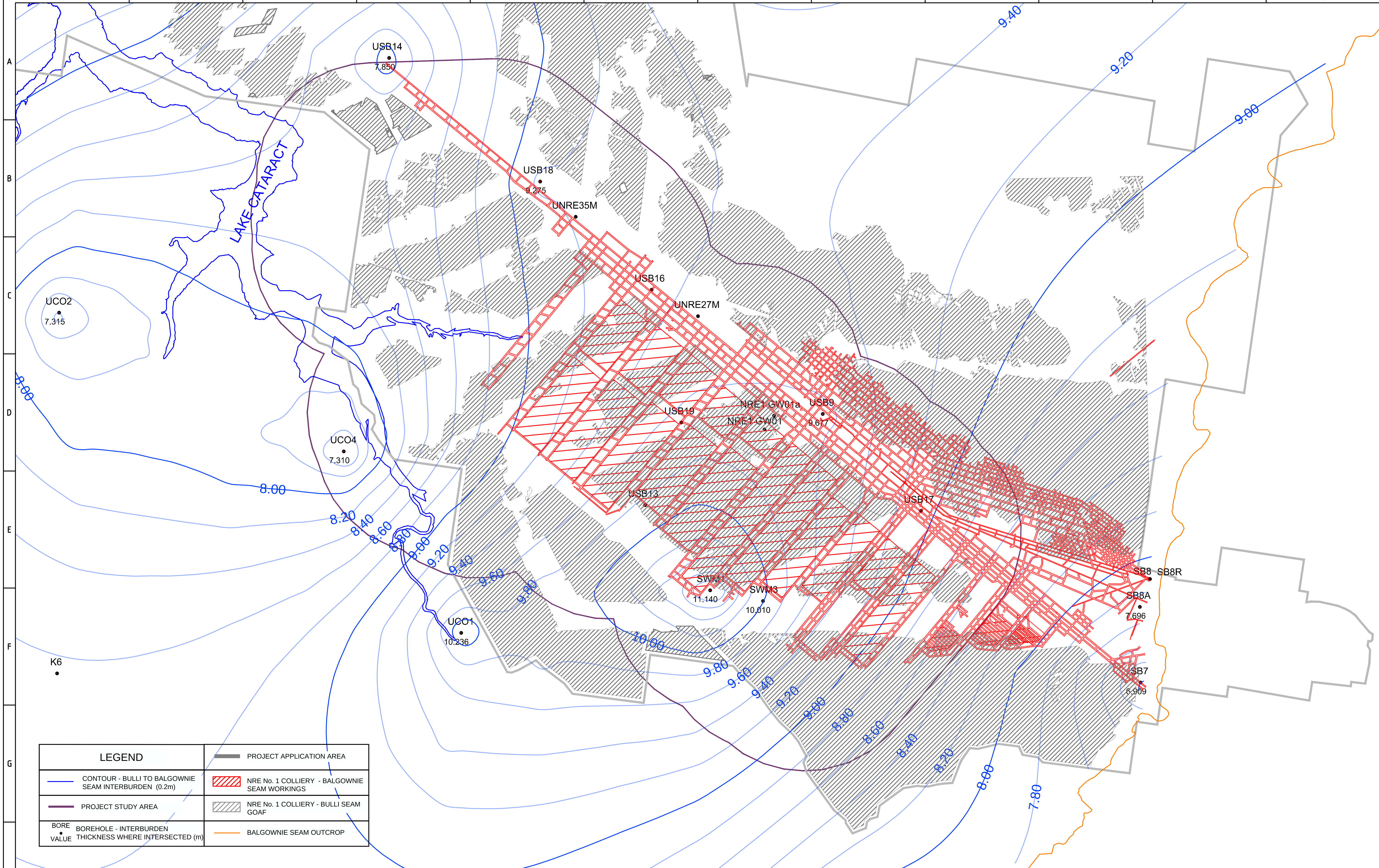
ABN 28 111 244 896

	Name	Date
DRN	RC	30.07.13
CKD		
APP	BC	
SCALE	1:15000	

Title: NRE No. 1 COLLIERY - PART 3A APPLICATION PPR
BALGOWNIE SEAM THICKNESS
AREA - WONGA EAST

DRAWING NUMBER: FIGURE 5

REV: 0



REV	DESCRIPTION	DATE	DRN	CKD	REV	DESCRIPTION	DATE	DRN	CKD

NRE No. 1 Colliery

GUJARAT NRE Coking Coal Pty Ltd

Princess Highway & Bellmabi Lane, Russell Vale, NSW. 2517
ABN 28 111 244 896

	Name	Date
DRN	RC	30.07.13
CKD		
APP	BC	
SCALE	1:15000	

Title NRE No. 1 COLLIERY - PART 3A APPLICATION PPR LODDON SANDSTONE THICKNESS VARIATION AREA - WONGA EAST

DRAWING NUMBER FIGURE 6

REV 0

In the NRE No.1 Wonga East Study Area there is a basal mining section varying between 2.6m to 2.8m that has been identified as the economic longwall mining section. Figure 7 details the mining section thickness across the Wonga East area.

The interval between the Bulli Seam and the roof of the Wongawilli mining section averages around 32m in the NRE No.1 lease area. Figure 8 details this interburden thickness.

2.2.1.6 American Creek

Occurring about 10m below the Wongawilli Seam the seam varies between 0.4m and 3.6m thick, consisting mainly of carbonaceous and coaly shale and is uneconomic.

2.2.1.7 Tongarra

Occurs about 33m below the American Creek Seam the Tongarra Seam has no economic potential, consisting mainly of carbonaceous shale and mudstone bands with thin coaly plies. Averages thickness is about 1.8m.

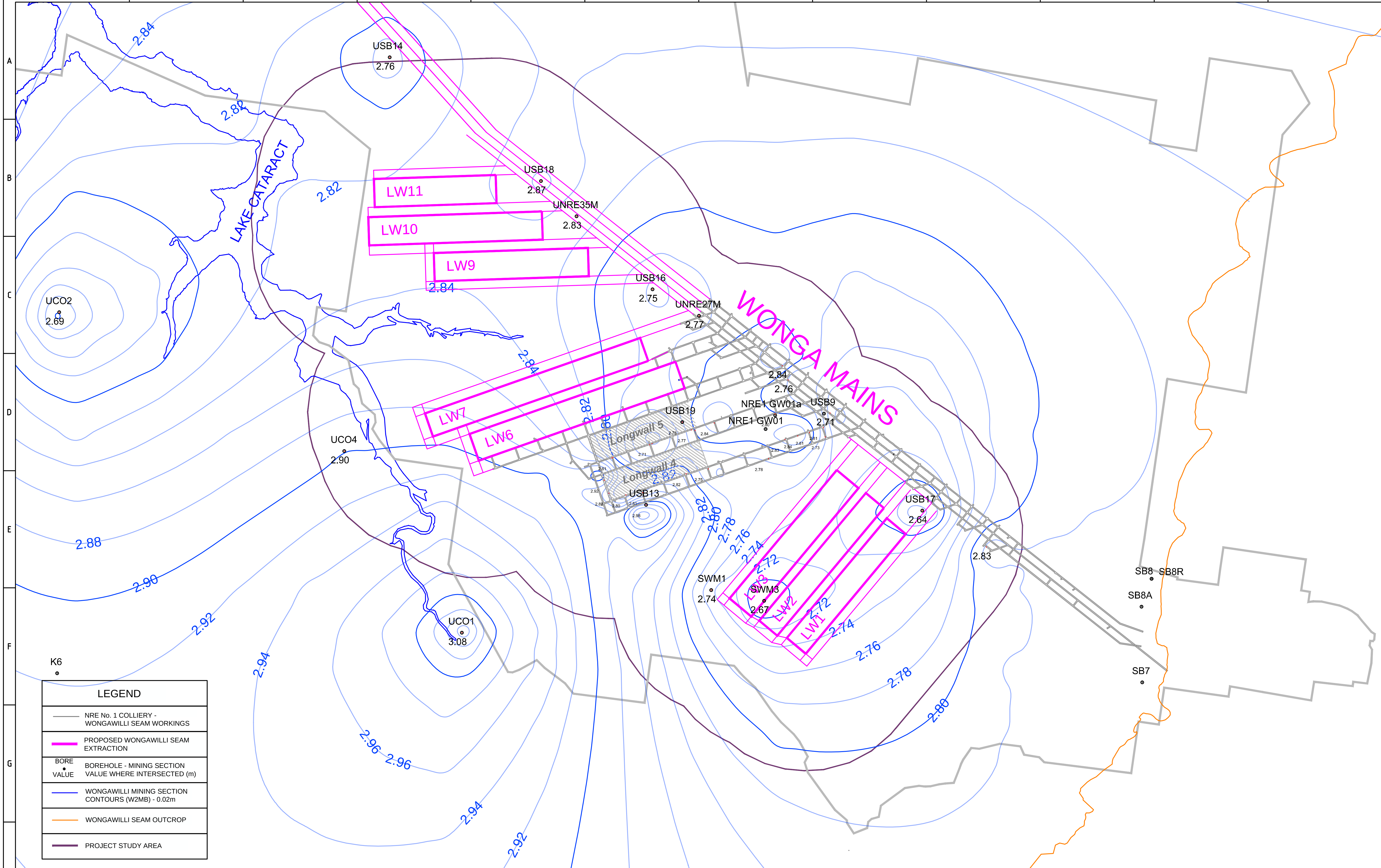
2.2.1.8 Other Seams

Three other seams are known to occur below the Tongarra Seam, namely the Woonona, Figtree and Unanderra Seams. Occurring about 17m below the Tongarra Seam the Woonona Seam is about 0.40m thick. Approximately 40m below the Woonona, the Figtree Seam is about 0.1m thick. The Unanderra Seam generally consists of numerous splits over an interval thickness of 9.5m and occurs some 17m below the Figtree Seam.

2.3 Depth of Cover

Topographic relief over NRE No.1 Wonga East Study Area consists of a series of ridges and plateaux that slope down into the Cataract Reservoir and its tributaries which incise the landscape. Figure 9 details the surface topography of the Study Area.Over the Study Area the depth of cover varies from around 225m toward the escarpment to over 350m in the northwest of the Wonga East area. The attached depth of cover plan, Figure 10, is to the roof of the Bulli Seam.

Depth of cover for the lower seams has similar trends to the Bulli Seam with the roof of the Balgownie Seam some 11.7m deeper than the Bulli Seam floor. For the Wongawilli Seam depth of



LEGEND

	NRE No. 1 COLLIERY - WONGAWILLI SEAM WORKINGS
	PROPOSED WONGAWILLI SEAM EXTRACTION
BORE VALUE	BOREHOLE - MINING SECTION VALUE WHERE INTERSECTED (m)
	WONGAWILLI MINING SECTION CONTOURS (W2MB) - 0.02m
	WONGAWILLI SEAM OUTCROP
	PROJECT STUDY AREA

REV	DESCRIPTION	DATE	DRN	CKD	REV	DESCRIPTION	DATE	DRN	CKD

NRE No. 1 Colliery

GUJARAT NRE Coking Coal Pty Ltd

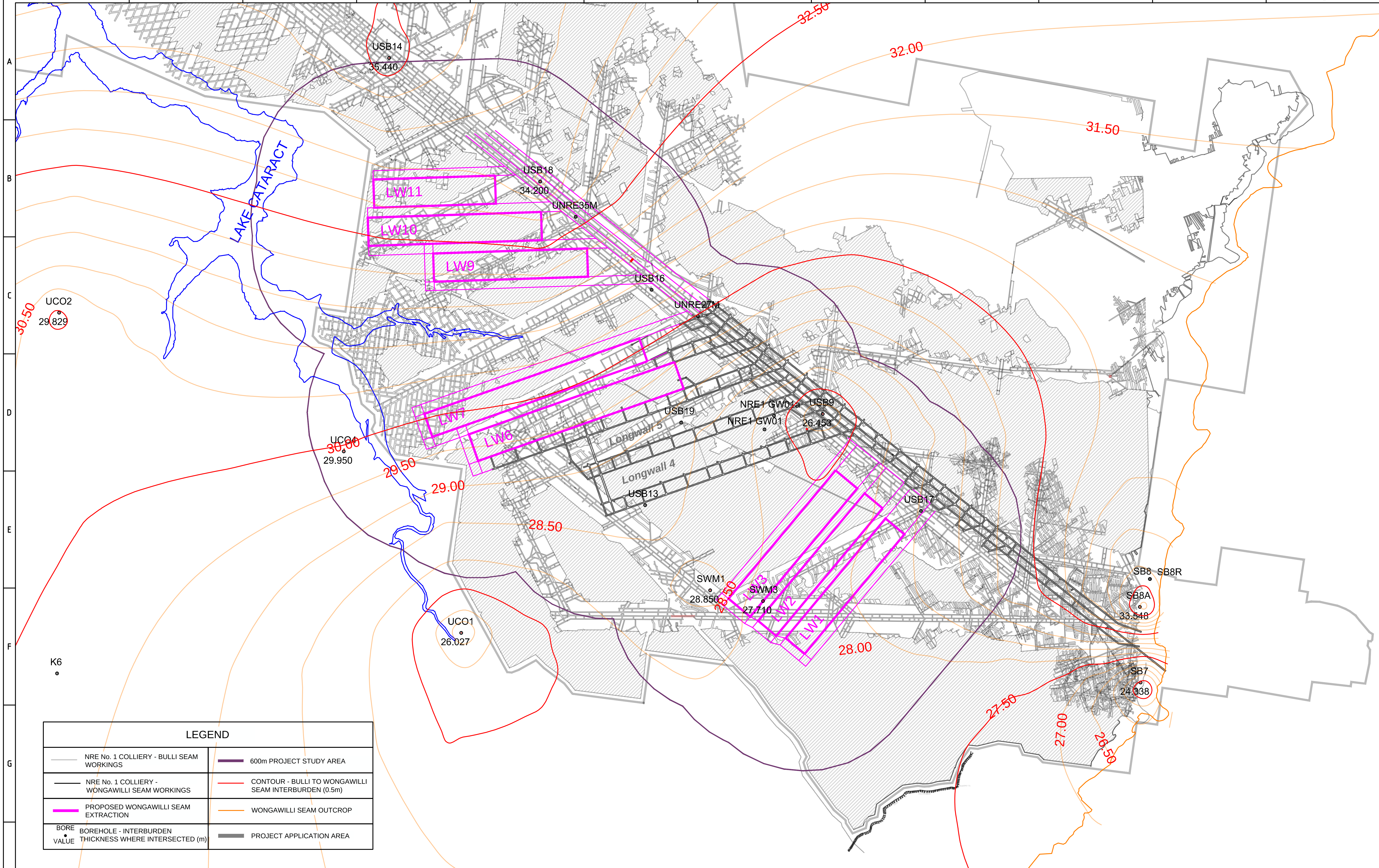
Princess Highway & Bellmabi Lane, Russell Vale, NSW. 2517
ABN 28 111 244 896

	Name	Date
DRN	RC	30.07.13
CKD		
APP	BC	
SCALE	1:15000	

Title: NRE No. 1 COLLIERY - PART 3A APPLICATION PPR
WONGAWILLI SEAM - MINING SECTION THICKNESS (W2MB)
AREA - WONGA EAST

DRAWING NUMBER: FIGURE 7

REV: 0



REV	DESCRIPTION	DATE	DRN	CKD	REV	DESCRIPTION	DATE	DRN	CKD

NRE No. 1 Colliery

GUJARAT NRE Coking Coal Pty Ltd

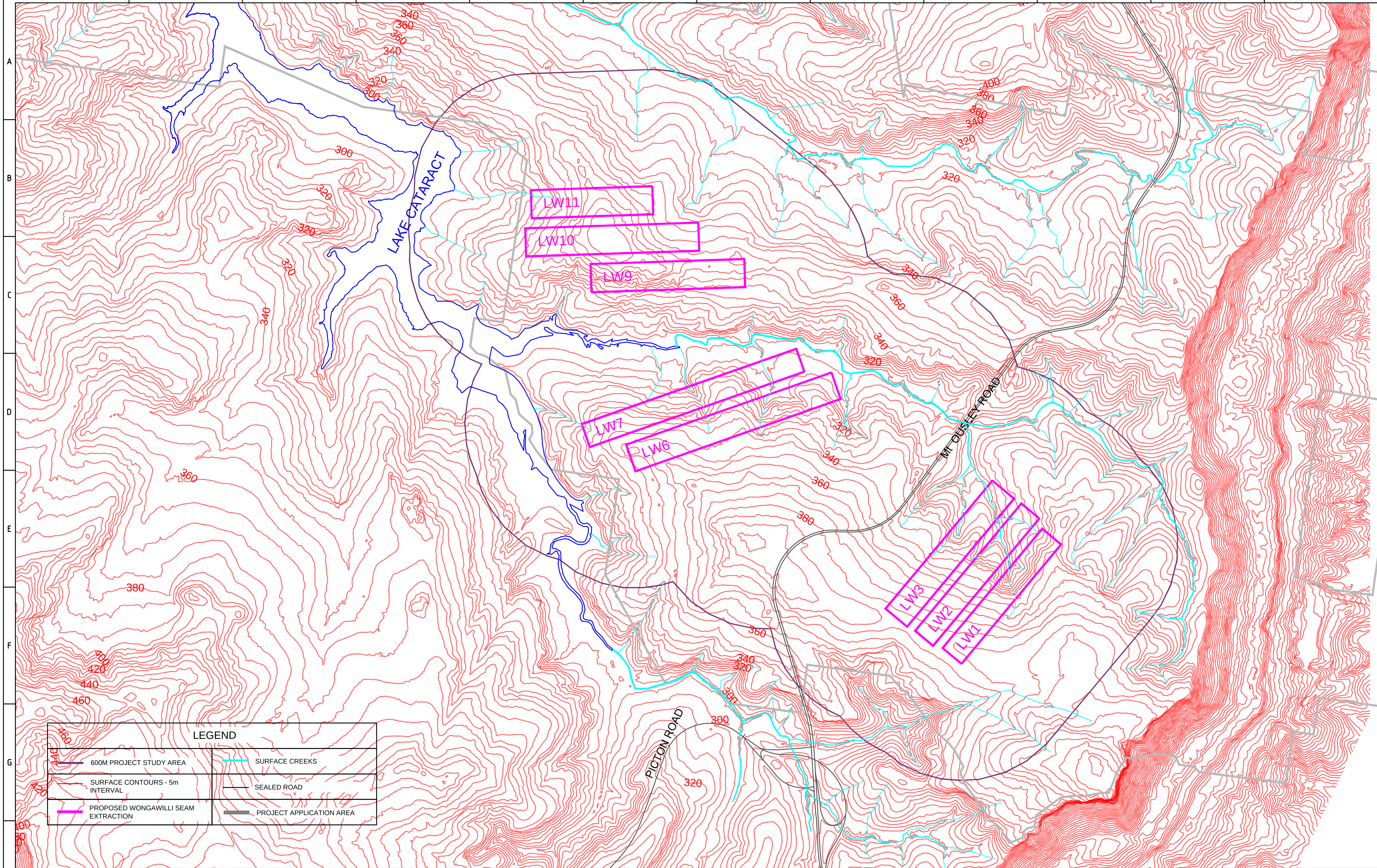
Princess Highway & Bellmabi Lane, Russell Vale, NSW. 2517
ABN 28 111 244 896

	Name	Date
DRN	RC	30.07.13
CKD		
APP	BC	
SCALE	1:15000	

Title: NRE No. 1 COLLIERY - PART 3A APPLICATION PPR
BULLI - WONGAWILLI SEAM INTERBURDEN
AREA - WONGA EAST

DRAWING NUMBER: FIGURE 8

REV: 0



REV	DESCRIPTION	DATE	DRN	CKD	REV	DESCRIPTION	DATE	DRN	CKD

NRE No. 1 Colliery

GUJARAT NRE Coking Coal Pty Ltd

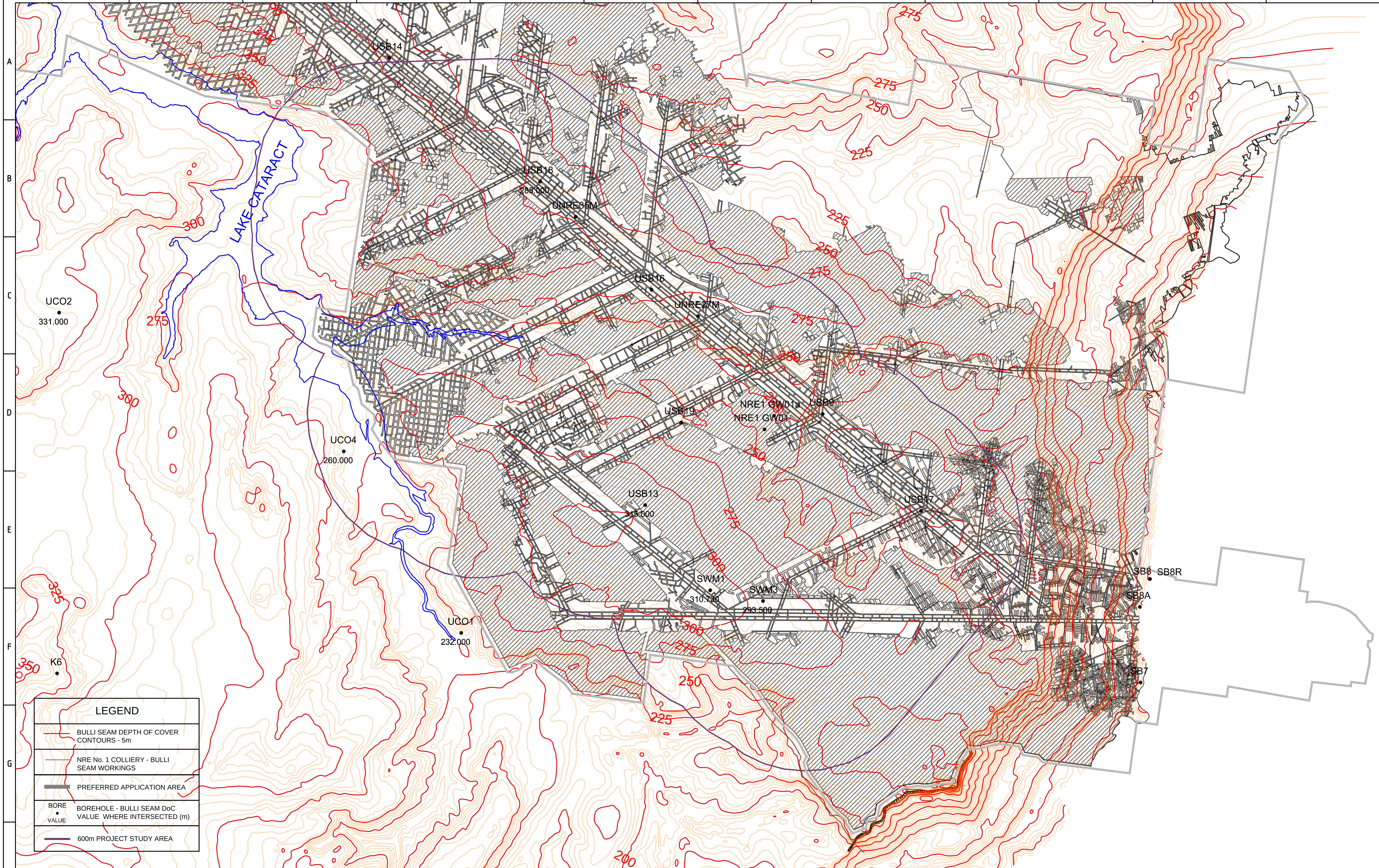
Princess Highway & Bellmabi Lane, Russell Vale, NSW. 2517
ABN 28 111 244 896

	Name	Date
DRN	RC	30.07.13
CKD		
APP	BC	
SCALE	1:15000	

Title: NRE No. 1 COLLIERY - PART3A APPLICATION PPR
TOPOGRAPHIC DETAILS & SURFACE CREEKS
AREA - WONGA EAST

DRAWING NUMBER: FIGURE 9

REV: 0



REV	DESCRIPTION	DATE	DRN	CKD	REV	DESCRIPTION	DATE	DRN	CKD

NRE No. 1 Colliery

GUJARAT NRE Coking Coal Pty Ltd

Princess Highway & Bellmabi Lane, Russell Vale, NSW. 2517
ABN 28 111 244 896

	Name	Date
DRN	RC	10.07.13
CKD		
APP	BC	
SCALE	1:15000	

Title
NRE No. 1 COLLIERY - PART 3A APPLICATION PPR
BULLI SEAM - DEPTH OF COVER
AREA - WONGA EAST

DRAWING NUMBER: FIGURE 10
REV: 0

cover is taken to the top of the planned longwall extraction height which is 2.8m. Depth to the mining roof for the Wongawilli Seam from the Bulli Seam floor averages 32.5m.

2.4 Surface Geology

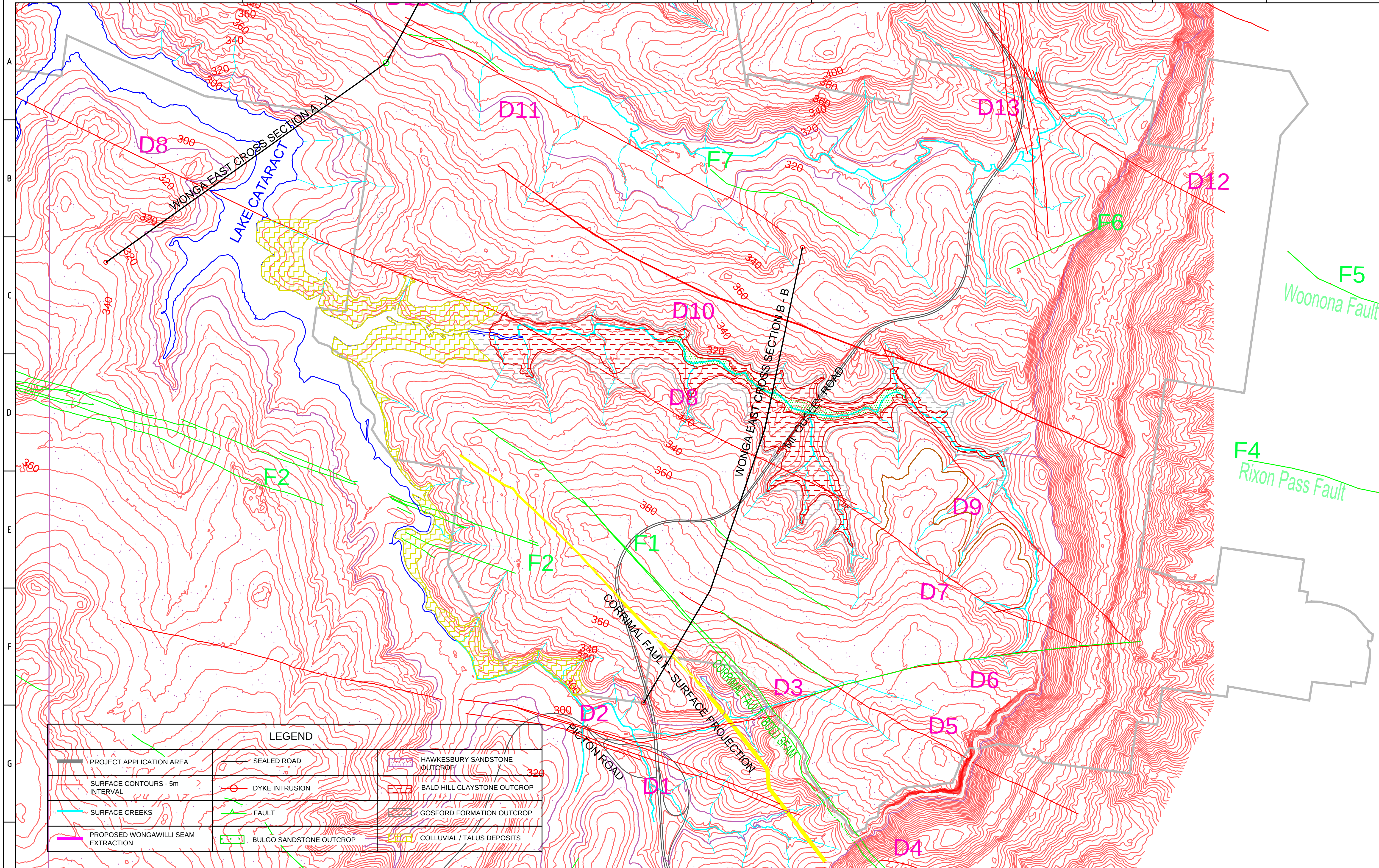
Surface geology in the Wonga East Study Area has been reviewed through ground proofing traverses, detailed Lidar topographic data at 1.0m contour intervals and aerial photography. Figure 11 details the understanding of the surface geology to date and the following section discusses the interpretation.

Dominant over the plateaux and ridges is the Hawkesbury Sandstone forming prominent cliff lines in some areas. Descending into the Cataract Reservoir foreshore the Hawkesbury Sandstone is still prominent on the eastern Reservoir shoreline where alluvium and colluvial deposits cover any outcrop of the lower stratigraphy. This colluvial deposit is still prominent toward Cataract Creek until the Gosford Formation, likely the lower Garie Formation, becomes evident. Further east along Cataract Creek the Bald Hill Claystone becomes evident in the creek bed. Approximately 800m west of Mt. Ousley Road the Bulgo Sandstone becomes evident in the creek bed. The Bulgo Sandstone appears to have undergone a small amount of erosion given the proximity of the Bald Hill Claystone boundary. The outcrop of the Bulgo Sandstone remains east of Mt. Ousley Road within the base of the Cataract Creek for about 500m, often covered by Bald Hill Claystone derived alluvium. East of Mt. Ousley Road the Bald Hill Claystone is prominent in the main tributaries of the Cataract Creek before ascending through the Gosford Formation to the widespread Hawkesbury Sandstone.

Figure 12 details two cross-sections within the Study Area, their traces are shown on Figure 11 as section lines A – A and B – B. These cross-sections show consistency in strata thickness across the Study Area with section B – B indicating a slight anticline across the northern section of the project area.

2.5 BULLI SEAM STRUCTURE

The contours of the floor level of the Bulli Seam (AHD) are based on surface drilling and Colliery workings and are shown in Figure 13. The extensive workings of the Bulli Seam and information from surrounding collieries (Bulli, Cordeaux and Corrimal) have been used to develop an understanding of



REV	DESCRIPTION	DATE	DRN	CKD	REV	DESCRIPTION	DATE	DRN	CKD

NRE No. 1 Colliery

GUJARAT NRE Coking Coal Pty Ltd

Princess Highway & Bellmabi Lane, Russell Vale, NSW. 2517
ABN 28 111 244 896

	Name	Date
DRN	RC	10.07.13
CKD		
APP	BC	
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Title: NRE No. 1 COLLIERY - PART 3A APPLICATION PPR
TOPOGRAPHIC DETAILS, SURFACE FEATURES & GEOLOGY
AREA - WONGA EAST

DRAWING NUMBER: FIGURE 11

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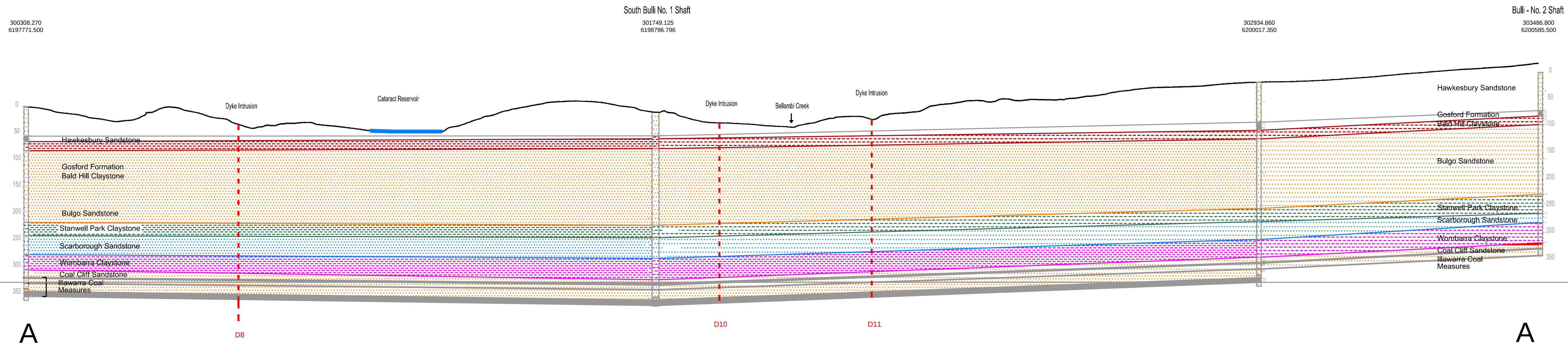

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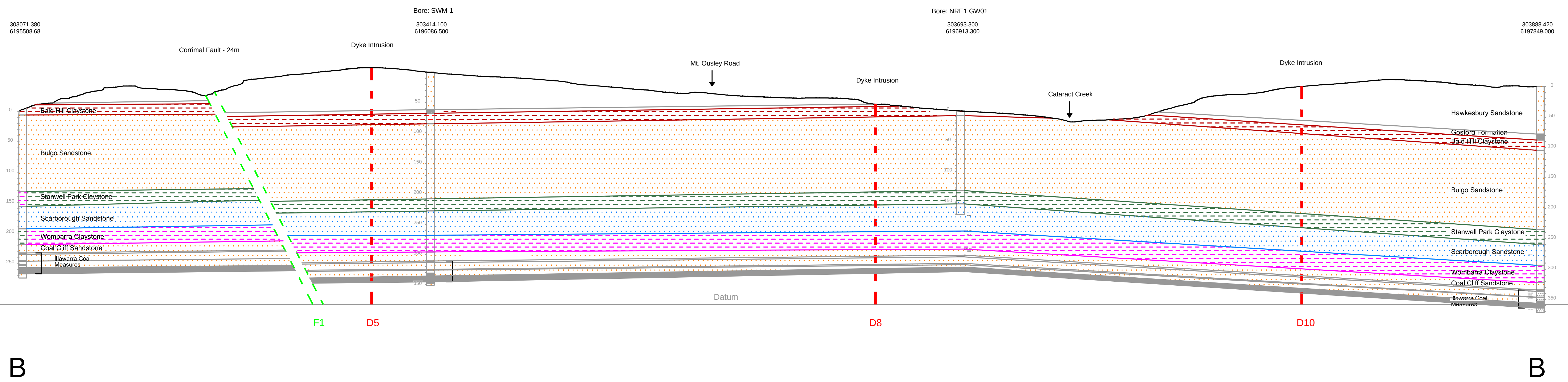

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NRE No. 1 Colliery

GUJARAT NRE Coking Coal Pty Ltd

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ABN 28 111 244 896

	Name	Date
DRN	RC	05.07.13
CKD		
APP		
SCALE	SHOWN	

Title
NRE No. 1 COLLIERY - PART 3A APPLICATION PPR
SECTION OF STRATA
AREA: WONGA EAST

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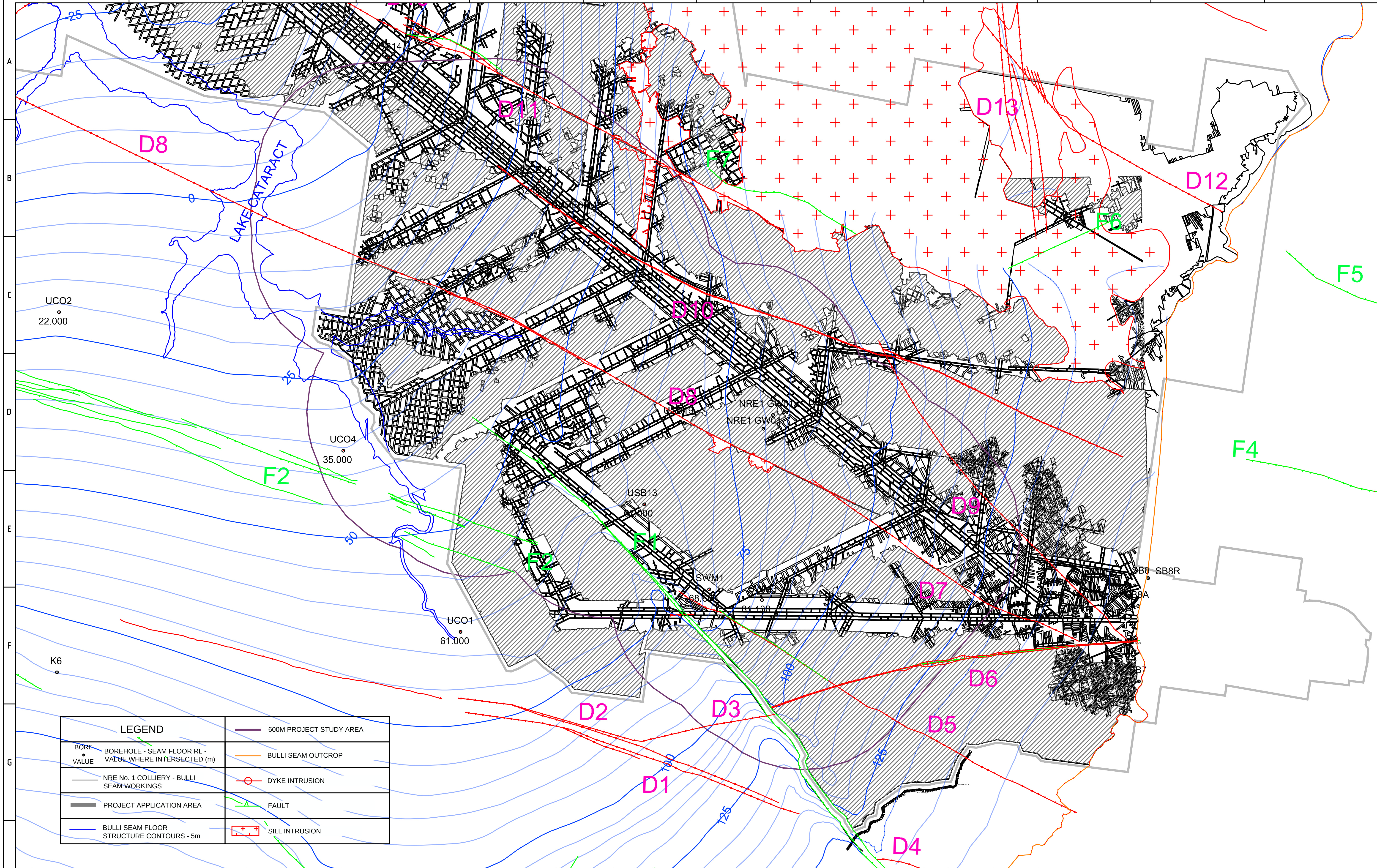

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NRE No. 1 Colliery

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APP	BC	
SCALE	1:15000	

Title: NRE No. 1 COLLIERY - PART 3A APPLICATION PPR
BULLI SEAM STRUCTURE
AREA - WONGA EAST

DRAWING NUMBER: FIGURE13

REV: 0

the structural nature of the Bulli Seam in the NRE No.1 Wonga East Study Area. The Bulli Seam across this area dips to the west-nor-west from 1 in 25 to 1 in 30 and reflects the eastern section of a broad synclinal structure (South Bulli Syncline) and minor anticline structure toward the north of the Study Area.

Figure 14 details the known structures in the Bulli Seam for the Wonga East Study Area. These structures have been derived from detailed examination of available mine plans. Each structure is annotated for easy reference and discussed in the following sections on faulting and igneous intrusions.

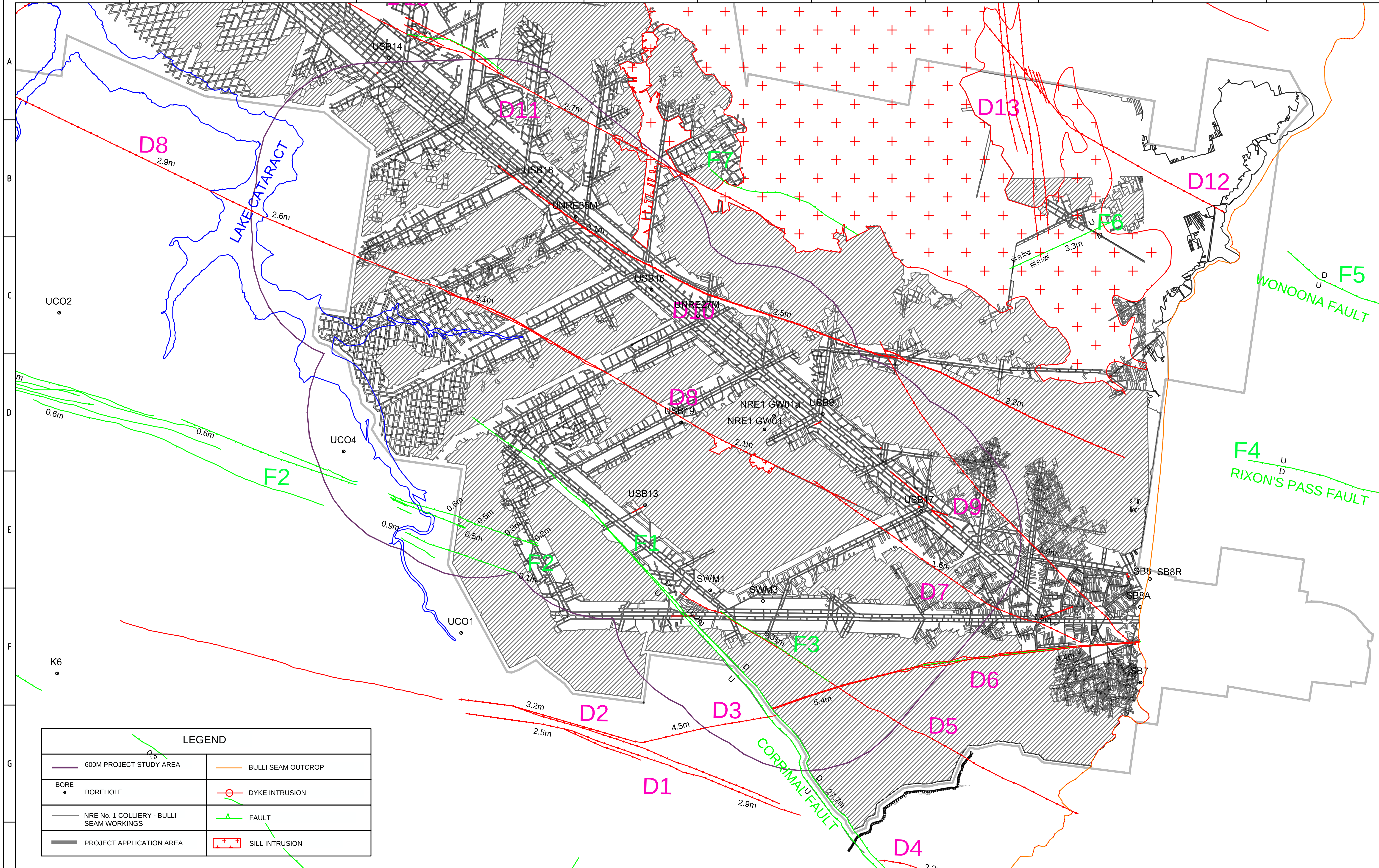
2.5.1 Faulting

Fault F1, commonly known as the Corrimal Fault, occurs from outcrop and extends approximately 3000m to the northwest (bearing 320 degrees) before dying out. Maximum recorded displacement has been measured at 28.7m with a fault width of approximately 20m. There are no records or documentation indicating moisture ingress being associated with the fault.

Fault F2 is a fault zone, some 170m wide, prominent in Corrimal Colliery and extending approximately 400m into the workings of South Bulli Colliery before dying out. Maximum displacement within the zone is 0.9m with the majority of the faults 0.6m or less and with a range in displacements from 0.1m to 0.9m. Strike of the fault zone is 110 degrees.

Fault F3 is a short strike length feature (approximately 610m long) bearing 300 degrees and is associated with dyke D5. It has a recorded displacement of 0.31m downthrown to the north. It is probable the fault formed as a result of the forces occurring during the injection of the dyke due to its concurrence with the dyke and its short strike length.

Fault F4 is recognized as the Rixon's Pass Fault and is believed to have been intersected, possibly in the Tongarra Seam, in a clay quarry east of the escarpment (Illawarra Brick Company quarry). The fault is annotated as being downthrown to the south and bears 285 degrees. No record of displacement of the fault has been found. Detailed examination of the South Bulli mine plans indicate the fault does not project to the west into the workings. There is a possible correlation with a thin, soft dyke (dyke D10) within the South Bulli Colliery workings but there is no record of this dyke being associated with faulting.



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Title

NRE No. 1 COLLIERY - PART 3A APPLICATION PPR

BULLI SEAM GEOLOGICAL PLAN

AREA - WONGA EAST

DRAWING NUMBER FIGURE 14

REV 0

Fault F5 is recognized as the Woonona Fault and occurs west of the escarpment. The fault is annotated as being downthrown to the north, arcuate (curved) in nature and bearing approximately 290 degrees. No recorded displacement of the fault has been sighted. The origin of the Woonona Fault is unknown. There is no record of the fault appearing in the South Bulli Colliery workings. It correlates closely with a thin, soft dyke (dyke D12) but again there is no record of faulting associated with the dyke.

Fault F6 is known from South Bulli Colliery workings with a recorded displacement of 3.3m. The fault has a strike length of approximately 500m and bears 60 degrees and may have an association with the major intrusion in the Bulli seam, the Bulli Sill Complex, as the sill is in the roof to the southeast of the fault and in the floor to the northwest.

Fault F7 is known from South Bulli Colliery workings with a strike length of about 830m, bearing 290 degrees and has no recorded displacement but from the mine plans it did not appear to cause disruption to the workings. The inference from this is the fault was of a small displacement allowing workings to be developed through the fault.

2.5.2 Igneous Intrusions

2.5.2.1 Dykes

Within the South Bulli Colliery mine workings of NRE No.1 Wonga East Study Area and surrounding collieries igneous intrusions of dykes and sills have been intersected within the Bulli seam. Dykes are the most common form of igneous intrusion and are generally oriented in a northeast – southwest direction, within the Study Area trending about 120 degrees. Igneous intrusions discussed here are shown and annotated in Figure 14.

Dykes D1 and D2 was intersected in Corrimal Colliery with thickness up to 3.2m, strike of 110 degrees and extent of over 3500m.

Dyke D3 is most likely a continuation of dyke D6, being offset across the Corrimal Fault. Thickness is 4.5m, strikes at 150 degrees and is 650m long.

Dyke D4 is also most likely a continuation of either dykes D1 or D2 and again is offset across the Corrimal Fault. Thickness is 3.3m, strike of 110 degrees and extent of 650m to outcrop.

Dyke D5 extends from outcrop for approximately 2300m before dying out near the Corrimal Fault. Thickness has been estimated from mine plans at about 1.5 to 1.6m. The dyke, striking 300 degrees, appeared to cause no disruption to mining based on the mine workings and is assumed to be a soft clay dyke.

Dyke D6 strikes at 80 degrees, strike length of 1890m and has a measured thickness of 4.4m and where it has silled into the Bulli seam appears to be about 10m which is likely to include the cinder zone and hardened coal. Mine workings skirted the dyke implying some degree of hardness.

Dyke D7 is estimated from mine plans to be about 1.6m thick and appears thin and soft from mine plan details. The dyke has a strike length of 1500m and strike direction of 300 degrees.

Dyke D8 is the most prominent in the Bulli Seam workings in the Wonga East area and extends for over 7.0km to the northwest (bearing 300 degrees) before dying out. It has a recorded thickness range of 2.1m to 3.1m and is associated with seam silling and cindering. The dyke is hard and possibly syenitic in nature.

Dyke D9 has a measured thickness of 0.9m and is soft clay. It has a strike length of 1900m and bears 325 degrees.

Dyke D10 has a recorded thickness of up to 3.1m and is noted as soft. The dyke has a strike length of 3700m and bears 290 degrees. The dyke is associated with silling in the seam floor near the escarpment and dies out within the Wonga East Study Area.

Dyke D11 has a recorded thickness of 2.7m near its convergence with the Bulli Sill Complex. The dyke is soft and becomes thin and intermittent on its projection to the west-nor-west (bearing 300 degrees). Overall length is 2750m.

Dyke D12 has no recorded thickness but appears to be soft and did not hinder mine development to any major extent. The dyke has a strike length of 1650m before it loses its identity within the Bulli Sill Complex. The dyke may be correlated with the Woonona Fault but there is no indication the dyke has a fault component.

Dyke D13 is a swarm of thin and intermittent soft clay dykes that bear almost north south. The swarm is likely to be related to the Bulli Sill Complex. The dykes had minimal impact on mine development.

Dyke D14 has an east west strike and length of 1400m and is coincident with the northern colliery boundary between Old Bulli Colliery and NRE No.1. No information on the dyke has been sighted and the dyke dies out to the west within the South Bulli mine workings, being soft and thin.

Dyke D15 has a recorded thickness of 1.2m, striking parallel to dyke D11 for approximately 1400m and tapers out to the west-nor-west. The dyke appears to be soft and had no impact on mine development.

2.5.2.2 Silling

Sills have a far greater impact on mine development than dykes. Their lateral intrusive nature often means that large areas of coal seams (often hectares) can be rendered uneconomic due to complete replacement (ingestion) of the coal or cindering, alteration and/or loss of coking properties. Sills are erratic and the larger sills are often transgressive in nature (intrude across several seams) and historically their definition other than in a general way has been difficult to define prior to mining. Within the Wonga East Study Area there is a significant sill event, the Bulli Sill Complex which has an areal extent of over 13km^2. The sill complex is transgressive in nature, known to intrude the Bulli, Balgownie and Wongawilli seams in NRE No.1 and affecting other collieries to the north. Mine workings within the Bulli seam at various collieries have enabled an accurate boundary definition of the Sill complex to be established and this is shown in Figure 14.

2.6 BALGOWNIE SEAM STRUCTURE

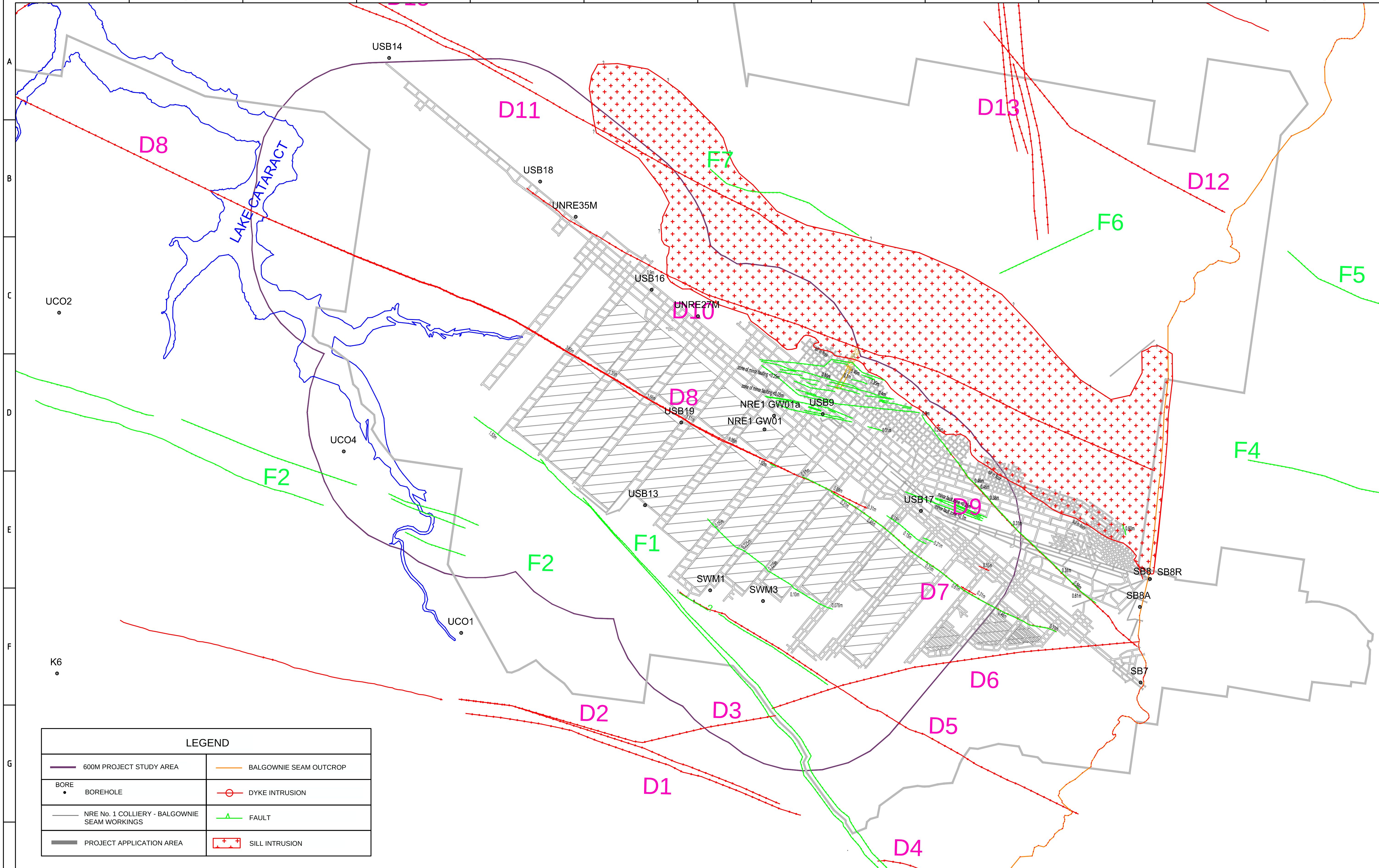
Mining within the Balgownie Seam in the Wonga East Study Area was undertaken between 1968 and 1982 (longwall method) and again in 2001 to 2003 (pillar driveage). Figure 15 details the mine workings and the known and interpreted geological structures within the seam.

2.6.1 Faulting

Faulting intersected by the Balgownie workings displays some correlation with known faulting in the overlying Bulli Seam.

Fault F1 in the Bulli Seam (Corrimal Fault) was intersected in a heading of gate road driveage and had a displacement of 1.53m and was offset 7.0m to the north from the fault position in the Bulli seam.

Fault F3 in the Bulli seam was associated with dyke D5. Intersected in an overdrive heading the fault and dyke still appear together in a very similar location to the location in the Bulli Seam. This gives weight to the fault being formed during injection of the dyke as the fault has no offset to its position in the Bulli seam.



REV	DESCRIPTION	DATE	DRN	CKD	REV	DESCRIPTION	DATE	DRN	CKD

NRE No. 1 Colliery

GUJARAT NRE Coking Coal Pty Ltd

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ABN 28 111 244 896

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NRE No. 1 COLLIERY - PART 3A APPLICATION PPR
BALGOWNIE SEAM GEOLOGICAL PLAN
AREA - WONGA EAST

DRAWING NUMBER: FIGURE 15

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Additional faulting intersected in the Balgownie workings have no expression in the overlying Bulli Seam. This faulting, consisting of very small scale displacements, is generally less than 0.3m and primarily confined to the more recent 2001 to 2003 workings. It is suggested here that the faulting to be a result of tensional deformation of the Balgownie seam due to increased stress levels from to goaf formation from longwall extraction in the Balgownie seam and the interaction from overlying Bulli seam pillars and goaf. The minor fault zones have a very limited strike length.

2.6.2 Igneous Intrusions

2.6.2.1 Dykes

Balgownie seam workings intersected 5 dykes. These dykes project through to the overlying Bulli Seam workings in almost the exact location indicating the dykes have been injected in a near vertical plane through the Coal Measure strata. The following dykes, annotated with the Bulli seam nomenclature in Figure 15, were intersected in the Balgownie workings.

Dyke D5 was intersected by an overdrive heading. No indication of thickness or strike length is known from the Balgownie Seam workings.

Dyke D6 was intersected in initial Balgownie Seam workings. No indication of dyke thickness has been sighted. Dyke strike direction is the same as the dyke intersected in the overlying Bulli Seam workings.

Dyke D7 was intersected in many roadways and varied in thickness from about 0.31m to 0.61m and from the Balgownie mine plan appears to be a soft clay dyke. Thickness on this dyke from the Bulli Seam workings indicated 1.5m to 1.6m. Strike length and direction are similar to the Bulli Seam dyke position.

Dyke D8, prominent in the Bulli Seam workings, is also prominent in the Balgownie Seam workings. The dyke varies from about 0.31m thick where first intersected to 3.65m at its last measured intersection. In a similar location in the overlying Bulli Seam to its last measured thickness in the Balgownie Seam the dyke was 3.7m thick. The dyke is hard and as it thickened the Balgownie seam longwall was recovered and reinstalled on a new install heading avoiding mining through the dyke.

Dyke D9 was intersected by numerous roadways. Dyke thickness has a maximum of 0.56m and dies out to the west-nor-west as it does in the Bulli Seam where it has a thickness of 0.9m.

Dyke D10 was intersected over several roadways and measured at 0.9m thick. Its thickness in the Bulli seam at a similar location was estimated at 3.1m.

2.6.2.2 Silling

Silling within the Balgownie seam was intersected by workings driven during 2001 to 2003. The silling initially appeared in the floor of the seam and has affected the quality of the coal. The extent of the sill where intersected by workings can be seen in Figure 15. The northern extent of the silling is unknown due to a lack of data but it is believed that initial workings into the Balgownie Seam by Bulli Colliery intersected igneous material.

The complexity and multiple intrusions of the silling can be seen from the location of the sill in the Balgownie seam when compared to the Bulli Seam. In the Balgownie seam the edge of the silling as defined by the workings varies between 450m to 750m further south than the edge of the silling in the Bulli Seam.

Based on the above discussion and comparison of structures intersected in both the Bulli and Balgownie seams it is justifiable to assume dykes intersected in Bulli Seam workings will be in the Balgownie seam at similar locations. Dyke thickness generally appears to be thinner in the Balgownie Seam than the Bulli Seam and may be a result of the thinner Balgownie Seam being more confined thus restricting expansion of the igneous material during injection when compared to the thicker Bulli Seam.

Projection of faulting is not as clear from the Bulli to Balgownie Seams. Based on the above analysis and previous experience of multiple seam mining in Cordeaux and Kemira Collieries minor faulting in one seam will not necessarily project through to other seams. Based on this generalization, faulting of less than approximately 0.4m occurring in one seam is not projected through to other seams. Faulting of greater than 0.4m is projected to other seams, the projection requiring an understanding of the angle of dip (hade) of the faulting to improve accuracy. Where the hade is unknown projection at an angle of 80 degrees, dependent upon its sense of throw, is used as a “best” estimate of location in other seams. Figure 15 details the known and predicted structural geology of the Balgownie seam based on the above synopsis.

2.7 WONGAWILLI SEAM STRUCTURE

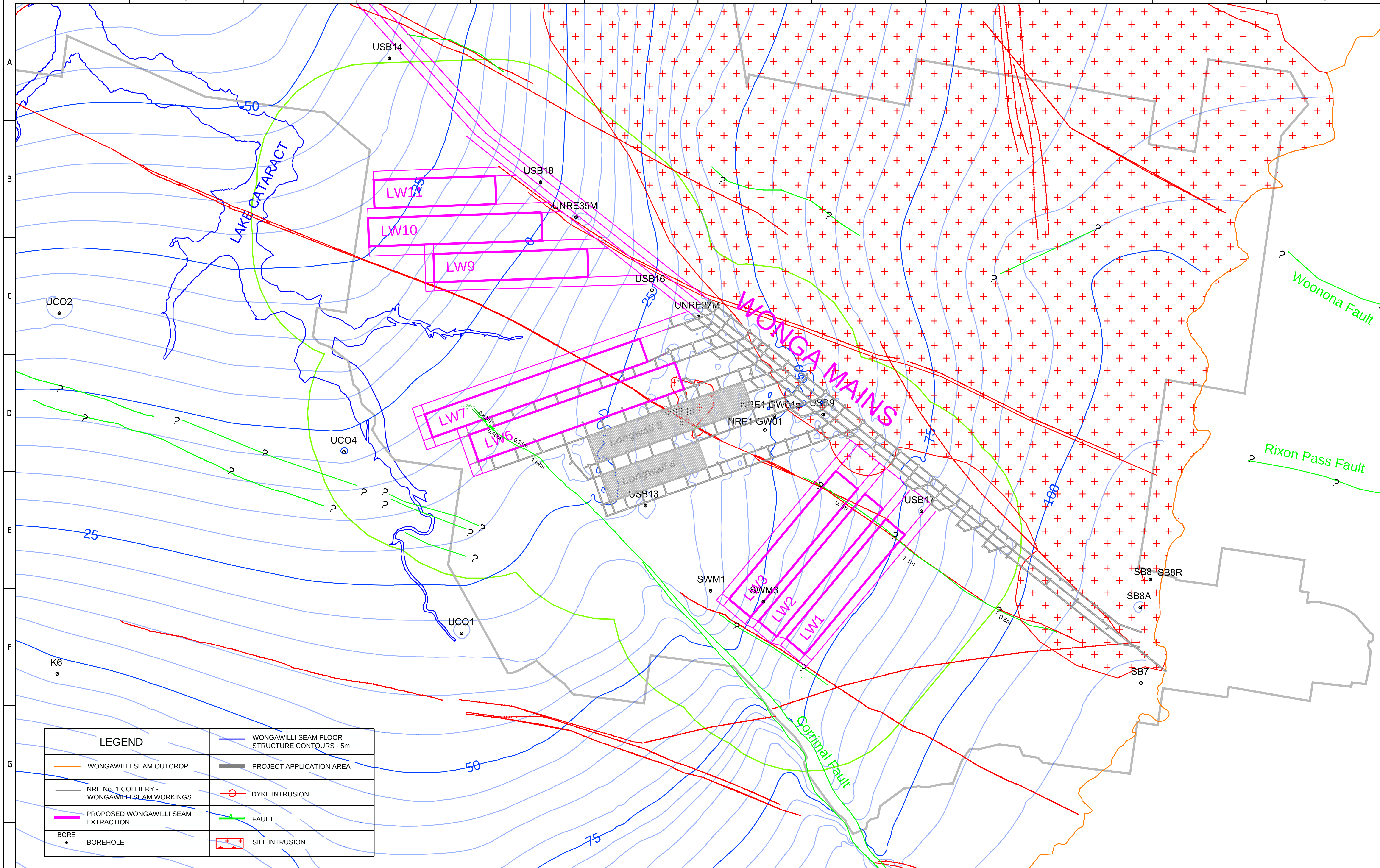
Development within the Wongawilli Seam in the Wonga East Study Area consists of mains roadways, currently reaching 2.9km from outcrop, and gate road driveage for longwall extraction with one longwall extracted (LW4) and another (LW5) currently being extracted.

The contours of the floor level of the Wongawilli Seam are based on surface drilling and mine working levels and known floor data from the overlying Bulli and Balgownie Seams and are shown in Figure 16. The Wongawilli Seam across this area dips to the west-nor-west from 1 in 25 to 1 in 30 and generally reflects the Bulli Seam floor structure. Current and proposed mine workings are also shown in Figure 16.

2.7.1 Faulting

Within the mine workings of the Wongawilli Seam the Corrimal Fault (Fault F1 in the Bulli Seam) has been intersected. No other faulting of significance has been intersected. The Corrimal Fault was first intersected in Maingate 5 development and had displacement of 1.84m to 0.35m (displacement was reassessed in MG5 B heading from 1.50m displacement to 0.35m after mining had progressed past the fault intersection) across the two headings, decreasing in displacement along its projected strike to the northwest. Characteristics of the fault are similar to those known from the Bulli and Balgownie Seams, being a normal fault down thrown to the north. Where intersected the fault had a measured dip of 35 degrees. The fault plane is offset approximately 24m to the north from its position in the Bulli Seam.

Further mine development in Maingate 6 has also intersected the Corrimal Fault. First intersected in the A Heading the fault has developed into a structural zone consisting of a set of three faults. The first fault is upthrown 0.93m followed by a downthrown fault of 0.55m and then another downthrown fault of 0.48m which decreases to 0.33m across the mined heading. This third fault is on the actual projection of the Corrimal Fault from Maingate 5. Also intersected in the B Heading the structural zone has the first fault downthrown 0.17m with the second fault downthrown 0.23m and the third fault plane downthrown 0.82m in the A heading and increasing to 0.98m across to the B heading.



REV	DESCRIPTION	DATE	DRN	CKD
1	UPDATED GEOLOGY & WORKINGS	22.05.14	RC	

NRE No. 1 Colliery

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Title
NRE No. 1 COLLIERY - PART 3A APPLICATION PPR
WONGAWILLI SEAM - SEAM STRUCTURE
AREA - WONGA EAST

DRAWING NUMBER
FIGURE 16

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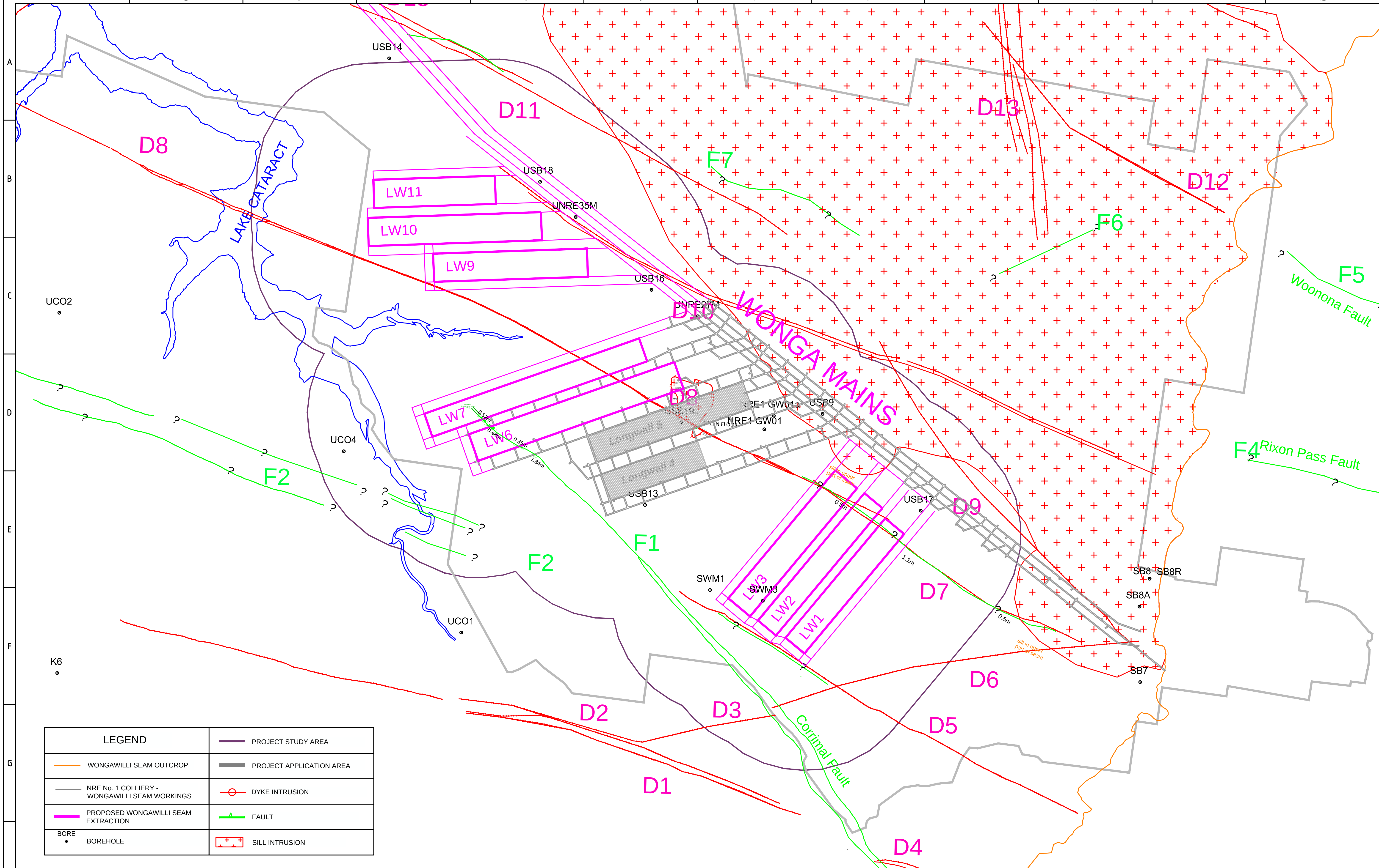
MAY 2014



REV	DESCRIPTION	DATE	DRN	CKD
1	UPDATED GEOLOGY & WORKINGS	22.05.14	RC	

NRE No. 1 Colliery

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WONGAWILLI SEAM GEOLOGICAL PLAN
AREA - WONGA EAST

DRAWING NUMBER: FIGURE 17

REV: MAY 2014

The Corrimal Fault has become erratic in nature and is displaying typical characteristics of terminating as it fragments into a series of small non-correlated faults of inconsistent displacement and sense of dip.

Based on the erratic nature of the structural zone it is predicted to decrease in severity and die out within a distance of less than 500m as shown in Figure 17 with the likelihood of further fragmentation resulting in small scale faulting disrupting mine development in the immediate location of the structures.

2.7.2 Igneous Intrusions

2.7.2.1 Dykes

Only one dyke known from the Bulli Seam workings has been intersected by current Wongawilli Seam mine development. The dyke is D8 and has been intersected in four sets of longwall gate road driveage (LW's 4, 5 and 6). The dyke has a maximum measured thickness of 4.1m and is hard and dry. It has been mined through in the current longwall 5 and was highly fractured and blocky in nature. No evidence of water ingress about the dyke was evident. Silling within the basal 2.0m of the Wongawilli Seam on the northern side of the dyke has also been intersected. The dyke continues to be consistent in its nature and remains dry.

Of the other potential dykes projected from the Bulli Seam dyke D6 was not recognized in early development and this is most likely due to silling occurring in the Wongawilli Seam at the expected location of the dyke.

Dyke D10 has not been intersected by mining but inseam drilling has detected the dyke approximately 75m ahead of current mine face location in C Heading, Wonga Mains. No details are available on its thickness but drilling indicated the dyke is soft.

2.7.2.2 Silling

Silling within the Wongawilli Seam was intersected early on in Wonga Mains driveage. The silling occurs in the roof on the northern most heading (C heading) and cuts across the seam to be in the floor in the southern most heading (A heading). The silling was intersected either in the mining section of the seam or determined to be above the mined roof by drilling with the sill extending over the first

745m of driveage. The sill was then not detected before reappearing again above the mining section in the roof at the 1600m mark and extended primarily above the mining horizon to the 2525m mark before no longer being detected.

A significant aspect of silling within the Wongawilli Seam, than in the Bulli and Balgownie Seams, is that due to the much thicker seam section the silling can, and does, occur in various sections within the seam. Thus the boundary of silling within the Wongawilli Seam as shown in Figure 17 represents a best estimate of silling within all sections of the seam. It is therefore not inconceivable that successful mining can take place within the boundary of silling where the sill is some distance above the mining section and does not impact coal quality or mining conditions.

The transgressive nature of the Bulli Sill Complex is again evident as the southern extent of the sill in the Wongawilli Seam is from between 800m to 1300m further south than the edge of the Sill Complex in the Bulli seam and between 500m to 720m south of the sill edge in the Balgownie seam.

3. DISCUSSION

A detailed review of the geological structure of the Wonga East Study Area has been undertaken as described in this report. Confidence has been established in the structural detail of the mine plans available of the workings of South Bulli Colliery through comparison and analysis of coincident structures in the workings of the Balgownie and Wongawilli seams.

The surface geology in the Wonga East Study Area has been reviewed through ground proofing traverses, detailed Lidar topographic data and aerial photography. Prominent structural features known from mine workings have been projected to the surface, either vertically for igneous dykes or at an angle for faulting determined by the hade of the fault. Figure 18 details the surface geology and any structural features that were identified as surface expressions.

In examination of the control on surface features by known geology there is some structural correlation but it is quite limited. The following section will review the projected structures and there implication on surface features.

2.8.1 Faulting

Of the prominent faults in the Study Area there is a correlation of the Corrimal Fault (Fault F1) projected to the surface with two small upper tributaries feeding the upper Cataract River approximately 840m nor-west of the escarpment. Field mapping could not identify the surface expression of the fault but a thickened section of Bald Hill Claystone on the southern side of the creek gully and apparent Hawkesbury Sandstone on the northern side imply evidence of the fault at this location.

Following the projected surface trace of the Corrimal Fault further to the northwest there is no other surface expression that is evident from ground proofing. As has been discussed in this report the validity of data on the old South Bulli mine plans has been confirmed as accurate thus confidence is high that the Corrimal Fault dies out within the Bulli seam workings and the decreasing throw of the fault in the Balgownie and Wongawilli workings support this. As such it is considered that any connection of the fault to surface waters of the Cataract Reservoir is not possible. Reactivation of the fault due to subsidence is considered remote with the main section of the fault well away from the main body of stored water. Subsidence lines along the middle of Longwall 4 and Longwall 5 have been traversed and no evidence of the fault trace or any movement that could be interpreted as a result of fault reactivation was found.

Small scale fault swarm F2 emanates from Corrimal Colliery and dies out in the old South Bulli workings. There appears to be a correlation with two bends in Cataract Reservoir / Cataract River. As no detail on the dip of the fault swarm is known an estimation of 80 degrees has been used. The surface expression of the projection of the fault swarm does not correspond with the river bends when projected to the surface. There is no surface feature that the projected fault swarm corresponds with hence there can be no connection with fault swarm F2 to the surface. It is more likely the surface expression of the reservoir is joint controlled within the Hawkesbury Sandstone outcrop.

There is no correlation of any surface feature with the Rixon's Pass Fault trace which, as discussed in the report, has no expression in any workings and as such is proposed not to exist west of the escarpment.

Within the Balgownie Seam there are several fault swarms with minor displacements. These fault swarms are confined to the Balgownie Seam and as previously discussed have no expression in either the Bulli or Wongawilli Seams. There is no justification in any attempt to correlate these minor fault swarms with any surface features or with any other structural feature such as the Rixon's Pass Fault.

There is no other faulting of any significance that could impact on any surface feature during extraction on the mine plan in the Study Area.

2.8.2 Dykes

Dykes D3 and D6 do correlate with stream directions near the escarpment. Dyke D6 correlates with a small tributary on the very upper drainage system for Cataract Creek. Along strike to the west-south-west dyke D6 and its equivalent across the Corrimal Fault, dyke D3 correlate with the upper most tributary of the Cataract River. As both these dykes were estimated to be hard and of reasonable thickness at coal seam level it is feasible to expect surface exposure. Field mapping has been undertaken and no evidence of the dykes at the surface was found.

Dyke D8 is exposed at the surface in an old bypassed section of Mt. Ousley Road at coordinate E303640, N6196780. The dyke was highly weathered to soft puggy clay. Dyke thickness was approximately 0.28m and had a strike of 320 degrees to the northwest. The projection of the dyke was traced along surface subsidence line 500 to location E303258 N6197006 where an open joint bearing 315 degrees to the northwest was located. No evidence of dyke D8 was found. The joint was approximately 0.3m wide. Across the Study Area there is no other surface evidence of the dyke and no apparent correlation with any surface feature. It is not until the dyke crosses into Corrimal Colliery that correlation with a notch on the western side of the Cataract Reservoir occurs. Workings of Corrimal Colliery have mined through the dyke about and under Cataract Reservoir with no apparent consequence to any form of water ingress. There is no indication on subsidence lines for longwall 4 and longwall 5 indicating any excessive movement on the projection of the dyke. Where the dyke has been mined through in workings, particularly recently by NRE No.1 in the Wongawilli Seam, the dyke does not show any water make at all.

3.3 Integrity of Structures

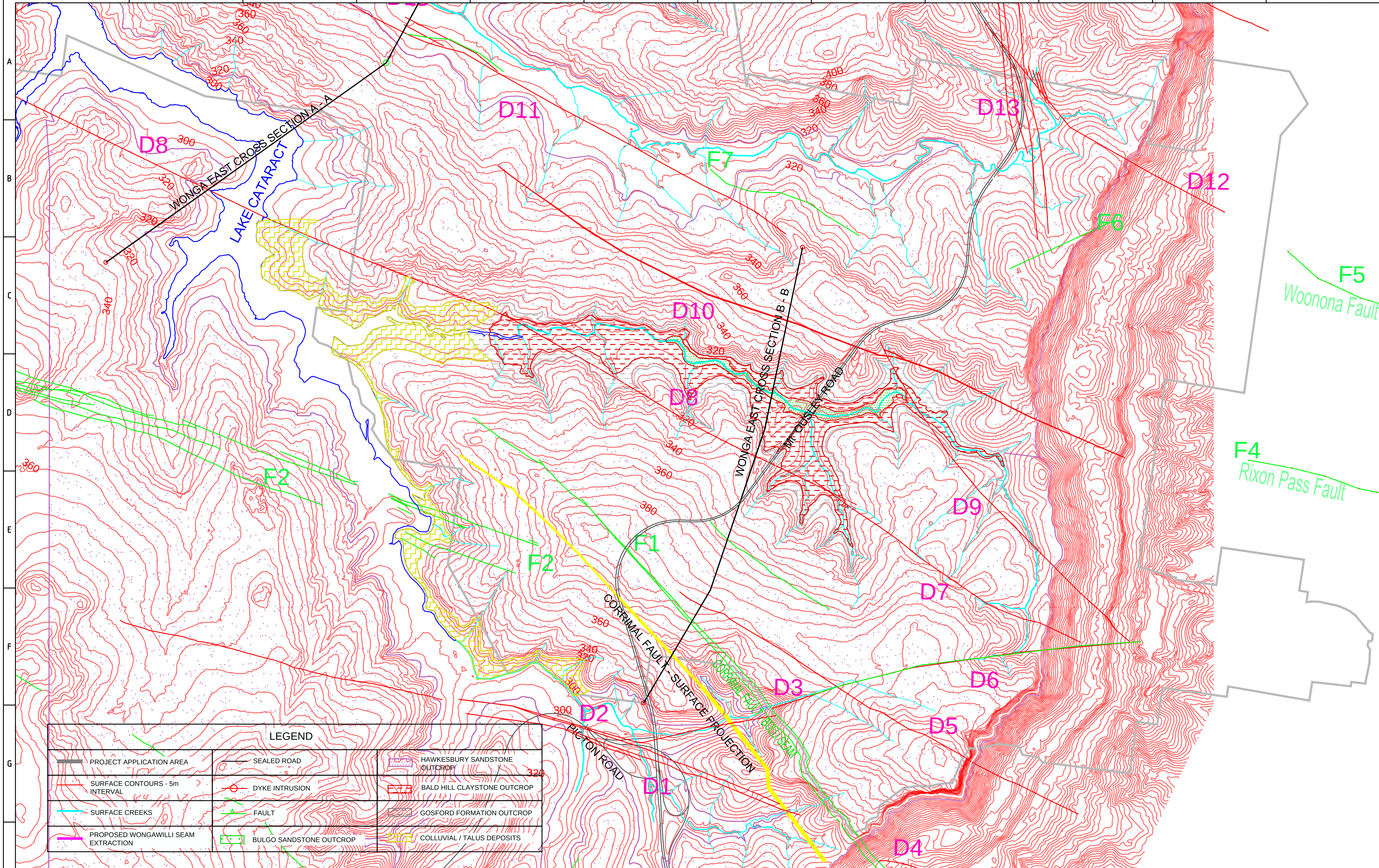
Within the study area there are only two main geological structures that could have an impact on, or influence, the potential hydraulic connectivity of surface or near surface groundwater into mine workings.

The Corrimal Fault (Fault F1) has been well documented and discussed in this report. It has been established the fault does not extend to the Cataract Reservoir. The only area where the fault has a surface relationship with surface features is with small upper tributaries of the Cataract River near the escarpment.

The Corrimal Fault has been intersected in the recent workings of NRE No.1 Colliery. The fault plane was a single, tight structure with a displacement of 1.8m to 0.35m decreasing to the northwest in MG5 development. Further mine development in MG6 has shown the fault to fragment into several small scale faults of an erratic character. The main fault plane is still evident but the Corrimal Fault has become a structurally disturbed zone and is displaying characteristics typical of a terminating structure. The fault is also intersected in the overlying Bulli and Balgownie Seams and there is obviously no water make occurring on the fault plane from these overlying workings or any potential migratory groundwater from overlying strata.

Reactivation along the fault plane by goaf formation appears to have very little substance. Longwall 4 and 5 have been extracted; the fault plane at seam level is approximately 140m away from the goafs. There is no evidence of reactivation on the surface. In fact there is no evidence the fault actually projects to the surface as its displacement decreases to the northwest.

The other main geological structure that intersects the surface is dyke D8. The dyke is prominent in the workings of all three coal seams and has an extensive strike length of over 7.0km. Ground proofing has noted the dyke at the surface near Mt Ousley Road where it was 0.28m thick and soft clay. No other actual surface exposure of the dyke has been found. Where dykes are weathered to soft, puggy clays they tend to act as seals to the movement of groundwater along their projections. As the dyke is prominent in all three coal seams no water ingress has been detected at any of the recent intersections in the workings of NRE No.1 Colliery. This could be taken to imply the dyke is not a conduit to water ingress from the coal seams above or the overlying strata intersected by the dyke.



REV	DESCRIPTION	DATE	DRN	CKD	REV	DESCRIPTION	DATE	DRN	CKD

NRE No. 1 Colliery

GUJARAT NRE Coking Coal Pty Ltd

Princess Highway & Bellmabi Lane, Russell Vale, NSW. 2517

ABN 28 111 244 896

	Name	Date
DRN	RC	10.07.13
CKD		
APP	BC	
SCALE	1:15000	

Title

NRE No. 1 COLLIERY - PART 3A APPLICATION PPR

TOPOGRAPHIC DETAILS, SURFACE FEATURES & GEOLOGY AREA - WONGA EAST

DRAWING NUMBER: FIGURE 18

REV: 0