    

**RUSSELL VALE COLLIERY**

# Response to Planning Assessment Commission Review Report Part 2

for

**Wollongong Coal Ltd**

September 2015

Hansen Bailey
ENVIRONMENTAL CONSULTANTS

# RUSSELL VALE COLLIERY
# UNDERGROUND EXPANSION PROJECT

# RESPONSE TO THE PLANNING ASSESSMENT COMMISSION REVIEW REPORT – PART 2

*Prepared by:*


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28 September 2015

*For:*

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# RUSSELL VALE UNDERGROUND EXPANSION PROJECT
# RESPONSE TO PLANNING ASSESSMENT COMMISSION REVIEW REPORT – PART 2

***For***

***Wollongong Coal Limited***

## 1 INTRODUCTION

### 1.1 BACKGROUND

Wollongong Coal Limited (WCL) operates the Russell Vale Colliery located approximately 8 km north of Wollongong and 70 km south of Sydney. WCL is seeking Project Approval under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the Underground Expansion Project (the Project).

On 9 December 2014, the Minister for Planning made a request to the NSW Planning Assessment Commission (PAC) to undertake a review of the Russell Vale Colliery Underground Expansion Project and assess the merits of the Project as a whole. A public hearing was held in Wollongong on 3 February 2014.

The PAC published its report of the review of the Project (PAC Review Report) on 2 April 2015. The PAC's report included recommendations regarding additional assessment that needed to be completed before the Project could be determined. The PAC concluded that:

> *"At this stage, the Commission does not have sufficient information or confidence to determine the merits of the proposal sufficient for a determination for approval. It may be possible for the proposal, or a modified proposal to be approved if all the additional information identified in this Review report provides a greater level of confidence for the protection of the water quality and quantity in the Sydney Catchment Area and satisfies all the other issues identified in this review."*

WCL and its technical specialists have considered each of the 15 recommendations made by the PAC and have responded to each. Hansen Bailey prepared the document '*Russell Vale Colliery Underground Expansion Project Response to Planning Assessment Commission Review Report – Part 1*' (Part 1) dated 23 July 2015, which considered and responded to Recommendations 5 to 15 and was supported by technical responses from WCL's specialists.

### 1.2 DOCUMENT PURPOSE

This document forms Part 2 of the proponent's Response to the PAC Review Report. This document addresses Recommendations 1 to 4, which relate to the Integrated Risk Assessment, water, subsidence and ecological offsets associated with the Project. This document is supported by technical responses from WCL's specialists which are provided as part of **Appendix A**.

# 2 RESPONSE TO PAC RECOMMENDATIONS

*This section lists Recommendations 1 – 4 in the PAC Review Report, which relate to the Integrated Risk Assessment, subsidence, water and upland swamps associated with the Project and provides a detailed response to each recommendation.*

## 2.1 RECOMMENDATION 1 – RISK ASSESSMENT PANEL

> *The establishment of a risk assessment panel, constituted by an independent chair, Water NSW, the Dams Safety Committee, the Division of Resources and Energy and the proponent to oversee an integrated risk assessment, particularly focusing on links between subsidence and water (both groundwater and surface water) impacts of the proposal. This risk assessment including associated work rerunning the groundwater modelling as recommended by Dr Mackie; and addressing the issues raised by the relevant agencies and experts (as highlighted in this report), needs to be completed before the application can be determined.*

WCL agrees and has complied with this recommendation as discussed below.

### 2.1.1 Overview

An Independent Risk Assessment Panel (IRAP) was formed in consultation with the Department of Planning & Environment (DP&E) and is comprised of an independent Chair to oversee the IRAP. Various meetings occurred between WaterNSW, Dams Safety Committee (DSC), the Division of Resources and Energy (DRE) and WCL and its specialists, and WCL and the IRAP in relation to the methodology and the Integrated Risk Assessment.

The Integrated Risk Assessment was facilitated by risk assessment specialist, Dr Dale Cooper from Broadleaf Capital International Pty Ltd (Broadleaf). The Integrated Risk Assessment focused on providing risk rankings to the potential impacts of the Project associated with subsidence, surface water and groundwater impacts, with a direct focus on water resources.

Hansen Bailey and WCL's technical specialists prepared an overview technical document which provides important context to and discusses the outcomes of the Integrated Risk Assessment (see **Appendix A**).

The groundwater model was "re-run" with particular consideration of the recommendations of Dr Mackie and the latest groundwater monitoring data and was subject to an independent peer review by Dr Noel Merrick. The groundwater assessment was also updated with the latest monitoring data (see **Section 2.2** which illustrates the current groundwater monitoring network).

Issues raised by regulators and PAC experts (Dr Mackie and Dr Galvin) have been directly addressed in the Integrated Risk Assessment (see **Appendix A**).

Comments on the Integrated Risk Assessment from the IRAP and relevant regulators are summarised in **Section 2.1.6** and presented in full in **Appendix A**.

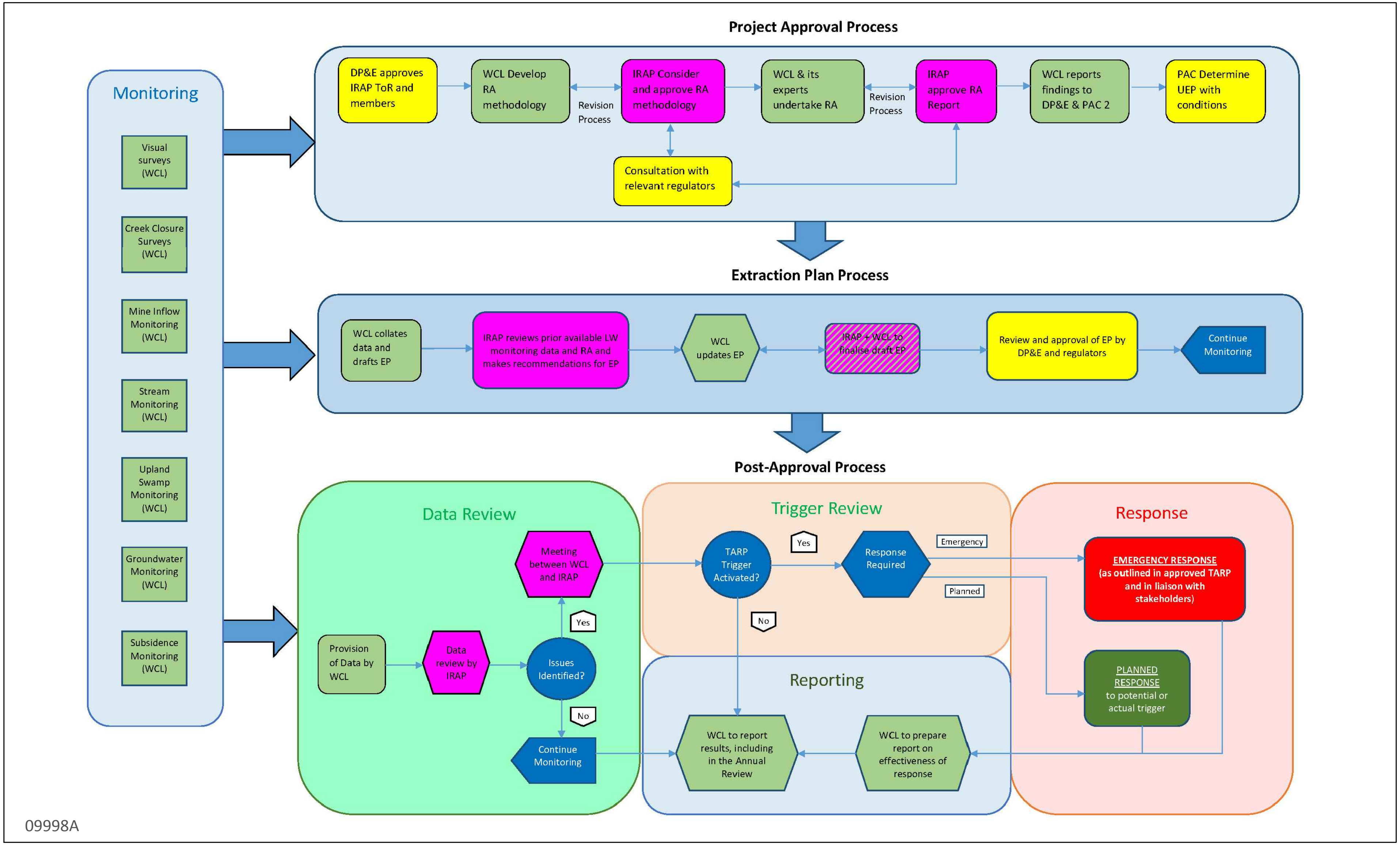
### 2.1.2 Establishment of Risk Assessment Panel

**Figure 1** illustrates the general process for the operation of the IRAP, and the consultation and participation of regulatory authorities, and WCL and its specialists in the process. This process is likely to evolve during the operation of the UEP. As such, the Terms of Reference (ToRs) (provided in **Appendix A**) will be subject to regular review in consultation with relevant regulators, as required.

The Integrated Risk Assessment process consisted of four phases over a three month period:

1. Constitution of IRAP and development of ToRs:
    - Appointment of panel members in consultation with DP&E and formation of the IRAP;
    - Development of the ToRs in consultation with DP&E;
2. Integrated Risk Assessment Methodology:
    - Development of draft Methodology by WCL and its specialists;
    - IRAP and regulatory review of the draft Methodology;
    - Update Methodology to address comments from the IRAP and regulatory authorities;
    - Endorsement of the Methodology by the IRAP;
3. Preparation of additional technical studies to support the Integrated Risk Assessment, including:
    - Revised groundwater assessment;
    - Addendum to surface water modelling;
    - Addendum to Swamp Impact Assessment; and
    - Additional subsidence studies.
4. Preparation of IRA documentation:
    - Preparation for and completion of the draft Integrated Risk Assessment;
    - Consultation with the IRAP and regulatory authorities;
    - IRAP and regulatory review of the draft Integrated Risk Assessment;
    - Finalisation of the Integrated Risk Assessment following receipt of comments from the IRAP; and
    - IRAP's final comments on the Integrated Risk Assessment.

**Appendix A** provides the final Integrated Risk Assessment.

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IRAP Process Flowchart

**FIGURE 1**

### 2.1.3 IRAP and Regulatory Interactions

The IRAP is comprised of the following members, whose appointment was approved by DP&E:

- Professor Ismet Canbulat (IRAP Chair), Kenneth Finlay Chair of Rock Mechanics at UNSW Mining Engineering;
- Andrea Madden, Principal Hydrogeologist at WSP Parsons Brinkerhoff;
- Steve Perrens, Principal at Advisian;
- Arthur A Waddington, Director at Mine Subsidence Engineering Consultants (MSEC); and
- Dr David Robertson, Director at Cumberland Ecology.

**Appendix B** lists the stakeholders involved in the Integrated Risk Assessment process including members of the IRAP, regulatory authorities, WCL representatives and technical specialists.

Extensive consultation was undertaken during the Integrated Risk Assessment process including the formation of the IRAP, review and endorsement of the methodology, and review and comment on the Integrated Risk Assessment.

### 2.1.4 Risk Assessment Outcomes

The findings of the technical assessments (succinctly summarised in **Section 2.1.5**) were used to inform the Integrated Risk Assessment. To address the intent of the ToRs, the Project was segregated into three series of longwall panels (i.e. LWs 1-3, 6-7 and 9-11) for the purposes of this assessment. The risks to environmental features (water resources and upland swamps) were considered separately for each longwall series.

The detailed IRA considered a total of 110 risks across the three longwall series.

The likelihood and consequence scales used to evaluate each risk are presented in Broadleaf (2015a). The likelihood and consequence ratings were combined to determine the level of risk. The likelihood and consequence ratings for each of the assessed risks, and the resultant levels of risk and discussed further below.

The large majority of the risks (107 of 110) were assessed as having either ‘low’ or ‘very low’ consequences (i.e. consequences categories 1 or 2).

The IRA did not identify any ‘extreme’ risks that may result from the Project.

The IRA identified two ‘high’ risks (BS 1113 and BS 1213), which both relate to potential impacts to swamp CCUS4. This swamp is assessed as being at high risk of environmental impacts due to fracturing of the bedrock beneath the swamp or fracturing of the controlling rockbar at the base of the swamp. The risks to swamp CCUS4 are discussed in detail in **Appendix A**.

There are no 'high' risks related to water quantity or water quality. Stream flow monitoring data indicates that swamp CCUS4 does not provide significant baseflow. Therefore, the risks to this swamp will not result in significant implications for water quantity in the catchment.

The IRA identified a total of 29 'medium' risks. Of these, 28 were assessed as having 'low' or 'very low' consequences. A number of these risks are unavoidable consequences of underground mining (such as mine inflows, groundwater depressurisation, shallow surface cracking), but are not significant in magnitude.

The 'medium' level of risk is therefore representative of the high likelihood of impact and is not a reflection of the magnitude of the impact. The 'medium' risks that relate to water quantity and quality are discussed in detailed in **Appendix A**.

The only 'medium' risk that was assessed as having 'moderate' consequences relates to swamp BCUS4. This swamp is assessed as being at a 'medium' risk of environmental impacts due to subsidence induced tilting. The risks to swamp CCUS4 are discussed in detail in **Appendix A**.

The IRA also identified 18 'low' risks and 61 'negligible' risks.

### 2.1.5 Risk Assessment Supporting Technical Information

***Geology***

SCT has undertaken a review of historical record tracings to determine the implications of previous interactions with key geological structures (Corrimal Fault and Dyke D8). SCT has used these observations to predict the extent and properties of these structures. The risk of elevated mine inflows via these structures has been assessed in Appendix F of **Appendix A**.

***Groundwater***

A revised groundwater assessment was undertaken by GeoTerra / GES (2015) to incorporate the recommendations made by Mackie Environmental Research (2015). The key changes to the existing groundwater modelling and reporting included:

- Simulation of the unsaturated zone using the 'Pseudo-soil' option;
- Use of variable drainable porosity values for different strata;
- Addition of figures illustrating the modelled pressure heads in the coal seams, Hawkesbury Sandstone and Bulgo Sandstone prior to, during and after mining (50, 100 and 200 year time horizons);
- Assessment of the long-term steady state groundwater flow systems post mining and identification of shallow and surficial areas that are likely to be dewatered; and
- Assessment of potential leakage via the mine adits and the implications for recovery of pore pressures.

The revised groundwater assessment also utilised the additional monitoring data collected subsequent to the previous groundwater assessment (GeoTerra / GES, 2014), which was completed in June 2014. The improvements to the water monitoring network since June 2014 include:

- Installation of five additional open standpipe piezometers;
- Installation of five additional vibrating wire piezometers;
- Improved monitoring of mine water pumping volumes; and
- Installation of 19 weirs to monitor stream flow.

The additional monitoring data was incorporated into the conceptualisation and calibration of the groundwater model. The revised groundwater assessment is presented in Appendix H of **Appendix A**.

***Surface Water***

The surface water assessment undertaken by WRM (2014) was updated using additional water monitoring data collected since June 2014. There are no long-term stream flow records for Cataract Creek and Cataract River. In lieu of measured stream flows, WRM (2014) modelled the flow regimes for these streams using rainfall-runoff parameters derived from the stream flow records for Bellambi Creek and Loddon River. WCL has since obtained stream flow data for Cataract River and Cataract Creek. A comparison of the modelled and measured stream flow indicates that the simulated flow-duration curve is generally a good match to the observed curve, especially for low flows. However, the modelled high flows are generally higher than the observed values.

WRM (2014) assessed the theoretical worst case impact on total stream flow by excluding the contributions from sub-catchments that are directly overlying or upstream of the proposed longwall panels. This analysis assumed that rainfall-runoff characteristics are uniform throughout the catchment. The available monitoring data for CC8 indicates that some sub-catchments contribute more to stream flow than others. The theoretical worst case impact on stream flow has been re-assessed using non-uniform rainfall-runoff parameters. The revised results of this analysis have been presented in Appendix I of **Appendix A**.

***Upland Swamps***

WCL has obtained additional aerial survey data since the completion of the Coastal Upland Swamp Impact Assessment Report (Biosis, 2014). This new survey data has resulted in the identification of two additional swamps (CRUS6 and CCUS24). The risks to these swamps have been assessed in Appendix J of **Appendix A**.

### 2.1.6 IRAP and Regulator Independent Risk Assessment Conclusions

Correspondence from the IRAP and relevant regulators in relation to the Integrated Risk Assessment is included in **Appendix B** and **Appendix A** respectively.

Key comments from the IRAP and regulators on the completed Integrated Risk Assessment included:

- The IRAP in its final correspondence dated 28 September concluded that:

  > *"It is the IRAP's opinion that the risk assessment has been conducted by appropriately qualified experts in the fields of mine subsidence engineering, groundwater, surface water and ecology. It is understood that the WCL experts worked on the project together for a considerable period of time, which provided them the experience and the knowledge required to conduct the "integrated" risk assessment, which aims to ensure that the risks associated with underground mining on the quantity and quality of groundwater and surface water as well as upland swamps have been assessed and appropriate controls are identified.*
  >
  > *Following an extensive review of the risk assessment and the relevant documentation, it is the opinion of IRAP that the risk assessment is 'integrated' and has been based upon an approach that is sufficiently detailed and at an appropriate level to evaluate the risks to the swamps, streams, groundwater and the waters of Cataract Reservoir."*

- DP&E distributed the draft Integrated Risk Assessment to DRE, WaterNSW, DSC, Primary Industries (Water) and Office of Environmental & Heritage (OEH) (although not listed in Recommendation 1). DP&E commented in its correspondence dated 7 September 2015 that:

  > *"The Department is satisfied that WCL is implementing the IRAP process in accordance with the TOR."*
  >
  > *"Overall, the Department is satisfied that the additional technical information provides greater confidence in the* previous *predictions made in relation to the impacts of the UEP on underground and surface waters, and the risks to the stored waters in Cataract Reservoir."*

  DP&E also noted that it is satisfied with and accepts the "comprehensive discussion" on the Corrimal Fault and Dyke D8, revised groundwater modelling, and (coarse estimate) surface water modelling. It also noted that "… the Dam Safety Committee (DSC) has indicated that it is also satisfied with the information included in the SCT reports."

- WaterNSW requested edits to the Integrated Risk Assessment on 7 September 2015 and had four further queries which have been responded to in the final Integrated Risk Assessment or through direct correspondence with WaterNSW.

Of note, WaterNSW made the following comment in relation to WCL's commitments in response to the DSC's issues regarding the purported risk of potential hydraulic conductivity via the Corrimal fault:

> *"… 'If the Fault is intercepted then the DSC will not recommend the approval of the western end of LW 7 and will request that the longwall be setback from the Fault, leaving a hydraulic barrier of coal against the Fault for protection against ingress.'*
>
> *If the Corrimal Fault is absent from LW 7 MG, the DSC has no concerns with the extraction of Longwall 7 regarding the Fault. WaterNSW understands the company has stated its commitment to add this requirement to the UEP's Statement of Commitments."*

WaterNSW also notes that any offsets should be located within the local catchment where the potentially impacted swamps are located. An additional commitment has been added to the revised Statement of Commitments (SoCs) to address this recommendation (see **Section 3**).

- DSC stated in its correspondence dated 10 September 2015 that

> *"DSC staff have had the opportunity to review the documents presented at the recent MSC meeting and are satisfied with the approaches WCL have taken to address issues with respect to the development of effective contingency and closure plans.*
>
> *DSC staff are confident that WCL have demonstrated that in the unlikely event of a connection to the Mine developing, that water from the outflow could be contained for an extended period (up to 10 years) in the workings that currently exist underground and would therefore have ample time to install effective seals where required.*
>
> *DSC would have no difficulty in approving extraction of longwall 7 if the Corrimal Fault is absent, or can be demonstrated to be terminating at longwall 7. Even if the Corrimal Fault is demonstrably present in LW7, DSC has no concerns with extraction of the Eastern 2/3 of LW7, but may insist on a leaving a hydraulic barrier of solid coal against the fault for protection against ingress.*
>
> *DSC staff are satisfied with the Integrated Risk Assessment that has been undertaken on behalf of WCL and feel that the process undertaken was as rigorous and far reaching as is possible given the nature of the risks being assessed."*

- DRE suggested minor edits in its correspondence dated 9 September 2015, all of which have been addressed in the final Integrated Risk Assessment.
- OEH raised issues in relation to upland swamps, which have been responded to in the Integrated Risk Assessment and this document.

## 2.2 RECOMMENDATION 2 – UPLAND SWAMP MONITORING

*The establishment of a network of piezometers within and surrounding the upland swamps, the establishment of this network should be guided by the relevant authorities (i.e. Office of Environment & Heritage, WaterNSW, the Dams Safety Committee and the Department of Planning & Environment). This network will collect additional baseline data and monitor the impacts to the swamps, through changes to the groundwater supporting the swamps, from the mining. This monitoring data should be made available to the independent risk assessment panel.*

WCL agrees with and has complied with this recommendation as discussed below.

### 2.2.1 Existing Piezometer Network

In March and May 2012 WCL installed eight shallow groundwater piezometers in upland swamps BCUS4, CCUS2, CCUS3, CCUS4, CCUS5, CCUS6 and CRUS1. One piezometer was installed in each swamp, with two piezometers in upland swamp CCUS5.

**Figure 2** illustrates upland swamp monitoring installed and monitored at Russell Vale Colliery.

A list of piezometers installed in 2012 is provided in **Table 1**. It also describes the swamp within which the piezometer is installed, installation date, intake depth and closest proximate longwall (note that this does not necessarily indicate that the piezometer is located over the longwall – but provides the nearest longwall for ease of locating the piezometer).

In October 2014, following consultation with WaterNSW and the OEH, WCL has installed an additional 15 shallow groundwater piezometers. This has resulted in the installation of a number of additional piezometers in upland swamps BCUS4 (3), CCUS4 (3), CCUS5 (2) and CRUS1 (3) as well as the installation of piezometers in upland swamps CCUS10 and CCUS12. A list of piezometers installed in 2014 is provided in **Table 2**.

**Table 1**
**Shallow Groundwater Piezometers Installed in Upland Swamps in 2012**

| Site | Swamp | Installation date | Intake depth (mbgl) | Proximate Longwall * |
|---|---|---|---|---|
| PB4C | BCUS4 | Mar-12 | 0.62 | (pillar of LW10) |
| PCc3 | CCUS3 | Mar-12 | 1.13 | LW5 |
| PCc4D | CCUS4 | Mar-12 | 1.00 | LW6 |
| PCc6 | CCUS6 | Mar-12 | 1.17 | (pillar of LW4) |
| PCr1A | CRUS1 | Mar-12 | 0.53 | (southeast of LW6) |
| PCc2 | CCUS2 | May-12 | 1.60 | (pillar of LWs 2 and 3) |
| PCc5A | CCUS5 | May-12 | 1.24 | (north of LW7) |
| PCc5B | CCUS5 | May-12 | 1.31 | (north of LW7) |

** Values (in brackets) indicate that the piezometer is not located over the longwall*

**Table 2**
**Shallow Groundwater Piezometers Installed in Upland Swamps in 2014**

| Site | Swamp | Installation date | Intake depth (mbgl) | Proximate Longwall |
|---|---|---|---|---|
| PB4A | BCUS4 | Oct-14 | 1.61 | LW10 |
| PB4B | BCUS4 | Oct-14 | 1.84 | LW10 |
| PB4D | BCUS4 | Oct-14 | 1.27 | LW10 |
| PCc10A | CCUS10 | Oct-14 | 0.6 | (south of LW9) |
| PCc10B | CCUS10 | Oct-14 | 0.98 | (south of LW9) |
| PCc12A | CCUS12 | Oct-14 | 0.71 | LW10 |
| PCc12B | CCUS12 | Oct-14 | 0.27 | LW10 |
| PCc4A | CCUS4 | Oct-14 | 1.61 | (pillar of LWs 6 and 7) |
| PCc4B | CCUS4 | Oct-14 | 1.84 | (pillar of LWs 6 and 7) |
| PCc4C | CCUS4 | Oct-14 | 1.27 | LW6 |
| PCc5C | CCUS5 | Oct-14 | 0.85 | LW7 |
| PCc5D | CCUS5 | Oct-14 | 1.23 | (north of LW7) |
| PCr1B | CRUS1 | Oct-14 | 0.69 | (southeast of LW6) |
| PCr1C | CRUS1 | Oct-14 | 1.15 | LW6 |
| PCr1D | CRUS1 | Oct-14 | 0.37 | LW6 |

** Values (in brackets) indicate that the piezometer is not located over the longwall*

### 2.2.2 Proposed Network

In response to the recommendations of the PAC, WCL will install a number of additional shallow groundwater piezometers in all upland swamps within 400 m of the longwalls (secondary extraction). This will include the installation of approximately 30 additional shallow groundwater piezometers. Where feasible, this will include the installation of open standpipes or shallow groundwater piezometers around upland swamps CCUS1 and CRUS3 to assess the inflow to these upland swamps from surrounding surficial and shallow groundwater aquifers.

Installation will be subject to further consultation with DRE and WaterNSW, as required, and will also be described in future Extraction Plans.

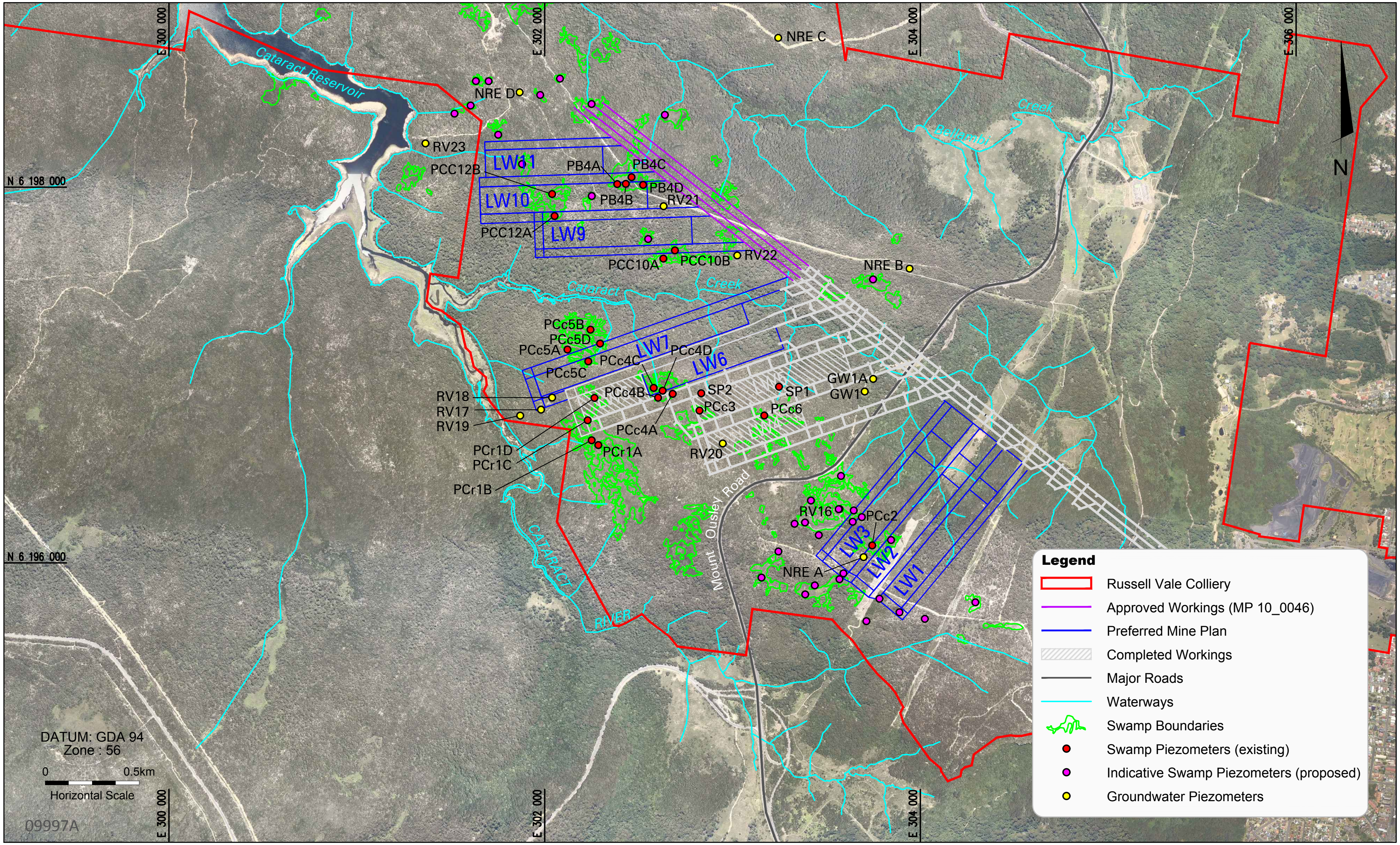
**Figure 2** also indicatively illustrates the proposed locations for piezometers to be installed (subject to consultation and approval of relevant regulators).

**Table 3** lists the extensive consultation that was conducted with the regulators in relation to the design and installation of the existing swamp piezometer monitoring network and as outlined in the approved 'Russell Vale Colliery, Russell Vale East – Longwalls 6 & 7, Upland Swamp Management Plan' (WCL, 2015).

Data obtained from this network of piezometers will be provided to the IRAP, as requested.

**Table 3**
**Summary of Consultation in Installing Swamp Monitoring**

| Agency | Consultation |
|---|---|
| OEH | Meeting, 10 November 2014<br>Provision of this USMP (via DP&E)<br>Development of the Upland Swamp Network Monitoring Plan<br>Provision of LW5 BMP (via DP&E)<br>Provision of LW4 BMP and receipt of comments, 6 April 2012 (via DRE)<br>Meeting, 26 April 2012<br>Meeting, 12 September 2012<br>Meeting, 24 October 2012<br>Meeting, 10 November 2014 |
| Division of Resources and Energy | Provision of this USMP (via DP&E)<br>Development of the Upland Swamp Network Monitoring Plan<br>Provision of LW5 BMP (via DP&E)<br>Provision of LW4 BMP and receipt of comments, 6 April 2012 (via DRE) |
| Sydney Catchment Authority | Provision of this USMP (via DP&E)<br>Development of the Upland Swamp Network Monitoring Plan<br>Provision of LW5 BMP (via DP&E)<br>Provision of LW4 BMP and receipt of comments, 6 April 2012 (via DRE) |
| Commonwealth Department of the Environment | Provision of this USMP (via DP&E)<br>Meeting, 8 August 2014<br>Meeting, 9 May 2014 |




RUSSELL VALE COLLIERY

Existing and Proposed Upland Swamp Monitoring Network

**FIGURE 2**

WOLLONGONG COAL

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ENVIRONMENTAL CONSULTANTS

## 2.3 RECOMMENDATION 3 – OFFSET POLICY IRAP CONSIDERATION

*Any more definitive policy developed regarding triggers for offsets and mitigation measures under the "Policy Framework for Biodiversity Offsets for Threatened Upland Swamps and Associated Threatened Species Impacted by Longwall Mining Subsidence" should be made available for consideration by the independent risk assessment panel (see Recommendation 1).*

The Draft *Policy Framework for Biodiversity Offsets for Upland Swamps and Associated Threatened Species* (Swamp Policy) was developed by the NSW Government in May 2015 as a part of the development of the Integrated Mining Policy.

The Draft Swamp Policy was placed on public exhibition, concluding on 13 June 2015. As at 28 September 2015 submissions made on the Swamp Policy are under consideration by DP&E. The Policy Framework is yet to be finalised.

WCL will make available the policy to the IRAP when it is finalised and publicly available generally within the framework illustrated in **Figure 1** and as described in **Section 2.1.2**.

## 2.4 RECOMMENDATION 4 – OFFSET POLICY INCLUSIONS

*Any potential offset policy should address key elements including:*

*a) The potential delayed onset of subsidence and associated hydrogeological and ecological impacts to swamps;*
*b) Potential ecological and structural tipping points; and*
*c) Mechanism to adequately secure offset sites (with consideration of the current land tenure and expiration licence and mining lease tenements of the proposed offset site; and the need for site specific offset management plans).*

This Recommendation is for the NSW government to address in its finalisation of the Swamp Offsets Policy.

WCL is currently investigating options to provide reasonable offsets for the UEP. The mechanism for protecting these areas will be defined in consultation with relevant regulators.

# 3 REVISED STATEMENT OF COMMITMENTS

**Table 4** presents a summary of additional actions which WCL has committed to during the Response to PAC Report process (including the Integrated Risk Assessment process). These will be added to the existing Project SOC.

**Table 4** also provides a reference for the commitment.

**Table 4**
**Additional Commitments**

| No | Commitment | Reference |
|---|---|---|
| 1. | WCL will install a number of additional shallow groundwater piezometers in all upland swamps within 400 m of the longwalls (secondary extraction). This will include the installation of approximately 30 additional shallow groundwater piezometers. Where feasible, this will include the installation of open standpipes or shallow groundwater piezometers around upland swamps CCUS1 and CRUS3 to assess the inflow to these upland swamps from surrounding surficial and shallow groundwater aquifers.<br>Installation will be subject to further consultation and approval by relevant regulators. | This document |
| 2. | WCL will implement offsets for impacts to swamps in accordance with the final Swamp Offset Policy (with precedent given to conditions of Project Approval). | This document |
| 3. | Where offsets for impacts to swamps are required, WCL will endeavour to preferentially locate offsets within the local catchment the swamps were located. | This document (WaterNSW) |
| 4. | If required by the DSC, the panel length of LW 7 will be truncated if the Corrimal Fault is intersected during the development of the gateroads for LW 7. | IRAP (DSC) |
| 5. | Undertake inspections of the Bulli Seam workings overlying LW 7 to confirm the accuracy of the record tracings (subject to the ability to safely access these workings). | IRAP recommendation |
| 6. | Conduct drilling of exploration boreholes to confirm the accuracy of the record tracings for the Bulli Seam workings overlying LW 7. | IRAP recommendation |
| 7. | Consult with the IRAP during the development of management plans (following approval of the Project). | IRAP recommendation |
| 8. | Implement the following noise mitigation measures:<br>• Fitting surface conveyors with poly rollers wherever possible;<br>• Maintain a volume of coal in bins at all times to minimise noise;<br>• Undertake a trial to determine the efficiency of tripper automation to reduce noise produced by falling material; and<br>• Undertake real time noise monitoring to confirm the need for noise barriers. | PAC Response Part 1 |
| 9. | Implement the following dust mitigation measures:<br>• Trial the use of chemical wetting agents on haul road and stockpiles, and report the results of the trial in the Annual Review;<br>• Sealing of the proposed haul road; and<br>• Include PM2.5 monitoring results in regular monitoring reports. | PAC Response Part 1 |
| 10. | Undertake detailed design of the dry sediment dam to ensure that there is sufficient treatment capacity. | PAC Response Part 1 |
| 11. | Consult with WCC regarding WCL's contribution to the maintenance of Bellambi Lane. | PAC Response Part 1 |

# 4 CONCLUSION

WCL trusts that DP&E will duly consider the information provided within this document during the preparation of its documentation to be provided to the PAC for determination.

Should you have any queries in relation to this document or have any further questions regarding the Project, please contact the Dianne Munro on 02 6575 2000.

* * *

For
**HANSEN BAILEY**

Andrew Wu
*Environmental Engineer*

Dianne Munro
*Principal*

# *APPENDIX A*

# *Integrated Risk Assessment*

# RUSSELL VALE COLLIERY
# UNDERGROUND EXPANSION PROJECT

# INTEGRATED RISK ASSESSMENT

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**INTEGRATED RISK ASSESSMENT**

***For***

***Wollongong Coal Limited***

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Recommendation 1 states:

> *"1. The establishment of a risk assessment panel, constituted by an independent chair, Water NSW, the Dams Safety Committee, the Division of Resources and Energy and the proponent to oversee an integrated risk assessment, particularly focusing on links between subsidence and water (both groundwater and surface water) impacts of the proposal. This risk assessment, including associated work rerunning the groundwater modelling as recommended by Dr Mackie, and addressing the issues raised by the relevant agencies and experts (as highlighted in this report), needs to be completed before the application can be determined."*

## 1.2 DOCUMENT PURPOSE

This overview document *'Integrated Risk Assessment'* (this document) provides a comprehensive response to Recommendation 1. The scope of the risk assessment is stipulated in the Terms of Reference (TORs) for the Independent Risk Assessment Panel (IRAP), which was developed in consultation with relevant regulatory authorities. The scope of this Integrated Risk Assessment is to assess the impacts of underground mining on the quantity and quality of underground and surface water, and on environmental values associated with swamps.

WCL engaged Broadleaf Capital International Pty Ltd (Broadleaf) to act as the independent facilitator of the Integrated Risk Assessment. Broadleaf reported the outcomes of the Independent Risk Assessment in the *'Final Report: Integrated Risk Assessment for the UEP'* (Broadleaf Risk Assessment) and the *'Risk Register: Integrated Risk Assessment for the UEP'* (Risk Register), which are provided as **Appendix A** and **Appendix B** respectively.

This document also includes further detail requested by the IRAP (in its correspondence dated 15 July 2015) regarding the methodology outlined in *'Discussion Paper: UEP Integrated Risk Assessment Approach'* (Broadleaf, 2015a).

A 'draft' of this document was provided to the IRAP and regulators for consultation on 19 August 2015. WCL attended meetings with the IRAP and regulatory authorities in August and September 2015. This document has been revised to respond to issues raised by the IRAP and regulatory authorities. Relevant correspondence from the IRAP and regulatory authorities is included in **Appendix C**

### 1.3 DOCUMENT STRUCTURE

**Section 2** provides the background information requested by the IRAP, including the history of mining at Russell Vale Colliery, modifications made to the mine plan as part of the Preferred Project Report, the status of the Project Application, and the longwall mining parameters for the Project.

**Section 3** includes a summary of the technical information prepared for the Project and indicates the contemporary version of each as relevant to this Risk Assessment.

**Section 4** provides a summary of the risk assessment methodology.

**Section 5** provides a summary of the key findings of the Integrated Risk Assessment.

**Section 6** provides overall risk classifications for key environmental features, namely water resources and upland swamps.

**Section 7** provides a summary of the controls to minimise the risks associated with the Project.

**Section 8** provides an action plan which includes a Revised Statement of Commitments (SoC) identified as a result of this Risk Assessment.

**Section 9** provides a brief conclusion.

**Section 10** defines the terminology specific to the Project. **Section 11** lists the references relied upon for the Integrated Risk Assessment.

**Appendix A** to **Appendix J** contain the Broadleaf Risk Assessment and Risk Register, correspondence with regulatory authorities and the IRAP, and the additional technical studies prepared by WCL's specialists in the fields of hydrology, hydrogeology, ecology (swamps), geology and subsidence.

# 2 BACKGROUND INFORMATION

*In its correspondence dated 15 July 2015, the IRAP requested a summary of background information related to the Project. This section provides the requested information.*

## 2.1 HISTORY OF MINING AT RUSSELL VALE COLLIERY

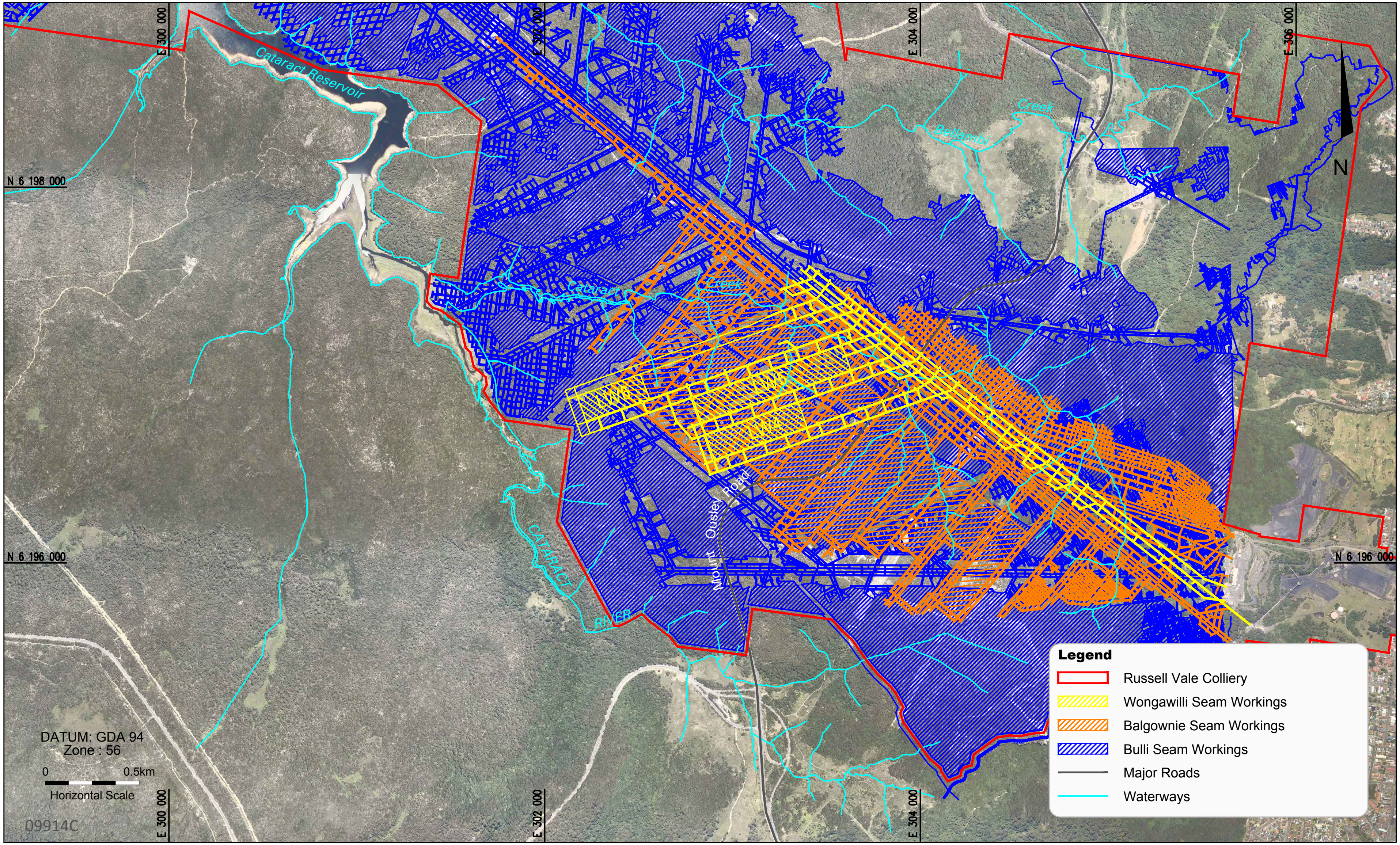
Originally known as the South Bulli Colliery, mining operations at Russell Vale Colliery have been conducted since the 1880s. Mining operations have been undertaken in the Bulli, Balgownie and Wongawilli coal seams.

Mining of the Bulli Seam commenced in the 1890s using hand bord and pillar mining techniques. As mining technology became more advanced, hand workings were superseded by mechanised mining techniques. Mining of the Bulli Seam in the Russell Vale East Domain was completed in the 1950s (SCT, 2014). The completed workings in the Bulli Seam are shown in **Figure 1**.

The Balgownie Seam is located 5 m to 10 m below the Bulli Seam. Russell Vale Colliery was one of the first mining operations in Australia to utilise longwall mining techniques. Within the Russell Vale East Domain, eleven longwall panels were extracted between September 1970 and May 1982. In addition, some bord and pillar workings were developed prior to 1970 (SCT, 2014). The completed workings in the Balgownie Seam are shown in **Figure 1**.

The Wongawilli Seam lies 20 m to 30 m below the Balgownie Seam. Two longwall panels have been extracted within the Wongawilli Seam to date. Longwall (LW) 4 was mined from 21 April 2012 to 21 September 2012. LW 5 was mined from 15 January 2013 to 12 January 2014. The completed workings in the Wongawilli Seam are shown in **Figure 1**.

Extensive mining of the Bulli Seam has also been undertaken in the Russell Vale West Domain. The Underground Expansion Project does not include any mining activities in the Russell Vale West Domain.




WOLLONGONG COAL

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RUSSELL VALE COLLIERY

Extent of Historical Mining

**FIGURE 1**

## 2.2 MODIFICATION OF THE MINE PLAN

The original mine plan for the Underground Expansion Project was proposed in the Environmental Assessment (ERM, 2013). This mine plan consisted of 11 longwall panels in the Russell Vale East Domain and 7 longwall panels in the Russell Vale West Domain. The original mine plan for the Russell Vale East Domain included LWs 4 & 5, which were subsequently undertaken pursuant to a separate Project Approval (MP 10_0046). The original mine plan is shown in **Figure 2**.

The mine plan was modified by the Preferred Project Report (Gujarat NRE Coking Coal Ltd, 2013a). The re-design of the mine plan was informed by subsidence monitoring data collected during mining of LWs 4 & 5, which provided insight into multi-seam subsidence behaviour at the site.

The following modifications were made to the original mine plan to achieve the preferred mine plan (for which approval is sought):

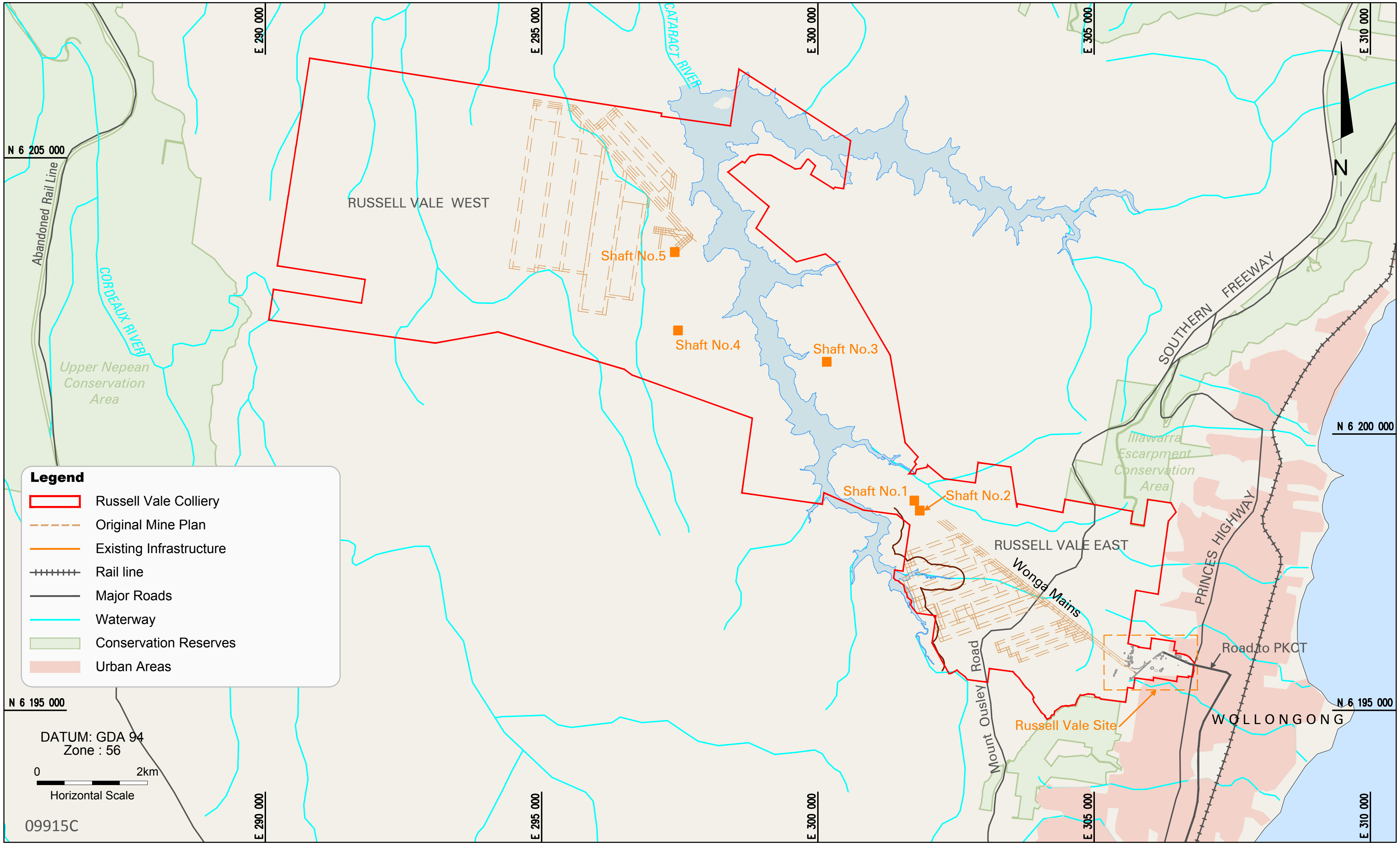
- Changes to the lengths, widths and orientations of LWs 1-3;
- Shortening of LW 6;
- Narrowing, shortening and re-positioning of LW 7;
- Removal of LW 8 from the mine plan; and
- Shortening and re-orientation of LWs 9-11.

A comparison between the original mine plan and the preferred mine plan is shown in **Figure** 3.

The removal of LW 8 and re-orientation of LWs 9-11 has resulted in avoidance of longwall mining beneath the fourth order reaches of Cataract Creek. This significantly reduces the risk of stream bed cracking due to subsidence.

The modifications to the mine plan have also reduced the extent of longwall mining beneath coastal upland swamps. Compared to the original mine plan, the preferred mine plan substantially avoids secondary extraction beneath swamps CCUS1, CCUS5 and CCUS10 (see **Figure 3** and **Figure 4**).

The preferred mine plan provides for the extraction of a total coal resource of 4.7 million tonnes of Run of Mine (ROM) coal over a period of five years. The maximum production rate that can be achieved in a particular year is 3 Mt per annum.

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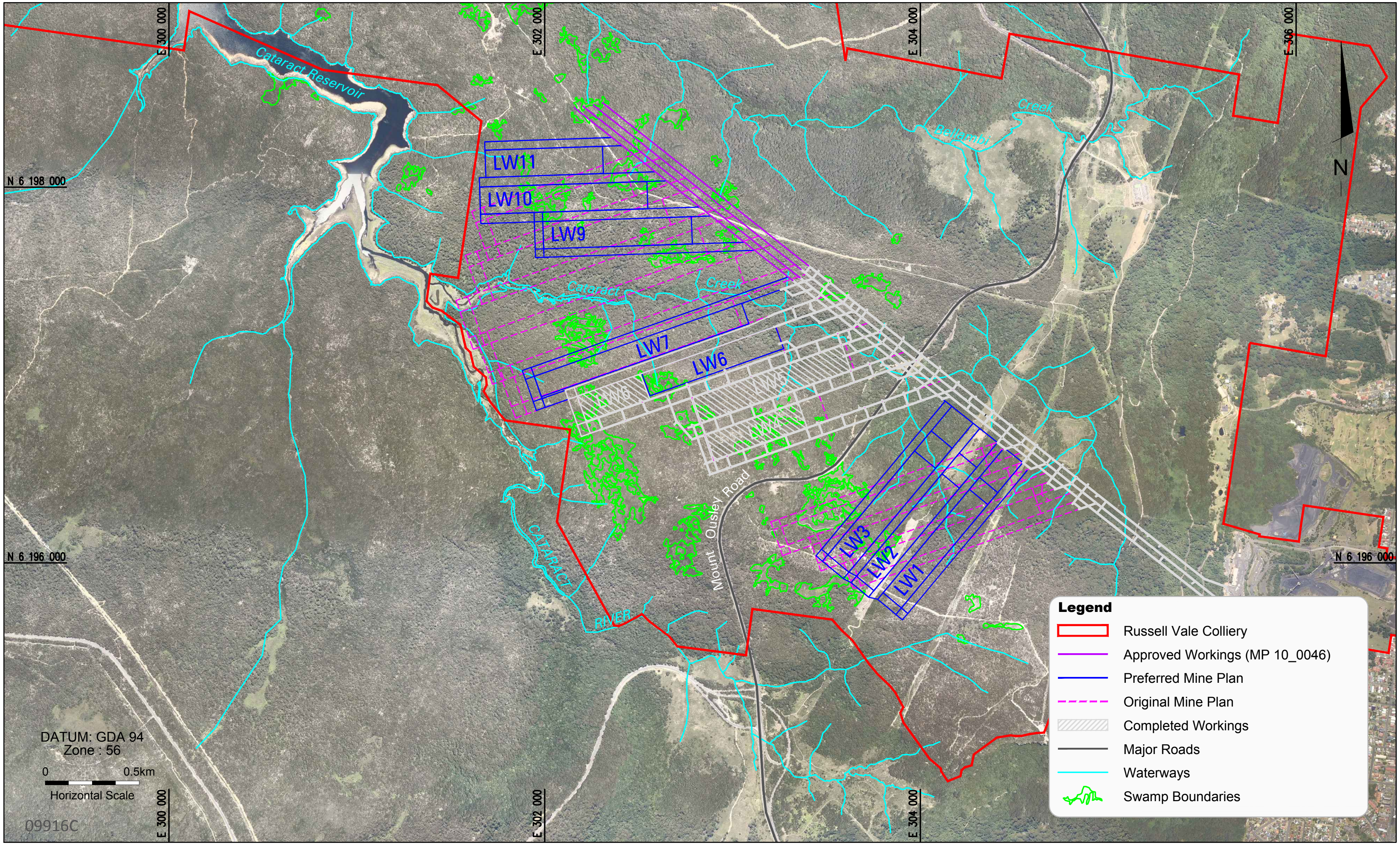
Original Mine Plan

**FIGURE 2**

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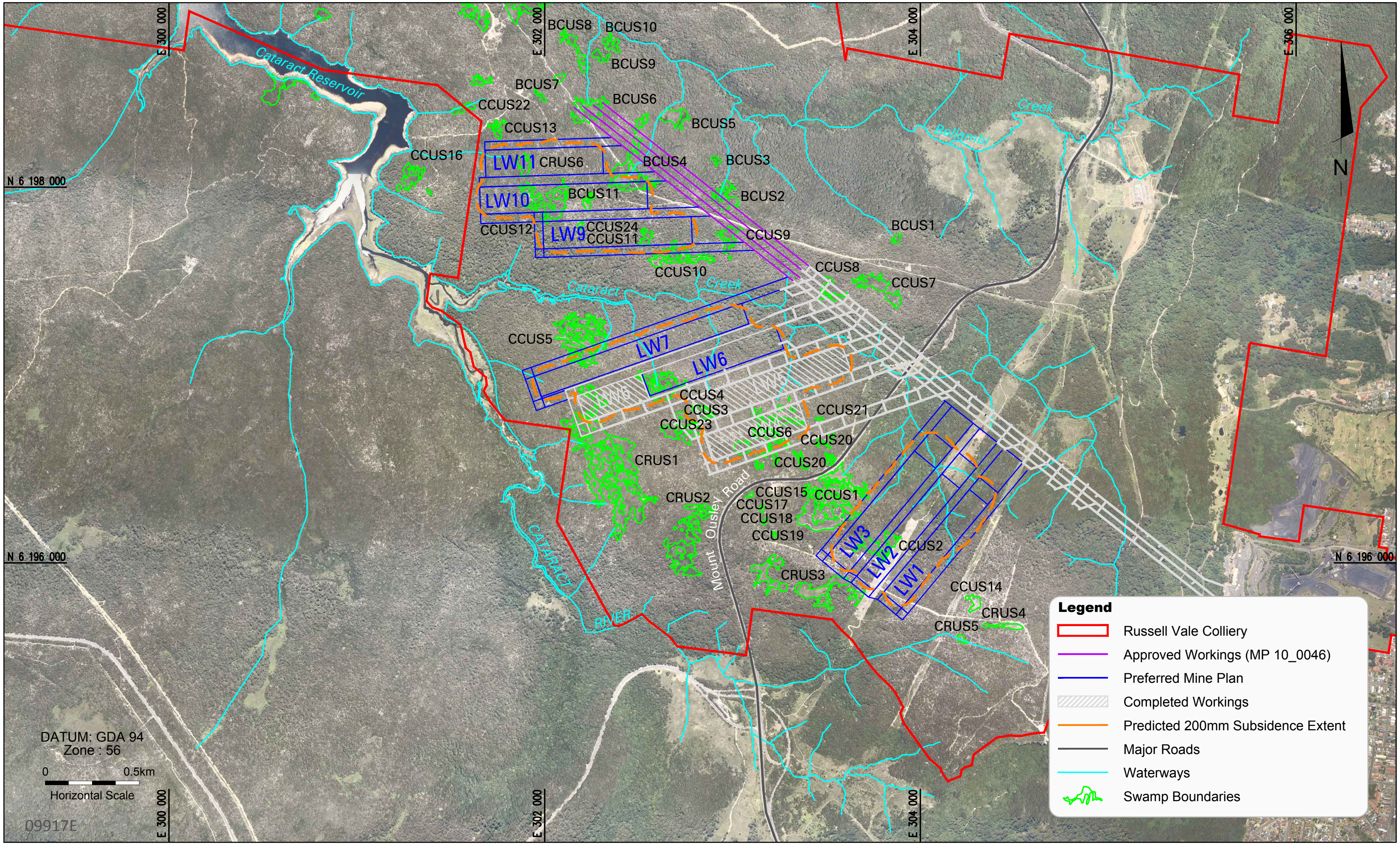
Comparison of Mine Plans

**FIGURE 3**

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RUSSELL VALE COLLIERY

Upland Swamps

**FIGURE 4**

## 2.3 APPLICATION HISTORY

### 2.3.1 Underground Expansion Project

WCL's predecessor, Gujarat NRE Minerals Ltd, lodged the Project Application for the Underground Expansion Project (MP 09_0013) on 12 August 2009. The Director-General's Requirements (DGRs) for the Underground Expansion Project were issued on 18 August 2009.

The *NRE No. 1 Colliery Project Application (09_0013) Environmental Assessment* (ERM, 2013) (EA) was prepared in accordance with the DGRs. The EA was placed on public exhibition from 18 February 2013 to 5 April 2013. A total of 840 submissions were received during the exhibition period. The total was comprised of 12 submissions from regulatory authorities, two submissions from special interest groups, and 826 submissions from individuals (446 of whom were in support and 380 of whom were in opposition).

Upon considering the submissions received, Gujarat NRE Minerals Ltd prepared a Preferred Project Report (PPR) including a Response to Submissions (RTS) in October 2013. The PPR made substantial modifications to the mine plan for the Underground Expansion Project. The technical assessments undertaken for the Underground Expansion Project were revised to reflect the modifications to the proposed mine plan. The revised technical assessments for the Project were presented in the PPR and the Residual Matters Report (Hansen Bailey, 2014).

On 11 December 2014, Department of Planning & Environment (DP&E) issued the *Secretary's Environmental Assessment Report* as required under section 75I of the EP&A Act. The Secretary of DP&E concluded that "*the project's benefits outweigh its residual impacts that it is in the public interest and should be approved, subject to stringent conditions".*

On 9 December 2014, the Minister for Planning requested the NSW Planning Assessment Commission (PAC) to undertake a review of the Russell Vale Colliery Underground Expansion Project and assess the merits of the Project as a whole. The PAC was required to conduct a public hearing on the project. A public hearing was held on 3 February 2014, at the WIN Entertainment Centre, Wollongong.

The PAC published its report on the review of the Project (PAC Review Report) on 2 April 2015. The PAC's report included recommendations regarding additional assessment that needs to be completed before the Project can be determined. The PAC concluded (at p. 52) that:

> *"At this stage, the Commission does not have sufficient information or confidence to determine the merits of the proposal sufficient for a determination for approval. It may be possible for the proposal, or a modified proposal to be approved if all the additional information identified in this Review report provides a greater level of confidence for the protection of the water quality and quantity in the Sydney Catchment Area and satisfies all the other issues identified in this review."*

### 2.3.2 Preliminary Works Project

The Underground Expansion Project includes only the proposed longwall panels and their associated gateroads. The main headings for the Russell Vale East Domain were assessed and approved through the application for the Preliminary Works Project (MP 10_0046). This approval authorises the development of the main headings (known as the Wonga Mains) and the gateroads for LWs 4 & 5.

On 24 December 2012, the Project Approval (MP 10_0046) was modified under section 75W of the EP&A Act to authorise the extraction of LWs 4 & 5.

On 19 November 2014, a further modification under section 75W was approved to allow extraction of the western-most 365 m of LW6.

## 2.4 LONGWALL MINING PARAMETERS

The dimensions of the longwall panels for the Project are presented in **Table 1**. The extraction thickness will vary from 2.5 m to 3 m. The first workings for the Project will consist of 3.2 m x 5.5 m main roads and gateroads.

**Table 1**
**Longwall Dimensions**

| Longwall No. | LW Width – rib to rib (m) | LW length (m) | Maingate Pillar Width (m) |
|---|---|---|---|
| **Longwall 1** | 131 | 805 | 40 |
| **Longwall 2** | 125 | 858 | 40 |
| **Longwall 3** | 150 | 863 | 40 |
| **Longwall 6** | 150 | 1124 | 45 |
| **Longwall 7** | 131 | 1175 | 45 |
| **Longwall 9** | 150 | 796 | 45 |
| **Longwall 10** | 150 | 896 | 45 |
| **Longwall 11** | 150 | 630 | 40 |

# 3 PROJECT DOCUMENTATION SUMMARY

*This section outlines the technical assessments that have been undertaken for the Project and identifies the studies that are relevant to the Integrated Risk Assessment.*

Extensive documentation has been prepared for the Project since 2010. **Table 2** provides a summary of the documentation prepared for the disciplines relevant to the Integrated Risk Assessment. It indicates the precedence of information and the reasons for the updates.

The documents in **bold** are the latest assessments for the Project. All other documents have been superseded. All documents are available at the DP&E website (except where indicated as appended to this Document) at: http://majorprojects.planning.nsw.gov.au/page/project-sectors/mining--petroleum---extractive-industries/mining/?action=view_job&job_id=3448

**Table 2**
**Project Historical Documentation Summary**

| Ref | Date | Author & Title | Detail | Reference |
|---|---|---|---|---|
| **SUBSIDENCE** | | | | |
| 1. | July 2012 | *Management of Subsidence Risks Associated with Wongawilli Seam Extraction* (Seedsman Geotechnics, 2012) | Subsidence assessment relating to the original mine plan, as proposed in the EA. | Annex M of EA |
| 2. | September 2013 | *Subsidence Assessment for Gujarat NRE Preferred Project Report Russell Vale No 1 Colliery* (SCT, 2013) | Subsidence Assessment relating to the preferred mine plan, as proposed in the PPR. | Attachment B of PPR |
| 3. | June 2014 | ***Update of Subsidence Assessment for Wollongong Coal Preferred Project Report Russell Vale No 1 Colliery*** (SCT, 2014) | Update of SCT (2013) following additional subsidence monitoring, identification of additional cliff formations and an independent peer review. | Appendix B of Residual Matters Report (Hansen Bailey, 2014) |
| 4. | August 2015 | ***Review of Barrier to Protect Stored Waters of Cataract Reservoir*** (SCT, 2015a) | Prepared to address issues raised in the PAC Review Report. | **Appendix D** |
| 5. | August 2015 | ***Response to Galvin and Associates Pty Ltd Report Dated 3 March 2015*** (SCT, 2015b) | Prepared to address issues raised in the PAC Review Report. | **Appendix E** |
| 6. | August 2015 | ***Assessment of Corrimal Fault and Dyke D8 at Russell Vale East as Risks to the Stored Waters of Cataract Reservoir*** (SCT, 2015c) | Prepared to address issues raised in the PAC Review Report. | **Appendix F** |
| 7. | September 2015 | ***Response to Residual Matters from Independent Risk Assessment Panel Comments*** (SCT, 2015d) | Prepared to address issues raised by the IRAP during the risk assessment process. | **Appendix G** |
| **GROUNDWATER** | | | | |
| 8. | November 2012 | *NRE No. 1 Colliery Major Expansion Groundwater Assessment* (GeoTerra, | Groundwater assessment for the original mine plan, as | Annex P of EA |

| Ref | Date | Author & Title | Detail | Reference |
|---|---|---|---|---|
| | | 2012a) | proposed in the EA. | |
| 9. | June 2014 | *Russell Vale Colliery Underground Expansion Project Preferred Project Report Wonga East Groundwater Assessment* (GeoTerra / GES, 2014) | New groundwater assessment for the preferred mine plan, as proposed in the PPR. | Appendix C of Residual Matters Report |
| 10. | September 2015 | ***Russell Vale Colliery Underground Expansion Project Russell Vale East Revised Groundwater Assessment*** (GeoTerra / GES, 2015) | New groundwater assessment prepared in response to the recommendations in the PAC Review Report. | **Appendix H** |
| **SURFACE WATER** | | | | |
| 11. | November 2012 | *NRE No. 1 Colliery Major Expansion Stream Assessment* (GeoTerra, 2012b) | Assessment of impacts to streams due to subsidence associated with the original mine plan, as proposed in the EA. | Annex O of EA |
| 12. | May 2014 | ***Russell Vale Colliery Wonga East Underground Expansion Project Surface Water Modelling*** (WRM, 2014) | Assessment of impacts to catchments due to subsidence associated with the preferred mine plan, as proposed in the PPR. | Appendix F of Residual Matters Report |
| 13. | June 2014 | ***Russell Vale Colliery Underground Expansion Project Preferred Project Report Groundwater & Surface Water Response to Submissions Residual Matters Addendum*** (GeoTerra, 2014) | Assessment of impacts to streams due to subsidence associated with the preferred mine plan, as proposed in the PPR. | Appendix E of Residual Matters Report |
| 14. | September 2015 | ***Russell Vale Colliery Underground Expansion Project Surface Water Modelling: Response to Planning Assessment Commission*** (WRM, 2015) | Addendum to WRM (2014) to address the recommendations in the PAC Review Report. | **Appendix I** |
| **UPLAND SWAMPS** | | | | |
| 15. | November 2012 | *NRE No. 1 Colliery Major Expansion Upland Swamp Assessment* (Biosis, 2012) | Assessment of impacts to upland swamps due to subsidence associated with the original mine plan in the EA. | Annex Q of the EA |
| 16. | August 2014 | ***Coastal Upland Swamp Impact Assessment Report*** (Biosis, 2014) | Assessment of impacts to upland swamps due to subsidence associated with the preferred mine plan in the EA. | Appendix D of *Response to Public Hearing* (Hansen Bailey, 2015) |
| 17. | September 2015 | ***Underground Expansion Project Independent Risk Assessment – Addendum Report*** (Biosis, 2015) | Prepared to address issues raised by the IRAP during the risk assessment process. | **Appendix J** |

# 4 RISK ASSESSMENT METHODOLOGY SUMMARY

*This section provides a brief summary of the process followed in the development of this Integrated Risk Assessment. A detailed discussion on the risk assessment methodology and risk assessment process is provided in* ***Appendix A****.*

## 4.1 IRAP ESTABLISHMENT

The formation of the IRAP was undertaken in consultation with DP&E, and all members of IRAP were approved by DP&E (see **Appendix C**). As illustrated in the TORs flowchart reproduced as **Figure 5**, relevant regulatory authorities were extensively consulted with, and their comments on the methodology and risk assessment were responded to.

**Figure 5** illustrates the general process for the operation of IRAP, and the involvement of regulators, WCL and its specialists in the process. This process flowchart was developed in consultation with the DP&E. This process will continue to evolve during the operation of the Project and the TORs will be subject to review in consultation with relevant regulators, as required. TORs are provided in **Appendix C.**

## 4.2 METHODOLOGY

WCL engaged Broadleaf to independently facilitate the Integrated Risk Assessment. Broadleaf was responsible for the development and implementation of the risk assessment methodology. The methodology developed by Broadleaf was based on the relevant Standard (i.e. AS/NZS ISO 31000:2009 *Risk management – Principles and Guidance*).

Potential risks from longwall mining to environmental features were considered separately for three groups of longwall panels: LWs 1-3, LWs 6-7 and LWs 9-11. Detailed event trees (with primary endpoints and indicators) were developed for each group of longwall panels.

A detailed risk register was developed from the event trees. Risks are presented in the form of sequence of causes, which potentially leads to a consequence at the endpoint.

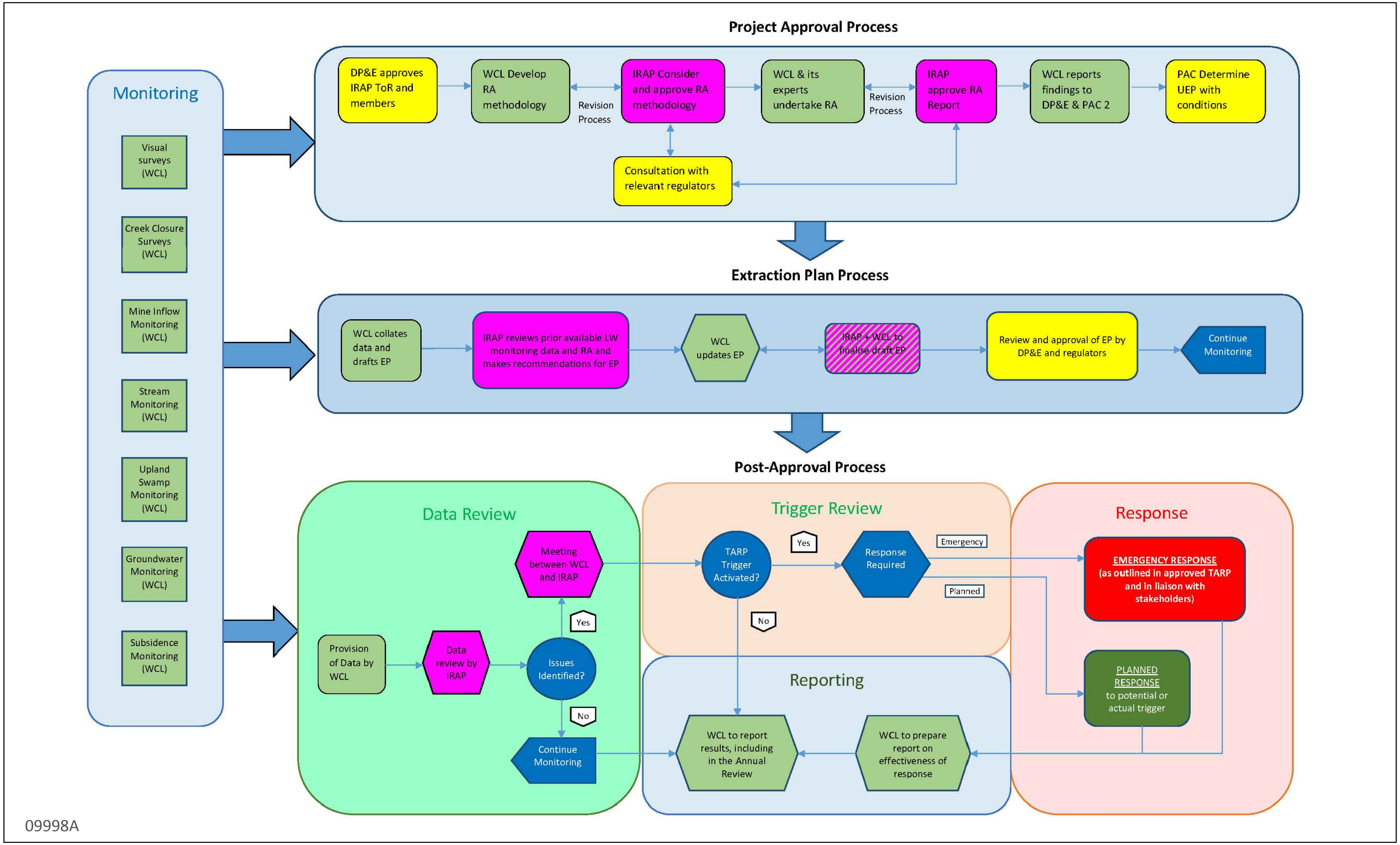
Risks were analysed using risk assessment scales (see **Appendix B**) that considered the effectiveness of controls, likelihood of occurrence and potential consequences. Each was based on standard risk assessment protocols and was tailored by Broadleaf to be specific to the Project. This enabled the overall level of risk for each event to be determined.

Where residual risks were identified, additional controls were identified and included in the Risk Register and added to the SoC for the Project (see **Section 8**).

Various risk assessment workshops were facilitated by Dr Dale Cooper from Broadleaf with contributions from WCL and its technical specialists.

Extensive consultation with the IRAP and regulatory authorities (in the form of meetings, presentations and written correspondence) culminated in the development of a 'draft' document. The 'draft' document was provided to the IRAP and regulatory authorities for comments. This document has been revised to address the issues raised.

A summary of consultation is provided in **Table A** of **Appendix C**.




RUSSELL VALE COLLIERY

IRAP Process Flowchart

**FIGURE 5**

# 5 SUMMARY OF INTEGRATED RISK ASSESSMENT

*This section provides a summary of the technical studies prepared by the relevant specialists (presented in **Appendices D to J**), which were relied upon to determine the risk classifications in the Risk Assessment.*

*This section also summarises the predicted impacts of the Project on water resources and upland swamps. This summary has been prepared at the request of key regulatory authorities and the IRAP. Controls to manage risks are summarised in **Section 7** and **Section 8**.*

## 5.1 GROUNDWATER

### 5.1.1 Seepage from Cataract Reservoir

*This section addresses the risks associated with seepage from Cataract Reservoir due to depressurisation of the regional groundwater system.*

**Relevant Risks**

| Risk ID | Description | Classification |
|---|---|---|
| AS 211 | Groundwater depressurisation leading to seepage from Cataract Reservoir (LWs 1-3) | Medium |
| BS 211 | Groundwater depressurisation leading to seepage from Cataract Reservoir (LWs 6-7) | Medium |
| CS 211 | Groundwater depressurisation leading to seepage from Cataract Reservoir (LWs 9-11) | Medium |

**Relevant Sections of Documentation**

- Section 10.5.2 of **Appendix H**

**Summary of Findings**

The regional piezometric surface is located within the Bulgo Sandstone below the base of Cataract Reservoir. The proposed mining activities will result in regional depressurisation of the groundwater system beneath Cataract Reservoir. This would cause stored water from Cataract Reservoir to seep into the underlying groundwater system. The revised groundwater model predicts a rate of seepage from Cataract Reservoir of 0.00024 ML/day (0.1 ML/year) at the end of mining.

Cataract Reservoir has a maximum storage capacity of 97,190 ML, which represents approximately 3.8% of the total storage capacity in the Greater Sydney water supply system (2,581,850 ML). Therefore, the impact of the Project on Cataract Reservoir is negligible in the context of Greater Sydney's drinking water supply.

Recovery of potentiometric heads within the overburden has been modelled up to 200 years after cessation of mining at Russell Vale East. However, recovery will occur over many centuries and will eventually reach a long-term steady state level below the pre-mining regional groundwater level (i.e. before mining at Russell Vale Colliery and other mines).

Risks associated with depressurisation of the regional groundwater system have been classified as 'medium' as mining is certain to result in groundwater depressurisation (high likelihood rating). However, the effect of depressurisation on water quantities in Cataract Reservoir is predicted to be negligible (low consequence rating).

### 5.1.2 Impacts on Stream Baseflow

*This section addresses the risks associated with changes in baseflow to the streams flowing to Cataract Reservoir (i.e. Cataract Creek, Cataract River and Bellambi Creek).*

**Relevant Risks**

| Risk ID | Description | Classification |
|---|---|---|
| AS 212 | Reduced baseflow to streams due to depressurisation of the regional aquifer (LWs 1-3) | Medium |
| BS 212 | Reduced baseflow to streams due to depressurisation of the regional aquifer (LWs 6-7) | Medium |
| CS 212 | Reduced baseflow to streams due to depressurisation of the regional aquifer resulting from mining (LWs 9-11) | Medium |

**Relevant Sections of Documentation**

- Section 10.4 of **Appendix H**

**Summary of Findings**

The proposed mining activities will result in depressurisation of the groundwater system under the catchments affected by mining. This would result in reduced groundwater baseflow recharge to Cataract Creek, Cataract River and Bellambi Creek.

Baseflow to Cataract Creek is predicted to decrease by 0.041 ML/day (14.9 ML/year) at the end of mining. This represents 1.0% of the average baseflow in Cataract Creek, which is estimated to be 4.1 ML/day under current conditions.

Baseflow to Cataract River is predicted to decrease by 0.00035 ML/day (0.14 ML/year) at the end of mining. This represents a 0.003% decrease in the average baseflow to Cataract River, which is estimated to be 13.2 ML/day under current conditions.

These volumes of water are not anticipated to be 'lost' from the catchment, as this water is expected to migrate (under gravity drainage) to lower elevations within the catchments and report to the reservoir via down-gradient groundwater seepage points.

Baseflow to Bellambi Creek is predicted to increase by 0.00064 ML/day (0.23 ML/year) at the end of mining. This represents a 0.009% increase in the average baseflow to Bellambi Creek, which is estimated to be 6.9 ML/day under current conditions.

These predicted impacts are negligible compared to the average daily inflow to Cataract Reservoir of 100 ML/day (see **Figure 10**).

Risks associated with depressurisation of the regional groundwater system have been classified as 'medium' because mining is certain to result in groundwater depressurisation (high likelihood rating). However, the effect of depressurisation on stream flows is predicted to be negligible (low consequence rating).

### 5.1.3 Groundwater Inflow

*This section addresses the risks associated with groundwater inflow into the mine workings.*

**Relevant Risks**

| Risk ID | Description | Classification |
|---|---|---|
| AS 221 | Fracturing of deeper strata leading to increased groundwater flowing into the mine from mining of LWs 1-3 | Medium |
| BS 221 | Fracturing of deeper strata leading to increased groundwater flowing into the mine from mining of LWs 6-7 | Medium |
| CS 221 | Fracturing of deeper strata leading to increased groundwater flowing into the mine from mining of LWs 9-11 | Medium |

**Relevant Sections of Documentation**

- Section 10.7 of **Appendix H**

**Summary of Findings**

The rates of groundwater inflow to the mine workings were predicted using the revised groundwater model. The predicted inflow rates are presented in **Table 3**. The total mine inflow includes groundwater inflow into the completed Bulli, Balgownie and Wongawilli seam workings in the Russell Vale East domain, as well as the decommissioned Bulli Seam workings in the Russell Vale West domain.

Given that the regional groundwater system is located within the Bulgo Sandstone beneath Cataract Reservoir, the predicted groundwater inflows to the mine workings will not result in significant losses of water from the reservoir. The majority of mine inflow will be drawn from drainage in deeper predominantly horizontally fractured strata and the highly vertically fractured goaf. The only impact on Cataract Reservoir is the predicted seepage of 0.00024 ML/day (see **Section 5.1.1**).

**Table 3**
**Predicted Groundwater Inflows**

| Stage | Bulli Seam Inflow (ML/day) / (ML/year) | Russell Vale East Inflow (ML/day) / (ML/year) | Total Mine Inflow (ML/day) / (ML/year) |
|---|---|---|---|
| Pre Longwall 4 | 0.40 / 146 | 0.20 / 73 | 0.60 / 219 |
| Post Longwall 5 | 0.49 / 179 | 1.04 / 383 | 1.54 / 562 |
| Post Longwalls 6 and 7 | 0.48 / 178 | 2.27 / 826 | 2.75 / 1,004 |
| Post Longwalls 9 to 11 | 0.49 / 179 | 2.7 / 996 | 3.22 / 1,175 |
| Post Longwalls 1 to 3 | 0.50 / 183 | 2.82 / 1,029 | 3.32 / 1,212 |

The modelled inflow rate after mining of mining LW 5 is approximately 1.5 ML/day. The inflow rate at the end of the Project is predicted to be approximately 3.3 ML/day. Therefore, the mine inflow rate is predicted to increase by 1.8 ML/day as a result of the Project.

As conceptually shown in **Figure 10**, the catchment of Cataract Reservoir receives an average of 350 ML/day in rainfall. Approximately 250 ML/day of this rainfall is lost to evaporation, transpiration and infiltration. The predicted groundwater inflows form a component of the total losses from the catchment. Therefore, the predicted groundwater inflows do not affect the volume of water captured by the reservoir (100 ML/day on average).

## 5.2 SURFACE WATER

### 5.2.1 Re-direction of Surface Flows

*This section addresses the risks associated with re-direction of surface flows to the subsurface via subsidence induced cracking.*

**Relevant Risks**

| Risk ID | Description | Classification |
|---|---|---|
| AH 2121 | Surface cracking leading to redirection of surface flow to groundwater system (LWs 1-3) | Medium |
| BH 2121 | Surface cracking leading to redirection of surface flow to groundwater system (LWs 6-7) | Medium |
| CH 2121 | Surface cracking leading to redirection of surface flow to groundwater system (LWs 9-11) | Medium |

**Relevant Sections of Documentation**

- Section 5 of **Appendix I**

**Summary of Findings**

Surface cracking resulting from subsidence has the potential to re-direct surface flows into the sub-surface. It is hypothesised that this water would flow towards Cataract Reservoir via subterranean flow paths and re-emerge at lower elevations as surface flow seeps further downstream (GeoTerra, 2012b). However, the Risk Assessment has conservatively assumed the highly unlikely scenario where none of the re-directed flows re-emerge downstream. This is considered to represent the worst case scenario.

Subsidence resulting from the Project will occur predominantly within the catchment of Cataract Creek. The Project will also result in lesser degrees of subsidence within the Cataract River and Bellambi Creek catchments. The Risk Assessment has conservatively assumed that subsidence induced cracking would result in re-direction of all surface flow from sub-catchments that are upstream of or overlying the proposed longwall panels. To determine the reductions in stream flow resulting from cracking, these sub-catchments were excluded from the catchment model (see **Appendix I**).

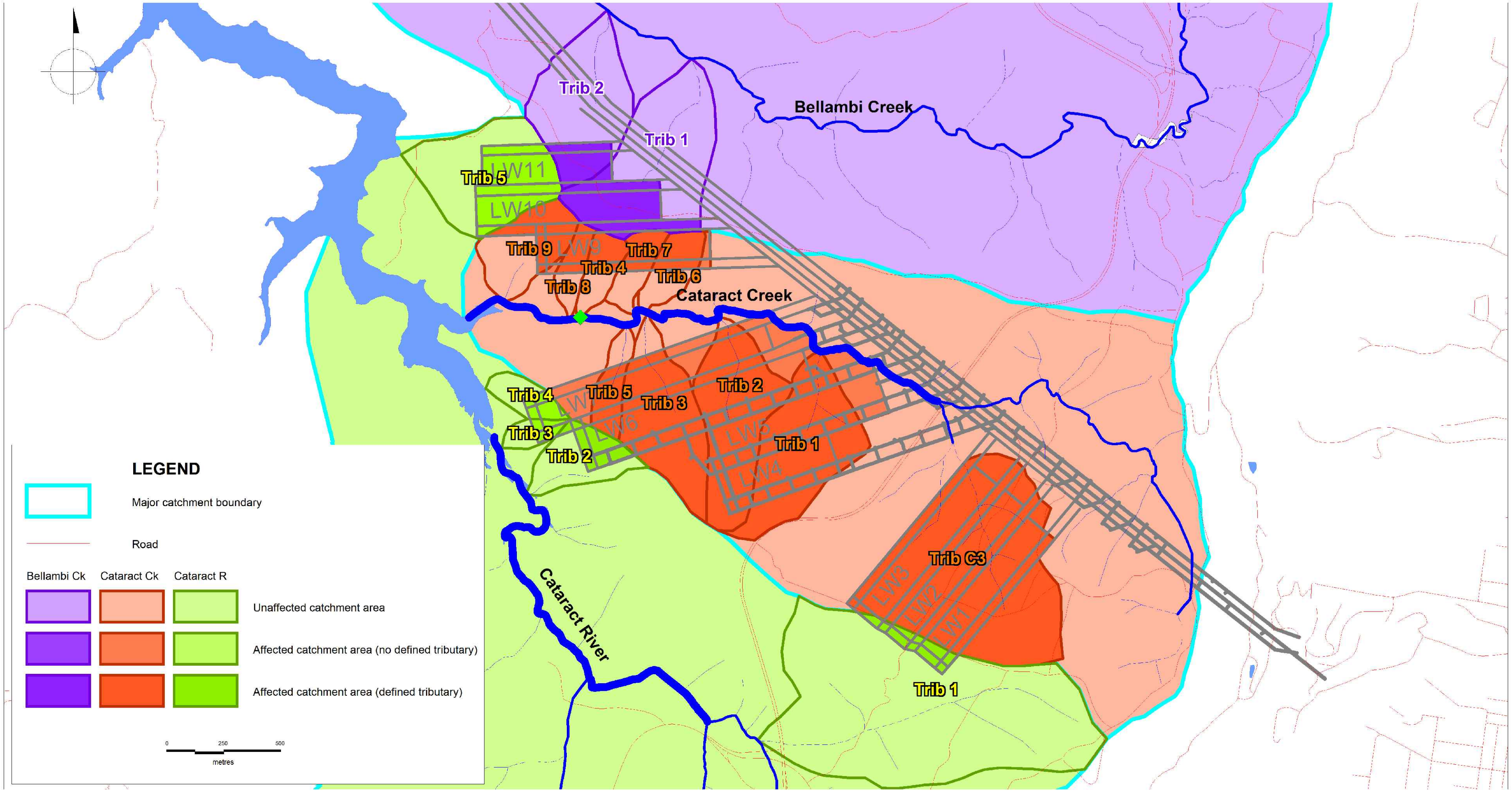
**Figure 6** shows the sub-catchments where complete re-direction of surface flow was assumed to occur. The sub-catchments that are downstream of the proposed longwall panels are not anticipated to exhibit any reduction in runoff contribution to the main stream channels.

Under the worst case scenario, subsidence induced cracking is predicted to reduce total flow in Cataract Creek by 6.38 ML/day. Similarly, total flows in Cataract River and Bellambi Creek are predicted to decrease by 0.56 ML/day and 0.40 ML/day. Therefore, the total flow to Cataract Reservoir is predicted to decrease by 7.34 ML/day under the modelled worst case scenario. Under existing conditions, the total average stream flow in Cataract Creek, Cataract River and Bellambi Creek is estimated to be 76.34 ML/day. The worst case scenario represents a 9.6% reduction in the total average stream flow provided by these catchments.

The predicted impacts from each area of the mine plan (i.e. LWs 1-3, 6-7 and 9-11), given the predicted reductions in flow to Cataract Reservoir resulting from the three areas of the mine plan are presented in **Table 4**.

**Table 4**
**Predicted Reductions in Stream Flow due to Cracking**

| LW Series | Catchment | Tributary | Average Total Flow (ML/day) | Total Loss for LW Series (ML/day) |
|---|---|---|---|---|
| 1-3 | Cataract Creek | Tributary C3 | 2.27 | 2.35 |
| | Cataract River | Tributary 1 | 0.08 | |
| 6-7 | Cataract Creek | Tributary 1 | 0.97 | 3.60 |
| | | Tributary 2 | 0.91 | |
| | | Tributary 3 | 0.75 | |
| | | Tributary 5 | 0.15 | |
| | | Residual areas (LW 4-7) | 0.64 | |
| | Cataract River | Tributary 2 | 0.09 | |
| | | Tributary 3 | 0.03 | |
| | | Tributary 4 | 0.05 | |
| 9-11 | Cataract Creek | Tributary 4 | 0.10 | 1.39 |
| | | Tributary 6 | 0.12 | |
| | | Tributary 7 | 0.11 | |
| | | Tributary 8 | 0.09 | |
| | | Tributary 9 | 0.23 | |
| | | Residual areas (LW 9-11) | 0.03 | |
| | Bellambi Creek | Tributary 1 | 0.28 | |
| | | Tributary 2 | 0.11 | |
| | Cataract River | Tributary 5 | 0.30 | |

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Source: WRM (2015)

RUSSELL VALE COLLIERY

Potentially Affected Catchments

**FIGURE 6**

WOLLONGONG COAL

Hansen Bailey
ENVIRONMENTAL CONSULTANTS

### 5.2.2 Connectivity to Reservoir via Geological Structures

*This section addresses the perceived risk of hydraulic connectivity to Cataract Reservoir via the Corrimal Fault and Dyke D8.*

**Relevant Risks**

| Risk ID | Description | Classification |
|---|---|---|
| BS 23 | Increased mine inflows due to hydraulic conductivity via the Corrimal Fault | Low |
| BS 24 | Increased mine inflows due to hydraulic conductivity via Dyke D8 | Low |

**Relevant Sections of Documentation**

- **Appendix F**

**Summary of Findings**

The Corrimal Fault has been intersected by previous extraction of the overlying coal seams. Mining of the Bulli Seam previously intersected the Corrimal Fault and Dyke D8 over distances of greater than 3.4 km (see **Figure 7**). These structures were exposed again by extraction of the Balgownie Seam (D8 Dyke for 2 km and Corrimal Fault at one location). In the Wongawilli seam, the Corrimal Fault has been intersected in gateroads and mined through in LW 6. There was no evidence that these intersections resulted in any additional inflows to the mine through these structures. The workings that intersected these structures remain open and there continues to be no evidence of inflows above background levels from the areas where these structures were intersected.

The intersections of the Corrimal Fault by all three seams in the Russell Vale East domain provide a high degree of confidence in the geometry of the fault structure in three dimensions. A significant offset (throw) across the fault is apparent near the escarpment, approximately 3 km to the east of LW 6. There is also evidence in the surface topography and lineation of drainage lines approximately 1.5 km from LW 6 towards the east that may be coincident with the Corrimal Fault. However, this alignment is considered more likely to be associated with the regional joint direction in the Hawkesbury Sandstone.

Survey measurements in the Bulli Seam indicate the maximum throw of the Corrimal Fault is 29 m near the Illawarra Escarpment (Harper, 1915). The throw reduces to 15 m at a distance of 1.3 km east of LW 6. At the location where the fault is exposed by the face of LW 6, the magnitude of the throw reaches a local high of 2.9 m and is generally about 1.0 - 1.5 m with the throw reducing in both directions (but mainly toward Cataract Reservoir to the west). The mine plans indicate that the throw in the Bulli Seam at this location and further to the west is not sufficient to have affected the layout of the workings and an intersection in the Balgownie Seam indicated a reduced throw compared to that observed in LW 6.

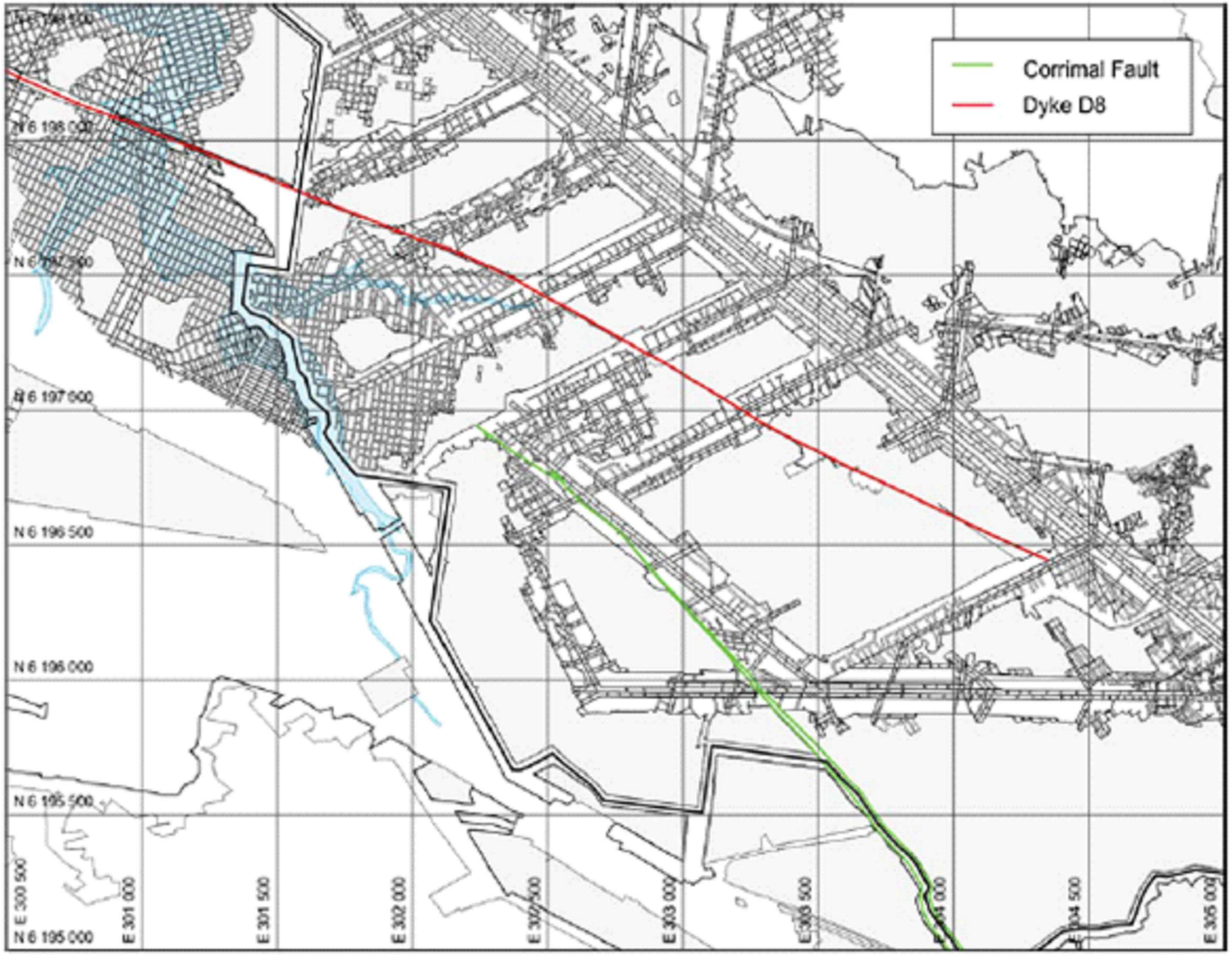
These observations indicate that the throw of the Corrimal Fault pinches out in the Bulli Seam near the location of LW 6 and is pinching out in the Balgownie and Wongawilli seams as well. Although there is some potential for the fault to be intersected in the Wongawilli Seam by LW 7, the throw is expected to be less than 1 m at this horizon and pinched out completely in the Bulli Seam above. The point where the Corrimal Fault may intersect LW 7 is approximately 540 m east of the full supply level of Cataract Reservoir. The overburden depth at the edge of the reservoir on the projected alignment is approximately 305 m. The fault projection is intersected by previous workings in the Bulli Seam at approximately 140 m from the reservoir.

Surveyed floor levels in the Bulli Seam indicate that the fault completely pinches out beneath Cataract Reservoir. The three-dimensional projection of the fault is shown in **Figure 8**. If the fault was hydraulically conductive, the intersection of the fault by workings in the Bulli and Balgownie seams would have shown some increased inflow. No such inflows have been observed, which suggests that the Corrimal Fault is not hydraulically conductive. This experience is consistent with most other fault intersections in the Southern Coalfield. Mining is not expected to cause any ground movements within the overburden strata that would cause the projected alignment of the fault to move differentially across the fault. There is no credible mechanism for mining to increase the hydraulic conductivity of the Corrimal Fault between LW 7 and Cataract Reservoir.

Dyke D8 extends at least 3.5 km across the Russell Vale East domain, including beneath Cataract Reservoir and Cataract Creek (immediately upstream of the full supply level). Dyke D8 was intersected in multiple pillar extraction areas in the Bulli Seam, the nearest of which is a lateral distance of 90 m from the full supply level of Cataract Reservoir (see **Figure 7**). The nearest point where Dyke D8 will be intersected by first workings is approximately 900 m from Cataract Reservoir. The nearest point where the dyke will be intersected by longwall extraction is along LW 7, approximately 1,700 m from Cataract Reservoir.

Dyke D8 was also intersected by LWs 4 & 5 in the Wongawilli Seam. There is no evidence of increase inflows as a result of previous intersections of Dyke D8, including the intersection of the Bulli Seam that is a lateral distance of 90 m from the full supply level of Cataract Reservoir. There is no potential for significant tensile movements or shear movements to occur along Dyke D8 as a result of mining LWs 6, 7, 9, 10 & 11.

Since there has been limited history of inflows from dyke intersections in the Southern Coalfield, it is difficult to provide a definitive estimate of inflow magnitude. The maximum recorded inflow of approximately 2.4 ML/day was observed in the Blue 2 Panel at Wongawilli Colliery. This intersection occurred at a nominal depth of 120 m where a significant dyke / sill system that extended below Avon Reservoir was intersected by pillar extraction workings mined to within about 100 m of Avon Reservoir (Doyle and Poole, 1986). This inflow rate decreased to less than 0.8 ML/day within 4 years. Even if Dyke D8 was hydraulically conductive, the maximum credible inflow rate (having regard to the location and size of intersections) is considered to be much less than 0.2 ML/day. This is within the limit of tolerability for inflows (0.5 ML/day) adopted by the DSC.

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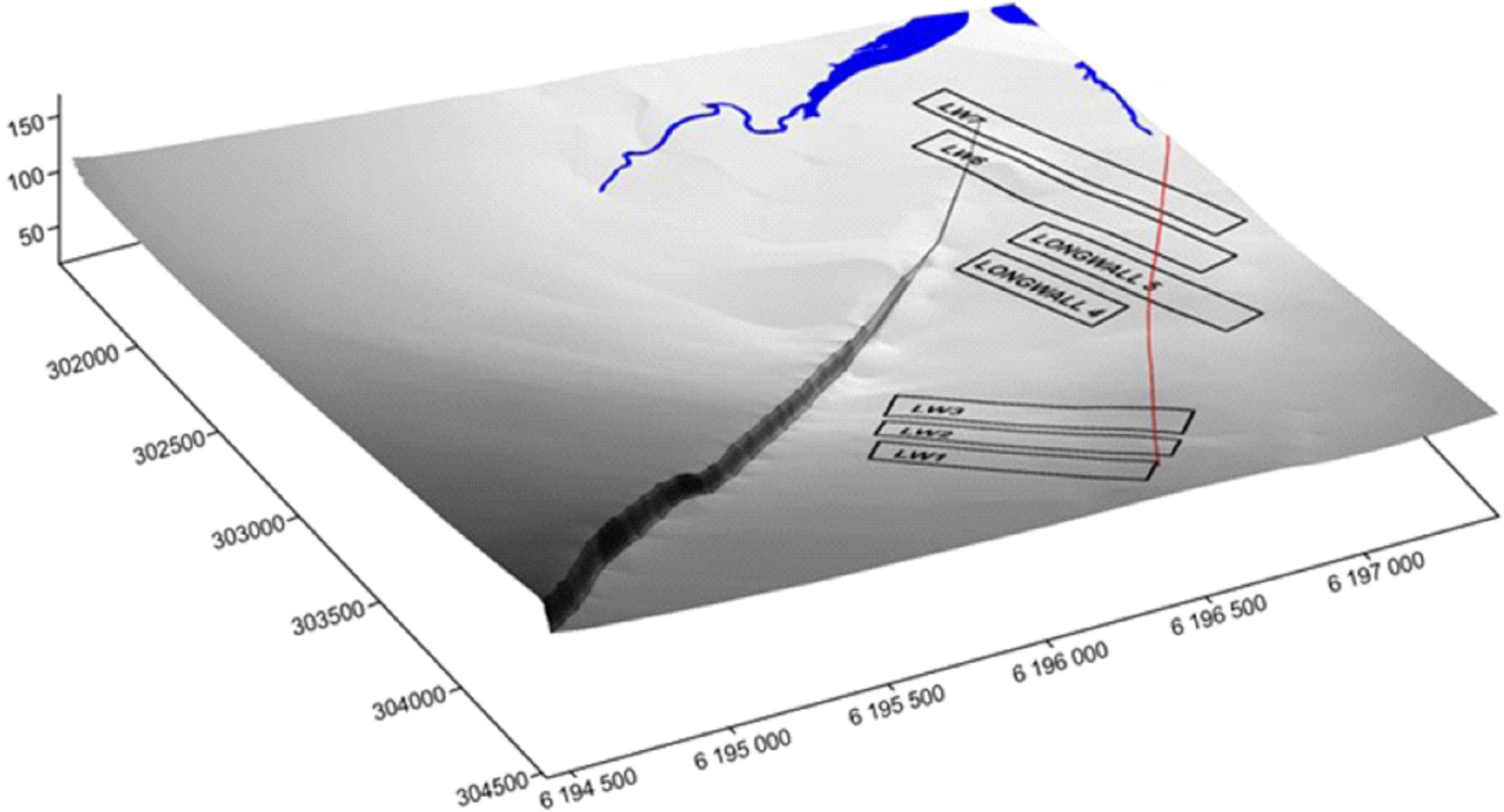
Source: SCT (2015)

RUSSELL VALE COLLIERY

Bulli Seam Intersections of Corrimal Fault and Dyke D8

**FIGURE 7**

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Source: SCT (2015)

**RUSSELL VALE COLLIERY**

Three Dimensional Representation of Corrimal Fault

**FIGURE 8**

### 5.2.3 Impacts on Water Quality

*This section addresses the risks to water quality in Cataract Reservoir associated with subsidence.*

#### Relevant Risks

| Risk ID | Description | Classification |
|---|---|---|
| AH 211 | Redirection of surface flow due to stream bed cracking resulting in a reduction in quality of streamflow re-emerging downstream into Cataract Reservoir (LWs 1-3) | Medium |
| AS 121 | Surface fracturing leading to increased iron oxide staining and causing a reduction in quality flowing into Cataract Reservoir (LWs 1-3) | Medium |
| AT 21 | Changes to stream water regime leading to increased pooling in streams (LWs 1-3) | Negligible |
| BH 211 | Redirection of surface flow due to stream bed cracking resulting in a reduction in quality of streamflow re-emerging downstream into Cataract Reservoir (LWs 6-7) | Low |
| BH 213 | Redirection of surface flow due to stream bed cracking resulting in an increase in iron oxidation (LWs 6-7) | Low |
| BS 131 | Surface fracturing leading to increased iron oxide staining and causing a reduction in quality flowing into Cataract Reservoir (LWs 6-7) | Medium |
| BT 21 | Changes to stream water regime leading to increased erosion downstream (LWs 6-7) | Negligible |
| BT 22 | Changes to stream water regime leading to increased pooling in streams (LWs 6-7) | Negligible |
| CH 211 | Redirection of surface flow due to stream bed cracking resulting in a reduction in quality of streamflow re-emerging downstream into Cataract Reservoir (LWs 9-11) | Low |
| CS 121 | Surface fracturing leading to increased iron oxide staining and causing a reduction in quality flowing into Cataract Reservoir (LWs 9-11) | Medium |
| CT 21 | Changes to stream water regime leading to increased erosion downstream (LWs 9-11) | Negligible |
| CT 22 | Changes to stream water regime leading to increased pooling in streams (LWs 9-11) | Negligible |

#### Relevant Sections of Documentation

- Sections 3 & 4 of *Russell Vale Colliery Underground Expansion Project Preferred Project Report Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014a)
- Section 8.4.2 of *End of Longwall 4 & Longwall 5 Groundwater & Surface Water Monitoring Assessment* (GeoTerra, 2014b)

**Summary of Findings**

No cracking is expected to occur along the stream beds of Cataract River and Bellambi Creek. Subsidence movements may result in cracking of the Cataract Creek stream bed. The main channel of Cataract Creek is hosted sequentially downstream within the Hawkesbury Sandstone, Newport and Garie Formations, Bald Hill Claystone and Bulgo Sandstone. The Newport and Garie Formations, Bald Hill Claystone and Bulgo Sandstone are more ductile than the Hawkesbury Sandstone. Although the Hawkesbury Sandstone is the dominant exposed bedrock in streams within mined areas in the Southern Coalfield, the presence of Hawkesbury Sandstone is limited to headwater tributaries (1$^{st}$ and 2$^{nd}$ order reaches) at Russell Vale East. Therefore, the risk of stream bed cracking is expected to be lower than observed at other mining areas in the Southern Coalfield.

Stream bed cracking may result in impacts to stream water quality through localised reduction of stream flow and / or increased interaction of groundwater and surface water. The impacts to stream water quality may include reduced dissolved oxygen, higher dissolved ions and precipitates, reduced pH and less temperature variation.

Impacts to stream water quality are expected to be localised. Due to the effect of dilution, changes to stream water chemistry are expected to be limited to a short distance downstream of each groundwater seepage point. Water quality monitoring data indicates that extraction of LWs 4 & 5 did not affect the chemistry of Cataract Creek where it discharges into Cataract Reservoir (location CC8) or the Cataract Reservoir itself (location CD1). Accordingly, the Project is not expected to impact on the water chemistry of Cataract Reservoir.

There is no evidence of cracking or delamination of the main stream beds as a result of pre-existing Bulli Seam or Balgownie Seam workings, or due to mining of the Wongawilli Seam in LWs 4, 5 and LW 6 (365 m). However, cracking has been observed in higher elevation tributary stream beds. As such, there have been no observed impacts to the main stream pool levels (to date). Although not anticipated, the Project may result in minor fracturing of the main Cataract Creek stream channel, which could lead to minor reductions in pool holding capacity.

## 5.3 UPLAND SWAMPS

### 5.3.1 Impacts Associated with Fracturing of Bedrock

*This section addresses the risk of impacts to upland swamps due to bedrock fracturing, and the flow-on impacts to water quantity and quality in Cataract Reservoir.*

#### Relevant Risks

| Risk ID | Description | Classification |
|---|---|---|
| AS 11111 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS1, reducing cleaning effects and reducing water quality flowing to the reservoir from mining of LW 3 | Negligible |
| AS 11121 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS1, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from mining of LW 3 | Low |
| AS 1113 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS1, leading to a detrimental effect on swamp ecosystems from mining of LW 3 | Medium |
| AS 1114 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS1, leading to an increased susceptibility to fire from mining of LW 3 | Negligible |
| AS 1115 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS1, leading to a diversion of baseflow from swamp from mining of LW 3 | Low |
| AS 11211 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS2, reducing cleaning effects and reducing water quality flowing to the reservoir from mining of LWs 2-3 | Negligible |
| AS 11221 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS2, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from mining of LWs 2-3 | Negligible |
| AS 1123 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS2, leading to a detrimental effect on swamp ecosystems from mining of LWs 2-3 | Negligible |
| AS 1124 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS2, leading to an increased susceptibility to fire from mining of LWs 2-3 | Medium |
| AS 1125 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS2, leading to a diversion of baseflow from swamp from mining of LWs 2-3 | Negligible |
| AS 11311 | Surface fracturing causing cracking of bedrock leading to drying of swamp CRUS3, reducing cleaning effects and reducing water quality flowing to the reservoir from mining of LWs 1-3 | Negligible |
| AS 11321 | Surface fracturing causing cracking of bedrock leading to drying of swamp CRUS3, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from mining of LWs 1-3 | Negligible |
| AS 1133 | Surface fracturing causing cracking of bedrock leading to drying of swamp CRUS3, leading to a detrimental effect on swamp ecosystems from mining of LWs 1-3 | Negligible |
| AS 1134 | Surface fracturing causing cracking of bedrock leading to drying of swamp CRUS3, leading to an increased susceptibility to fire from mining of LWs 1-3 | Negligible |

| Risk ID | Description | Classification |
|---|---|---|
| AS 1135 | Surface fracturing causing cracking of bedrock leading to drying of swamp CRUS3, leading to a diversion of baseflow from swamp from mining of LWs 1-3 | Negligible |
| BS 11111 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS4, reducing cleaning effects and reducing water quality flowing to the reservoir from mining of LWs 6-7 | Negligible |
| BS 11121 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS4, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from mining of LWs 6-7 | Low |
| BS 1113 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS4, leading to a detrimental effect on swamp ecosystems from mining of LWs 6-7 | High |
| BS 1114 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS4, leading to an increased susceptibility to fire from mining of LWs 6-7 | Medium |
| BS 1115 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS4, leading to a diversion of baseflow from swamp from mining of LWs 6-7 | Medium |
| BS 11211 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS5, reducing cleaning effects and reducing water quality flowing to the reservoir from mining of LW 7 | Negligible |
| BS 11221 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS5, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from mining of LW 7 | Low |
| BS 1123 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS5, leading to a detrimental effect on swamp ecosystems from mining of LW 7 | Low |
| BS 1124 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS5, leading to an increased susceptibility to fire from mining of LW 7 | Low |
| BS 1125 | Surface fracturing causing cracking of bedrock leading to drying of swamp CRUS5, leading to a diversion of baseflow from swamp from mining LW 7 | Negligible |
| BS 11311 | Surface fracturing causing cracking of bedrock leading to drying of swamp CRUS1, reducing cleaning effects and reducing water quality flowing to the reservoir from LW mining | Negligible |
| BS 11321 | Surface fracturing causing cracking of bedrock leading to drying of swamp CRUS1, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from LW mining | Negligible |
| BS 1133 | Surface fracturing causing cracking of bedrock leading to drying of swamp CRUS1, leading to a detrimental effect on swamp ecosystems from LW mining | Negligible |
| BS 1134 | Surface fracturing causing cracking of bedrock leading to drying of swamp CRUS1, leading to an increased susceptibility to fire from LW mining | Negligible |
| BS 1135 | Surface fracturing causing cracking of bedrock leading to drying of swamp CRUS1, leading to a diversion of baseflow from swamp from LW mining | Negligible |
| BS 12111 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS4, reducing cleaning effects and reducing water quality flowing to the reservoir from the mining of LW 6 | Negligible |
| BS 12121 | Surface fracturing of controlling rockbars leading to drying of swamp CCUS4, reducing cleaning effects and reducing water quality flowing to the reservoir from the mining of LW 6 | Negligible |

| Risk ID | Description | Classification |
|---|---|---|
| BS 1213 | Surface fracturing of controlling rockbars causing the drying of swamp CCUS4, leading to a detrimental effect on swamp ecosystems from the mining of LW 6 | High |
| BS 1214 | Surface fracturing of controlling rockbars causing the drying of swamp CCUS4, leading to an increased susceptibility to fire from the mining of LW 6 | Medium |
| CS 11111 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS10, reducing cleaning effects and reducing water quality flowing to the reservoir from the mining of LW 9 | Negligible |
| CS 11121 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS10, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from the mining of LW 9 | Low |
| CS 1113 | Surface fracturing causing cracking of bedrock causing the drying of swamp CCUS10, leading to a detrimental effect on swamp ecosystems from the mining of LW 9 | Negligible |
| CS 1114 | Surface fracturing of controlling rockbars causing the drying of swamp CCUS10, leading to an increased susceptibility to fire from the mining of LW 9 | Negligible |
| CS 11211 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS11, reducing cleaning effects and reducing water quality flowing to the reservoir from the mining of LW 9 | Negligible |
| CS 11221 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS11, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from the mining of LW 9 | Low |
| CS 1123 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS11, leading to a detrimental effect on swamp ecosystems from the mining of LW 9 | Negligible |
| CS 1124 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS11, leading to an increased susceptibility to fire from mining of LW 9 | Negligible |
| CS 11311 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS12, reducing cleaning effects and reducing water quality flowing to the reservoir from mining of LWs 9-10 | Negligible |
| CS 11321 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS12, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from the mining of LWs 9-10 | Negligible |
| CS 1133 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS12, leading to a detrimental effect on swamp ecosystems from the mining of LWs 9-10 | Low |
| CS 1134 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS12, leading to an increased susceptibility to fire from mining of LWs 9-10 | Negligible |
| CS 11411 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS24, reducing cleaning effects and reducing water quality flowing to the reservoir from mining of LW 9 | Negligible |
| CS 11421 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS24, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from the mining of LW 9 | Negligible |
| CS 1143 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS24, leading to a detrimental effect on swamp ecosystems from the mining of LW 9 | Negligible |

| Risk ID | Description | Classification |
|---|---|---|
| CS 1144 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS24, leading to an increased susceptibility to fire from mining of LW 9 | Negligible |
| CS 11511 | Surface fracturing causing cracking of bedrock leading to drying of swamp BCUS4, reducing cleaning effects and reducing water quality flowing to the reservoir from mining of LW 10 | Negligible |
| CS 11521 | Surface fracturing causing cracking of bedrock leading to drying of swamp BCUS4, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from the mining of LW 10 | Low |
| CS 1153 | Surface fracturing causing cracking of bedrock leading to drying of swamp BCUS4, leading to a detrimental effect on swamp ecosystems from the mining of LW 10 | Medium |
| CS 1154 | Surface fracturing causing cracking of bedrock leading to drying of swamp BCUS4, leading to an increased susceptibility to fire from mining of LW 10 | Medium |
| CS 1155 | Surface fracturing causing cracking of bedrock leading to drying of swamp BCUS4, leading to a diversion of baseflow from swamp from mining of LW 10 | Medium |
| CS 11611 | Surface fracturing causing cracking of bedrock leading to drying of swamp BCUS11, reducing cleaning effects and reducing water quality flowing to the reservoir from mining of LW 10 | Negligible |
| CS 11621 | Surface fracturing causing cracking of bedrock leading to drying of swamp BCUS11, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from the mining of LW 10 | Low |
| CS 1163 | Surface fracturing causing cracking of bedrock leading to drying of swamp BCUS11, leading to a detrimental effect on swamp ecosystems from the mining of LW 10 | Negligible |
| CS 1164 | Surface fracturing causing cracking of bedrock leading to drying of swamp BCUS11, leading to an increased susceptibility to fire from mining of LW 10 | Negligible |
| CS 11711 | Surface fracturing causing cracking of bedrock leading to drying of swamp CRUS6, reducing cleaning effects and reducing water quality flowing to the reservoir from mining of LW 11 | Negligible |
| CS 11721 | Surface fracturing causing cracking of bedrock leading to drying of swamp CRUS6, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from the mining of LW 11 | Low |
| CS 1173 | Surface fracturing causing cracking of bedrock leading to drying of swamp CRUS6, leading to a detrimental effect on swamp ecosystems from the mining of LW 11 | Negligible |
| CS 1174 | Surface fracturing causing cracking of bedrock leading to drying of swamp CRUS6, leading to an increased susceptibility to fire from mining of LW 11 | Negligible |

## Relevant Sections of Documentation

- Section 4.4 of *Russell Vale Colliery Underground Expansion Project EPBC Referral (EPBC2014/7268) Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)
- Section 3.3 of **Appendix J**

**Summary of Findings**

The primary impact mechanism associated with subsidence is potential fracturing of bedrock beneath swamps due to tensile strain. This may cause perched water to drain from the swamp, thereby altering the hydrological regime of the swamp.

Most of the swamps in the Russell Vale East domain have previously been subsided due to mining of the Bulli and / or Balgownie Seams. Despite evidence of fracturing, these swamps persist and continue to support a perched water table. Measured water levels in swamps are presented in Appendix 1 of **Appendix J**.

Subsidence monitoring results for mining of LWs 4 & 5 indicate that previous mining of the Bulli and Balgownie seams has resulted in softening of the underlying rock strata. As a result, subsidence associated with mining of the Wongawilli Seam is occurring over a much smaller area than has occurred in unmined areas. Monitoring data indicates that subsidence is largely restricted to the area immediately overlying the goaf. Compared to single seam mining, subsidence resulting from mining at Russell Vale East occurs over a smaller area, resulting in greater tilts and strains (SCT, 2014).

Perceptible fracturing of the sandstone bedrock may potentially occur when tensile strains exceed 1-2 mm/m and compressive strains exceed 2-3 mm/m (SCT, 2014). Fracturing may (but does not necessarily) result in a decline in the perched water table (where present). The predicted strains resulting from mining are of sufficient magnitude to potentially result in fracturing of the bedrock.

Impacts to swamps are expected to be confined to the region where vertical subsidence is greater than 200 mm. Monitoring data indicates that where subsidence levels are less than 200 mm, tensile strains are predicted to be lower than 0.5 mm/m and compressive strains are predicted to be lower than 1.2 mm/m. These levels of strain are unlikely to result in fracturing of the bedrock, and are less than the criteria outlined in DoP (2010), OEH (2012) and DoE (2014). Therefore, impacts to swamps are expected to occur only within the predicted 200 mm subsidence extent (see **Figure 4**).

The initial risk assessment considered the predicted strains and tilts for each swamp and compared these values to the criteria outlined in DoP (2010), OEH (2012) and DoE (2014). The initial risk assessment determined that the predicted subsidence effects for swamp CRUS3 were below the thresholds that may result in an impact to the swamp. Accordingly, CRUS3 was not considered in the final risk assessment. All other swamps in the vicinity of the proposed longwall panels were considered in the final risk assessment.

Due to each swamp being geomorphologically, hydrologically and pedologically different, risks to upland swamps have been assessed on a swamp by swamp basis. **Table 5** assesses the risks to upland swamps associated with strains.

**Table 5**
**Risks to Swamps associated with Subsidence**

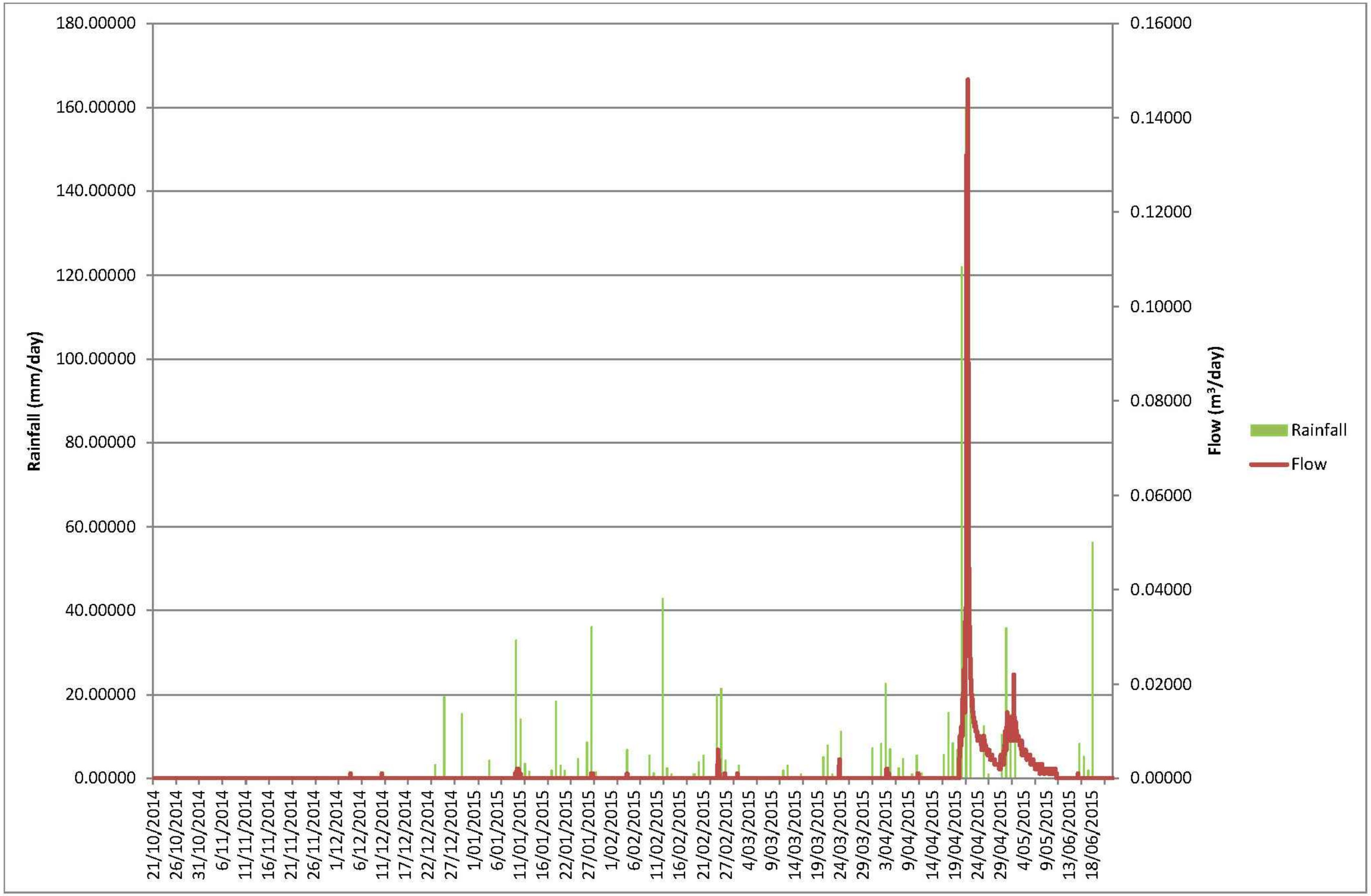
| Swamp | Risks Associated with Tilts and Strains |
|---|---|
| **BCUS4** | BCUS4 is located over the edge of Longwall 9. Soils in BCUS4 are up to 160 cm in depth and consist of humic sandy clay.<br>Tilts and strains affect a small section of MU43 Tea-tree Thicket. Lower sections of the upland swamp are unlikely to be subject to strains of sufficient magnitude to fracture bedrock.<br>BCUS4 undergoes evapotranspiration as well as gradual drainage after rainfall. There is no evidence of adverse effects due to prior subsidence in this swamp.<br>Risk is assessed as low due to impacts to only a small section of this swamp. |
| **BCUS11** | BCUS11 does not support vegetation communities reliant on waterlogging.<br>No groundwater data is available.<br>Risk is assessed as low. |
| **CCUS1** | Potential 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.<br>No groundwater data is available.<br>Risk is assessed as low. |
| **CCUS2** | CCUS2 does not support vegetation communities reliant on waterlogging.<br>Undergoes evapotranspiration as well as gradual drainage after rainfall. There is no evidence of adverse effects due to prior subsidence in this swamp.<br>Risk of impact 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. Undergoes evapotranspiration as well as gradual drainage after rainfall. The location of water-dependent communities, including MU44C Cyperoid Heath and MU43 Tea-tree Thicket near the centreline of the longwall, in areas of lowest strain and tilt, are likely to mitigate impacts to some degree.<br>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 swamp 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, 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.<br>There is no evidence of adverse effects due to prior subsidence in this swamp.<br>Risk is assessed as high. |

| Swamp | Risks Associated with Tilts and Strains |
|---|---|
| **CCUS5** | CCUS5 supports a mix of MU43 Tea-tree Thicket, which depends on permanent water availability, and MU42 Banksia Thicket and MU44a Sedgeland. Upslope sections of CCUS5, 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.<br>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.<br>Undergoes evapotranspiration as well as gradual drainage after rainfall. There is no evidence of adverse effects due to prior subsidence in this swamp.<br>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.<br>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.<br>No groundwater data is available.<br>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.<br>No groundwater data is available.<br>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.<br>No groundwater data is available. However this upland swamp is unlikely to support significant groundwater.<br>Risk is assessed as low. |
| **CCUS24** | CCUS24 supports small areas of MU43 Tea-Tree Thicket and MU44B Restioid Heath. The small (0.02 ha) section of MU43 Tea-Tree Thicket is likely to be maintained by a depression in the underlying geology, with the swamp having a small catchment area (0.54 ha).<br>No groundwater data is available. However this upland swamp is unlikely to support significant groundwater.<br>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 a small, upstream section of this upland swamp is located within the predicted subsidence impact zone (>200 mm subsidence). Soils in this area are between 25 and 70 cm deep, and consist of mineral sands. These areas are unlikely to support significant groundwater. Vegetation in this area consists of MU42 Banksia Thicket.<br>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. |

| Swamp | Risks Associated with Tilts and Strains |
|---|---|
| | Risk is assessed as low. |
| **CRUS6** | CRUS6 supports MU42 Banksia Thicket, which is not reliant on waterlogging and is thus deemed less susceptible to decreased groundwater availability. Soils consist largely of minerals sands with little organic material.<br>No groundwater data is available. However this upland swamp is unlikely to support significant groundwater.<br>Risk is assessed as low. |

The risk of impacts due to fracturing is assessed as low for all swamps except CCUS4, which is assessed as being at a high risk of impact. WCL has installed a weir (CT3A) immediately downstream of swamp CCUS4 to measure the outflow from the swamp. As shown in **Figure** 9, flow monitoring data indicates that CCUS4 only provides flows for short periods after heavy rainfall (i.e. it does not provide significant baseflow). Therefore, impacts on swamp CCUS4 would not have a significant impact on flow volumes within the catchment of Cataract Reservoir.

It has been hypothesised by a number of stakeholders that swamps can improve water quality in the catchment by providing 'cleaning effects'. The 'cleaning effects' are provided by the vegetation within the swamp. The impacts of mining on the hydrology of swamps may affect the vegetation composition of particular swamps (i.e. transition for wetter to drier sub-communities). However, subsidence is not expected to result in the complete loss of swamp vegetation. Accordingly, subsidence is not expected to result in any observable change in the potential 'cleaning effects' provided by upland swamps.

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RUSSELL VALE COLLIERY

Stream Flow at CT3A

**FIGURE 9**

WOLLONGONG COAL

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### 5.3.2 Changes to Swamp Water Regimes

*This section addresses the risk of impacts to upland swamps due to tilting, and the flow-on impacts to water quantity in Cataract Reservoir.*

#### Relevant Risks

| Risk ID | Description | Classification |
|---|---|---|
| AT 111 | Tilting causing changes to swamp water regimes leading to a reduction in cleaning effects and a reduction of water flowing into the reservoir from mining of LWs 1-3 | Negligible |
| AT 12 | Tilting causing changes to swamp water regimes leading to detrimental effects on swamp ecosystems from mining of LWs 1-3 | Negligible |
| AT 13 | Tilting causing changes to swamp water regimes leading to an increased susceptibility to fire from mining of LWs 1-3 | Negligible |
| AT 14 | Tilting causing changes to swamp water regimes leading to a diversion of baseflow provided by swamp from mining of LWs 1-3 | Negligible |
| AT 31 | Tilting causing the development of a knick point leading to an increased susceptibility to erosion (in sediment based streams) from mining of LWs 1-3 | Negligible |
| BT 111 | Tilting causing changes to swamp water regimes leading to a reduction in cleaning effects and reduced water flowing to the reservoir from mining of LWs 6-7 | Negligible |
| BT 121 | Tilting causing changes to swamp water regimes leading to detrimental effects on CCUS4 from mining of LWs 6-7 | Medium |
| BT 122 | Tilting causing changes to swamp water regimes leading to detrimental effects on swamps other than CCUS4 from mining of LWs 6-7 | Negligible |
| BT 13 | Tilting causing changes to swamp water regimes leading to an increased susceptibility to fire from mining of LWs 6-7 | Negligible |
| BT 31 | Tilting causing knickpoints to develop leading to an increased susceptibility to erosion from mining of LWs 6-7 | Negligible |
| CT 111 | Tilting causing changes to swamp water regimes leading to a reduction in cleaning effects and reduced water flowing to the reservoir from mining of LWs 9-11 | Negligible |
| CT 121 | Tilting causing changes to swamp water regimes leading to detrimental effects on swamp ecosystem BCUS4 from mining of LWs 9-11 | Medium |
| CT 122 | Tilting causing changes to swamp water regimes leading to detrimental effects on swamp ecosystems other than BCUS4 from mining of LWs 9-11 | Negligible |
| CT 13 | Tilting causing changes to swamp water regimes leading to an increased susceptibility to fire from mining of LWs 9-11 | Negligible |
| CT 31 | Tilting causing knickpoints to develop leading to an increased susceptibility to erosion from mining of LWs 9-11 | Negligible |

#### Relevant Sections of Documentation

- Section 4.3 of *Russell Vale Colliery Underground Expansion Project EPBC Referral (EPBC2014/7268) Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)
- Section 3.3 of **Appendix J**

**Summary of Findings**

Tilting due to subsidence has the potential to alter the water distribution within a swamp and in some circumstances, may cause water to escape from the swamp margins. Tilting may also re-concentrate runoff leading to erosion and scouring.

The potential impacts of tilting on swamps were assessed using flow accumulation modelling. The flow accumulation model compares the flow pathways for the pre-mining and post-mining landforms to predict the change in surface and sub-surface flows through a swamp. The methodology for the flow accumulation modelling is outlined in Biosis (2012).

The initial risk assessment considered the predicted strains and tilts for each swamp and compared these values to the criteria outlined in DoP (2010), OEH (2012) and DoE (2014). The initial risk assessment determined that the predicted subsidence effects for swamp CRUS3 were below the thresholds that may result in an impact to the swamp. Accordingly, CRUS3 was not considered in the flow accumulation modelling. Flow accumulation modelling was not undertaken for swamps CCUS24 and CRUS6 due to their small catchment sizes.

Due to each swamp being geomorphologically, hydrologically and pedologically different, risks to upland swamps have been assessed on a swamp by swamp basis. **Table 6** assesses the risks to upland swamps associated with tilting.

**Table 6**
**Risks to Swamps Associated with Tilting**

| Swamp | % change in flow accumulation post-mining | Discussion of changes in flow accumulation |
|---|---|---|
| BCUS4 | 115 | Flow accumulation modelling 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.<br>Modelling of post-mining flow indicates an increase in catchment yield of 15%. 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 | Flow accumulation modelling for BCUS11 pre-mining indicates that this small upland swamp has three flow pathways through the swamp.<br>Following mining, changes in tilt are likely to result in a very minor increase in summed flow within this upland swamp of 8%. There is unlikely to be any change to flow pathways through the upland swamp.<br>Changes to vegetation composition are predicted to be negligible. |

| Swamp | % change in flow accumulation post-mining | Discussion of changes in flow accumulation |
|---|---|---|
| CCUS1 | 98 | Flow accumulation modelling 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.<br>Flow accumulation modelling 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 (2%) decrease in catchment area. This is likely to result in an increase in water availability for a small section of MU44a Sedgeland in this south-eastern section.<br>Any changes to vegetation composition are likely to be minor. |
| CCUS2 | 100 | Pre-mining flow accumulation modelling for CCUS2 indicates a dispersed flow of water through this upland swamp.<br>Tilts associated with Longwalls 2 and 3 will result in only a negligible (<1%) decrease in 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 to vegetation composition. |
| CCUS4 | 95 | Flow accumulation modelling 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.<br>Post-mining, tilts will result in a minor (5%) 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.<br>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, such as an increase in the abundance of species more tolerant of dry conditions. |
| CCUS5 | 74 | Pre-mining flow accumulation modelling 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.<br>It is likely that community composition in this swamp relates to a combination |

| Swamp | % change in flow accumulation post-mining | Discussion of changes in flow accumulation |
|---|---|---|
| | | of flow and these rockbars allowing pooling of water at these locations.<br>Tilts associated with Longwall 7 are likely to result in a significant (26%) decline in overall water availability within this swamp. This decline is likely to 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. |
| CCUS10 | 107 | Flow accumulation modelling 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.<br>Post-mining flow accumulation modelling indicates a small (7%) increase in catchment yield, and only minor changes in flow pathways through this swamp. |
| CCUS11 | 50 | Flow accumulation modelling indicates that this upland swamp has a small catchment, with the upland swamp likely to be reliant on terracing and accumulation of water.<br>Post-mining modelling indicates a significant (50%) 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; however, the catchment for this swamp is 1.18 ha and these changes are unlikely to have a significant impact on water availability. |
| CCUS12 | 104 | CCUS12 is located at the boundary between the catchments of Cataract Creek and Bellambi Creek, and as a result, has a very small catchment area. Pre-mining versus post-mining flow accumulation modelling indicates that only minor (4%) increases in catchment yield and no change in flow pathways. Negligible changes to vegetation compositions are predicted to occur. |
| CRUS1 | 100 | Only the 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 (<1%) increase in catchment yield and negligible changes in flow pathways through this upland swamps.<br>No changes in water availability are predicted to occur. |

# 6 OVERALL RISK CLASSIFICATIONS FOR ENVIRONMENTAL FEATURES

*This section consolidates the assessed risks from Broadleaf (2015b) to generate an overall risk for each environmental feature. As requested by the IRAP, this discussion synthesizes the information presented in the specialist's reports (**Appendices D** to **J**).*

## 6.1 WATER RESOURCES

### 6.1.1 Streams

### Relevant Risks

| Risk ID | Impact Type | Classification |
|---|---|---|
| AH 211 | Redirection of surface flow due to stream bed cracking resulting in a reduction in quality of streamflow re-emerging downstream into Cataract Reservoir (LWs 1-3) | Medium |
| AH 2121 | Surface cracking leading to redirection of surface flow to groundwater system (LWs 1-3) | Medium |
| AS 121 | Surface fracturing leading to increased iron oxide staining and causing a reduction in water quality flowing into Cataract Reservoir (LWs 1-3) | Medium |
| AS 212 | Reduced baseflow to streams due to depressurisation of the regional aquifer (LWs 1-3) | Medium |
| AT 21 | Changes to stream water regime leading to increased pooling in streams (LWs 1-3) | Negligible |
| BH 211 | Redirection of surface flow due to stream bed cracking resulting in a reduction in quality of streamflow re-emerging downstream into Cataract Reservoir (LWs 6-7) | Low |
| BH 2121 | Surface cracking leading to redirection of surface flow to groundwater system (LWs 6-7) | Medium |
| BH 213 | Redirection of surface flow due to stream bed cracking from resulting in an increase in iron oxidation (LWs 6-7) | Low |
| BS 131 | Surface fracturing leading to increased iron oxide staining and causing a reduction in quality flowing into Cataract Reservoir (LWs 6-7) | Medium |
| BS 212 | Reduced baseflow to streams due to depressurisation of the regional aquifer (LWs 6-7) | Medium |
| BT 21 | Changes to stream water regime leading to increased erosion downstream (LWs 6-7) | Negligible |
| BT 22 | Changes to stream water regime leading to increased pooling in streams (LWs 6-7) | Negligible |
| CH 211 | Redirection of surface flow due to stream bed cracking resulting in a reduction in quality of streamflow re-emerging downstream into Cataract Reservoir (LWs 9-11) | Low |
| CH 2121 | Surface cracking leading to redirection of surface flow to groundwater system (LWs 9-11) | Medium |
| CS 121 | Surface fracturing leading to increased iron oxide staining and causing a reduction in quality flowing into Cataract Reservoir (LWs 9-11) | Medium |
| CS 212 | Reduced baseflow to streams due to depressurisation of the regional aquifer resulting from mining (LWs 9-11) | Medium |
| CT 21 | Changes to stream water regime leading to increased erosion downstream (LWs 9-11) | Negligible |
| CT 22 | Changes to stream water regime leading to increased pooling in streams (LWs | Negligible |

| Risk ID | Impact Type | Classification |
|---|---|---|
| | 9-11) | |

**Overall Assessment**

Impacts to Cataract Creek, Cataract River and Bellambi Creek were considered in the context of the overall water quantity and quality in Cataract Reservoir.

Impacts to stream flow can occur via two mechanisms:

- Reduction in baseflow recharge due to groundwater depressurisation; and
- Diversion of surface flows to the sub-surface via subsidence induced cracking.

The reduction in total baseflow to Cataract Creek, Cataract River and Bellambi Creek as a result of groundwater depressurisation is predicted to be 0.041 ML/day (refer to Section 10.4.2 of **Appendix H**).

Surface cracking will cause surface flows to be diverted to subterranean flow paths upstream of and over the subsided workings, with re-entry of flow back in to the streams and/or reservoir at lower elevations within the catchment. However, it is not possible to calculate the proportion of flow that would re-emerge downstream. To determine the theoretical worst case scenario, which is highly unlikely to occur, it was assumed that there is no downstream re-emergence of diverted flows. Under this worst case scenario, the theoretical maximum reduction in stream flow in Cataract Creek, Cataract Creek and Bellambi Creek is 7.34 ML/day (refer to Section 5 of **Appendix I**).

The theoretical best case scenario assumes that all of the flows diverted to the subsurface would re-emerge downstream. Under this best case scenario, the only impact on Cataract Creek would be the 0.0041 ML/day reduction in baseflow due to groundwater depressurisation.

Therefore, the total impact on stream flow may range from 0.041 ML/day to 7.34 ML/day.

Impacts to stream water quality may occur via localised reduction of stream flow and / or increased interaction of groundwater and surface water. Based on the available water quality monitoring data, impacts to stream water quality are expected to be localised due to the effect of dilution, and limited to a short distance (<10 m) downstream of each groundwater seepage point. The extraction of LWs 4 & 5 did not observably alter the stream chemistry of Cataract Creek or Cataract Reservoir.

The Project is not expected to result in any cracking of the stream beds for Cataract River and Bellambi Creek. Accordingly, the Project is not expected to have any impact on the water quality of these streams.

When considered in the context of water quantity and quality in Cataract Reservoir, the overall risk to Cataract Creek, Cataract River and Bellambi Creek is considered to be ‘medium’. This risk classification represents a high likelihood of impacts occurring, but with minor consequences.

### 6.1.2 Cataract Reservoir

## Relevant Risks

| Risk ID | Impact Type | Classification |
|---|---|---|
| AH 211 | Redirection of surface flow due to stream bed cracking resulting in a reduction in quality of streamflow re-emerging downstream into Cataract Reservoir (LWs 1-3) | Medium |
| AH 2121 | Surface cracking leading to redirection of surface flow to groundwater system (LWs 1-3) | Medium |
| AS 121 | Surface fracturing leading to increased iron oxide staining and causing a reduction in quality flowing into Cataract Reservoir (LWs 1-3) | Medium |
| AS 211 | Groundwater depressurisation leading to seepage from Cataract Reservoir (LWs 1-3) | Medium |
| AT 111 | Tilting causing changes to swamp water regimes leading to a reduction in cleaning effects and a reduction of water flowing into the reservoir from mining of LWs 1-3 | Negligible |
| AT 14 | Tilting causing changes to swamp water regimes leading to a diversion of baseflow provided by swamp from mining of LWs 1-3 | Negligible |
| AT 21 | Changes to stream water regime leading to increased pooling in streams (LWs 1-3) | Negligible |
| BH 211 | Redirection of surface flow due to stream bed cracking resulting in a reduction in quality of streamflow re-emerging downstream into Cataract Reservoir (LWs 6-7) | Low |
| BH 2121 | Surface cracking leading to redirection of surface flow to groundwater system (LWs 6-7) | Medium |
| BH 213 | Redirection of surface flow due to stream bed cracking from resulting in an increase in iron oxidation (LWs 6-7) | Low |
| BS 131 | Surface fracturing leading to increased iron oxide staining and causing a reduction in quality flowing into Cataract Reservoir (LWs 6-7) | Medium |
| BS 211 | Groundwater depressurisation leading to seepage from Cataract Reservoir (LWs 6-7) | Medium |
| BS 23 | Increased mine inflows due to hydraulic conductivity via the Corrimal Fault | Low |
| BS 24 | Increased mine inflows due to hydraulic conductivity via Dyke D8 | Low |
| BT 111 | Tilting causing changes to swamp water regimes leading to a reduction in cleaning effects and reduced water flowing to the reservoir from mining of LWs 6-7 | Negligible |
| BT 21 | Changes to stream water regime leading to increased erosion downstream (LWs 6-7) | Negligible |
| BT 22 | Changes to stream water regime leading to increased pooling in streams (LWs 6-7) | Negligible |
| CH 211 | Redirection of surface flow due to stream bed cracking resulting in a reduction in quality of streamflow re-emerging downstream into Cataract Reservoir (LWs 9-11) | Low |
| CH 2121 | Surface cracking leading to redirection of surface flow to groundwater system (LWs 9-11) | Medium |
| CS 121 | Surface fracturing leading to increased iron oxide staining and causing a reduction in quality flowing into Cataract Reservoir (LWs 9-11) | Medium |
| CS 211 | Groundwater depressurisation leading to seepage from Cataract Reservoir (LWs 9-11) | Medium |

| Risk ID | Impact Type | Classification |
|---|---|---|
| CT 111 | Tilting causing changes to swamp water regimes leading to a reduction in cleaning effects and reduced water flowing to the reservoir from mining of LWs 9-11 | Negligible |
| CT 21 | Changes to stream water regime leading to increased erosion downstream (LWs 9-11) | Negligible |
| CT 22 | Changes to stream water regime leading to increased pooling in streams (LWs 9-11) | Negligible |

**Overall Assessment**

**Figure 10** conceptually illustrates the water balance for the Cataract Reservoir catchment. Based on a conservative average annual rainfall of 1,000 mm/year and total catchment area of 127.8 km$^2$, the catchment of Cataract Reservoir receives an average of 350 ML/day in rainfall. Approximately 100 ML/day of the total rainfall volume is captured by the reservoir (*pers. comm.* Sydney Catchment Authority). The remaining 250 ML/day is lost from the catchment through evaporation, transpiration and infiltration.

The proposed mining will result in regional depressurisation of the groundwater system beneath Cataract Reservoir. This would cause stored water from Cataract Reservoir to seep into the underlying groundwater system. The groundwater model predicts a rate of seepage from Cataract Reservoir of 0.00024 ML/day (0.1 ML/year) at the end of mining. This impact is negligible when compared to the 100 ML/day that flows into Cataract Reservoir.

Water volumes in Cataract Reservoir will also be affected by impacts to stream flows in Cataract Creek, Cataract River and Bellambi Creek (as discussed in **Section 6.1.1**). The available monitoring data indicates that the swamps in the Russell Vale East domain are not significant sources of baseflow. As discussed in **Section 5.3.1**, the swamps only provide baseflow for short periods after heavy or prolonged rainfall. Therefore, the potential impacts on upland swamps would not significantly affect water quantity in the Cataract Reservoir catchment.

As discussed in **Section 5.2.3**, observations from previous mining have indicated that changes to water chemistry are limited to within 10 m downstream of each seepage point along Cataract River. The impact on the overall water quality in Cataract Reservoir is predicted to be negligible.

The overall risk to Cataract Reservoir has been classified as 'medium' due to a high likelihood rating and low consequence rating. That is, impacts to Cataract Reservoir are likely to occur; but are expected to be very minor in magnitude.

### 6.1.3 Regional Groundwater System

**Relevant Risks**

| Risk ID | Impact Type | Classification |
|---|---|---|
| AS 221 | Fracturing of deeper strata leading to increased groundwater flowing into the mine from mining of LWs 1-3 | Medium |
| BS 221 | Fracturing of deeper strata leading to increased groundwater flowing into the mine from mining of LWs 6-7 | Medium |
| CS 221 | Fracturing of deeper strata leading to increased groundwater flowing into the mine from mining of LWs 9-11 | Medium |

**Overall Assessment**

The regional groundwater system is located within the Bulgo Sandstone beneath Cataract Reservoir. As a result, the predicted groundwater inflows to the mine workings will not result in significant losses of water from storage within the reservoir. The majority of mine inflow would be drawn from drainage in deeper predominantly horizontally fractured strata and the highly vertically fractured goaf.

The revised groundwater model predicts a maximum mine inflow rate of approximately 3.3 ML/day. As shown in **Figure 10**, the catchment of Cataract Reservoir receives an average of 350 ML/day in rainfall. Approximately 250 ML/day of this rainfall is lost to evaporation, transpiration and infiltration. The predicted groundwater inflows form a component of the losses from the catchment. Therefore, the predicted groundwater inflows do not affect the volume of water captured by the reservoir (100 ML/day on average).

The overall risk to the regional groundwater system is considered to be 'medium' due to a high likelihood rating and low consequence rating. That is, impacts are likely to occur; but are expected to be minor in magnitude. However, the regional groundwater system is not significant from a private bore or reservoir water supply perspective. The regional piezometric surface is located beneath the reservoir and therefore does not contribute to storage volumes. Furthermore, there are no water supply works (bores or wells) that extract water from the regional aquifer.

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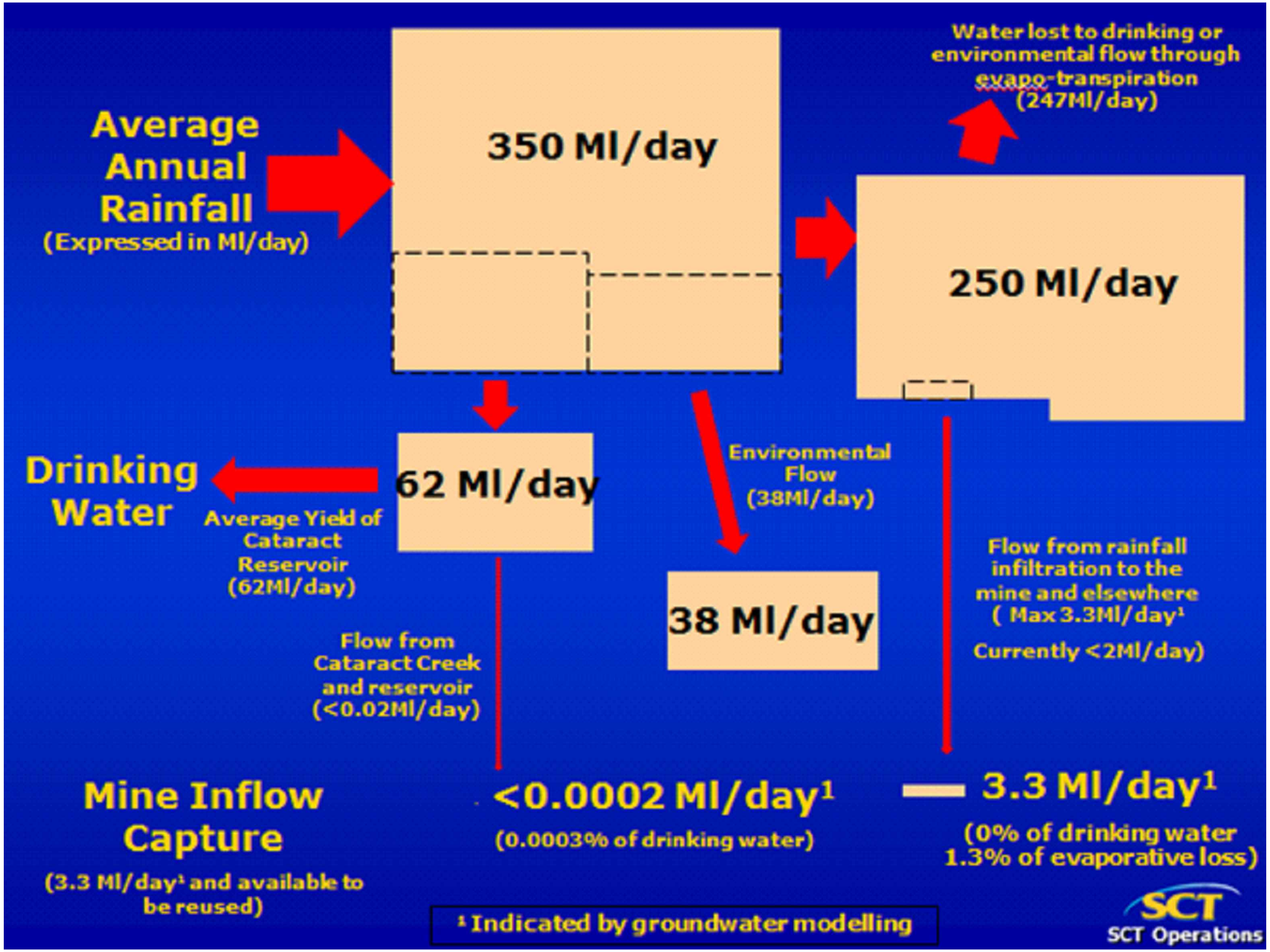


Source: SCT (2015)

RUSSELL VALE COLLIERY

Conceptual Cataract Reservoir Water Balance

**FIGURE 10**

WOLLONGONG COAL

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## 6.2 UPLAND SWAMPS

The risk assessment considered all swamps located in close proximity to the proposed mine plan. **Table 7** presents the overall risk for each of these swamps. The swamps that were assessed as being at 'medium' or 'high' risk are addressed in greater detail below.

**Table 7**
**Overall Risk Classifications for Swamps**

| Swamp | Overall Risk |
|---|---|
| BCUS4 | Medium |
| BCUS11 | Low |
| CCUS1 | Medium |
| CCUS2 | Medium |
| CCUS4 | High |
| CCUS5 | Low |
| CCUS10 | Low |
| CCUS11 | Low |
| CCUS12 | Low |
| CCUS24 | Negligible |
| CRUS1 | Negligible |
| CRUS3 | Negligible |
| CRUS6 | Low |

### 6.2.1 Swamp CCUS1

### Relevant Risks

| Risk ID | Impact Type | Classification |
|---|---|---|
| AS 11111 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS1, reducing cleaning effects and reducing water quality flowing to the reservoir from mining of LW 3 | Negligible |
| AS 11121 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS1, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from mining of LW 3 | Low |
| AS 1113 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS1, leading to a detrimental effect on swamp ecosystems from mining of LW 3 | Medium |
| AS 1114 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS1, leading to an increased susceptibility to fire from mining of LW 3 | Negligible |
| AS 1115 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS1, leading to a diversion of baseflow from swamp from mining of LW 3 | Low |

### Overall Assessment

A very small (0.15 ha) area of this swamp will be subject to strains of sufficient magnitude to result in fracturing of bedrock and consequent impacts to the swamp ecosystem (see **Figure 11**). Other risks are assessed as low or negligible.

Due to the small percentage of the swamp that will be impacted (3.14%), the overall risk to the swamp is assessed as medium.

### 6.2.2 Swamp CCUS2

### Relevant Risks

| Risk ID | Impact Type | Classification |
|---|---|---|
| AS 11211 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS2, reducing cleaning effects and reducing water quality flowing to the reservoir from mining of LWs 2-3 | Negligible |
| AS 11221 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS2, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from mining of LWs 2-3 | Negligible |
| AS 1123 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS2, leading to a detrimental effect on swamp ecosystems from mining of LWs 2-3 | Negligible |
| AS 1124 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS2, leading to an increased susceptibility to fire from mining of LWs 2-3 | Medium |
| AS 1125 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS2, leading to a diversion of baseflow from swamp from mining of LWs 2-3 | Negligible |

### Overall Assessment

Swamp CCUS2 directly overlies LWs 2 and 3 (see **Figure 11**). Subsidence will result in strains of sufficient magnitude to result in fracturing of the underlying bedrock. CCUS2 does not support vegetation communities reliant on waterlogging, with data from piezometers indicating that the perched groundwater table in this upland swamp rarely demonstrates surface expression. Whilst some compositional change may occur, this is likely to be minor in nature. This swamp does not provide significant baseflow due to its small catchment area.

The overall risk to the swamp is assessed as ‘medium’.

### 6.2.3 Swamp CCUS4

#### Relevant Risks

| Risk ID | Impact Type | Classification |
|---|---|---|
| BS 11111 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS4, reducing cleaning effects and reducing water quality flowing to the reservoir from mining of LWs 6-7 | Negligible |
| BS 11121 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS4, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from mining of LWs 6-7 | Low |
| BS 1113 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS4, leading to a detrimental effect on swamp ecosystems from mining of LWs 6-7 | High |
| BS 1114 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS4, leading to an increased susceptibility to fire from mining of LWs 6-7 | Medium |
| BS 1115 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS4, leading to a diversion of baseflow from swamp from mining of LWs 6-7 | Medium |
| BS 12111 | Surface fracturing causing cracking of bedrock leading to drying of swamp CCUS4, reducing cleaning effects and reducing water quality flowing to the reservoir from the mining of LW 6 | Negligible |
| BS 12121 | Surface fracturing of controlling rockbars leading to drying of swamp CCUS4, reducing cleaning effects and reducing water quality flowing to the reservoir from the mining of LW 6 | Negligible |
| BS 1213 | Surface fracturing of controlling rockbars causing the drying of swamp CCUS4, leading to a detrimental effect on swamp ecosystems from the mining of LW 6 | High |
| BS 1214 | Surface fracturing of controlling rockbars causing the drying of swamp CCUS4, leading to an increased susceptibility to fire from the mining of LW 6 | Medium |
| BT 121 | Tilting causing changes to swamp water regimes leading to detrimental effects on CCUS4 from mining of LWs 6-7 | Medium |

#### Overall Assessment

CCUS4 overlies LW 6 (see **Figure 12**) and will experience strains of sufficient magnitude to result in fracturing of underlying bedrock, as well as potential for fracturing of the controlling rockbar at the base of this swamp. Fracturing of bedrock or the controlling rockbar, and consequent drying of the swamp, has the potential to result in increased susceptibility to fire, diversion of baseflow and detrimental effects on the swamp ecosystem.

Whilst the outer margins of this swamp support vegetation communities that are not reliant on waterlogging, the central axis of this swamp supports MU43 Tea-tree Thicket and MU44c Cyperoid Heath which are reliant on surface or near surface expression of the perched groundwater table. This may result in compositional change within this swamp and increase susceptibility to fire. This may also result in localised impacts to the Giant Dragonfly, which relies on the perched water table during the species' larval stage.

Whilst impacts to baseflow may occur, flow monitoring data for weir CT3A (see **Figure 9**), which is located immediately downstream of CCUS4, shows that this swamp only provides flow for short periods (days) following rainfall, and does not provide significant baseflow. The overall risk to the swamp is assessed as 'high'.

### 6.2.4 Swamp BCUS4

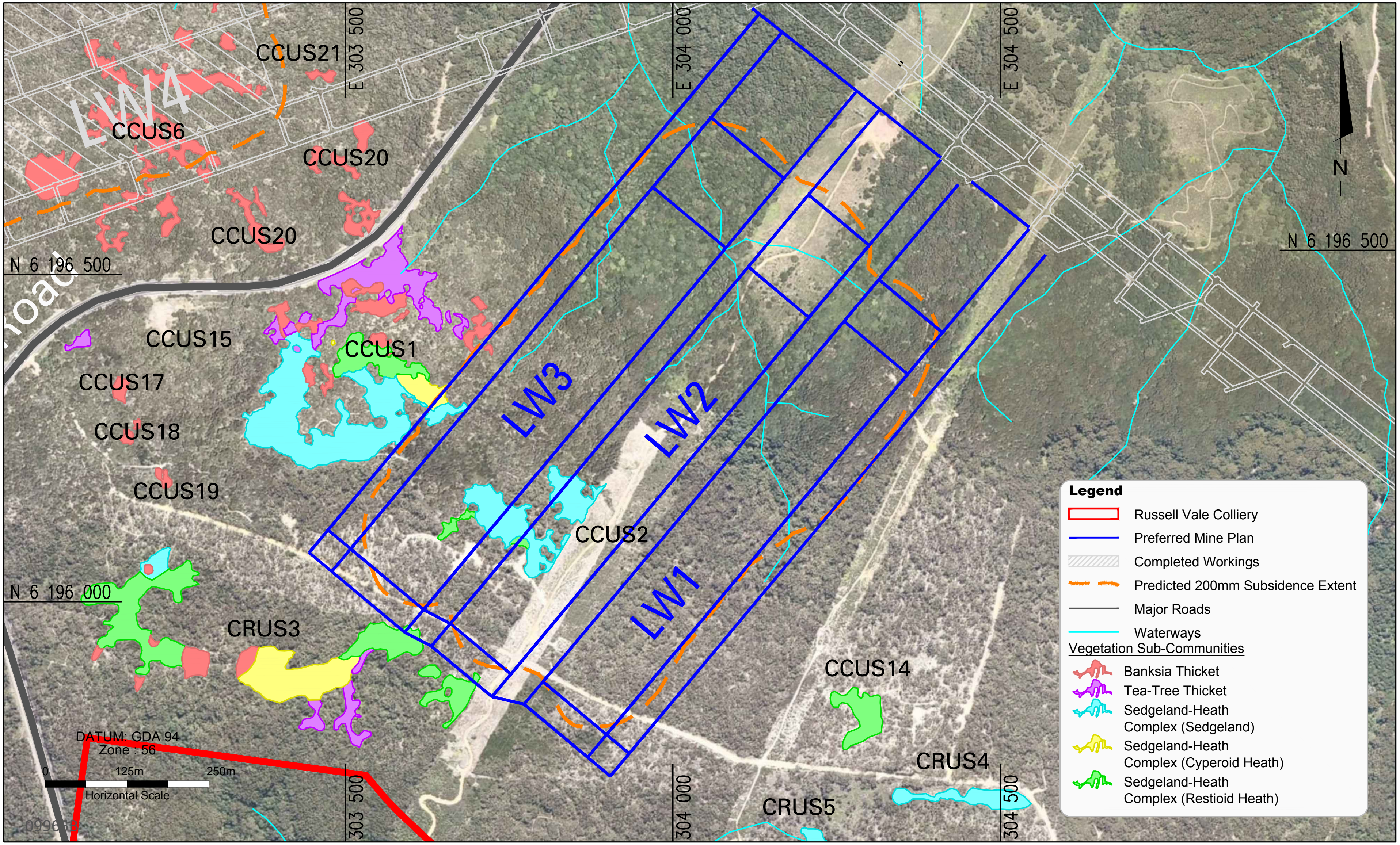
#### Relevant Risks

| Risk ID | Impact Type | Classification |
|---|---|---|
| CS 11511 | Surface fracturing causing cracking of bedrock leading to drying of swamp BCUS4, reducing cleaning effects and reducing water quality flowing to the reservoir from mining of LW 10 | Negligible |
| CS 11521 | Surface fracturing causing cracking of bedrock leading to drying of swamp BCUS4, increasing susceptibility of erosion after rain leading to reduced water quality flowing to the reservoir from the mining of LW 10 | Low |
| CS 1153 | Surface fracturing causing cracking of bedrock leading to drying of swamp BCUS4, leading to a detrimental effect on swamp ecosystems from the mining of LW 10 | Medium |
| CS 1154 | Surface fracturing causing cracking of bedrock leading to drying of swamp BCUS4, leading to an increased susceptibility to fire from mining of LW 10 | Medium |
| CS 1155 | Surface fracturing causing cracking of bedrock leading to drying of swamp BCUS4, leading to a diversion of baseflow from swamp from mining of LW 10 | Medium |
| CT 121 | Tilting causing changes to swamp water regimes leading to detrimental effects on swamp ecosystem BCUS4 from mining of LWs 9-11 | Medium |

#### Overall Assessment

A small section of BCUS4 overlies the proposed longwall panels (see **Figure 13**). Tilts and strains of sufficient magnitude to result in fracturing of underlying bedrock will occur over a small, upper section of the swamp. Fracturing of bedrock, and consequent drying of the swamp, has the potential to result in increased susceptibility to fire, diversion of baseflow and detrimental effects on the swamp ecosystem. However, the area where fracturing is predicted to occur supports communities that are not reliant on a perched water table, and is already fire prone. Tilts resulting from extraction of LW 11 may result in diversion of flow around a section of MU43 Tea-tree Thicket, with potential for compositional change.

The overall risk to this swamp is assessed as 'medium'.

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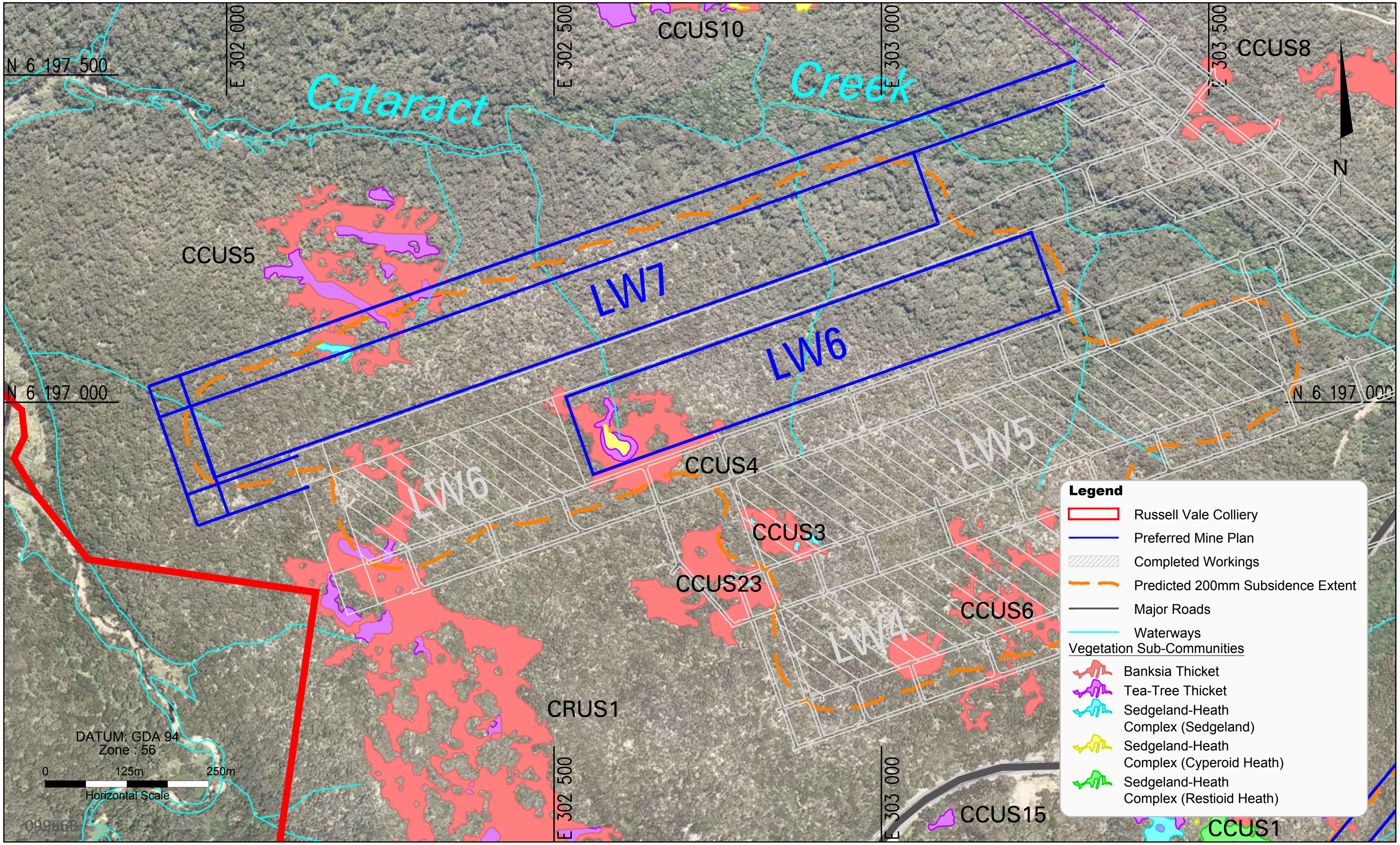
Upland Swamps - Longwalls 1-3

**FIGURE 11**

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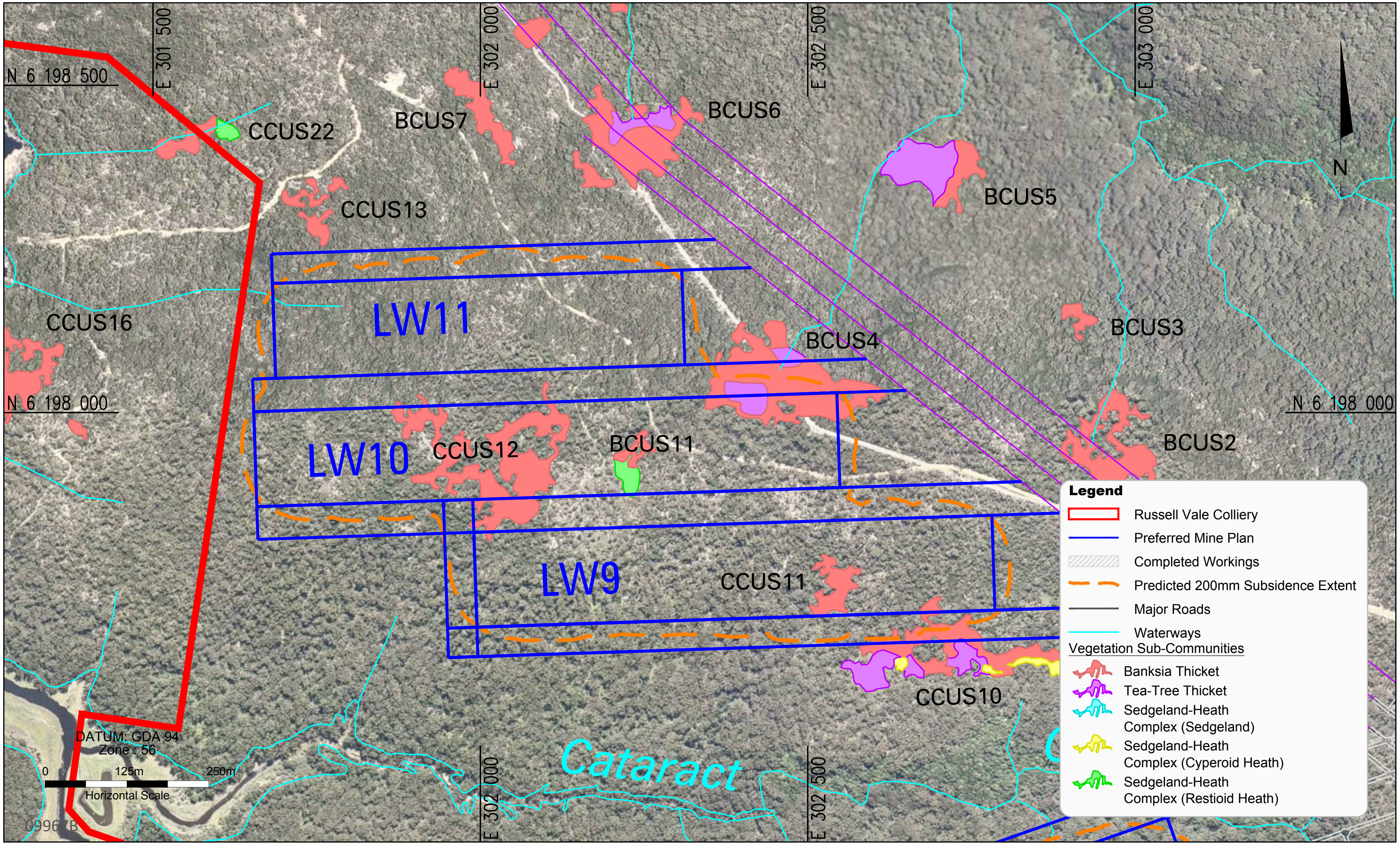
Upland Swamps - Longwalls 6-7

**FIGURE 12**

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Upland Swamps - Longwalls 9-11

**FIGURE 13**

# 7 SUMMARY OF CONTROLS

*This section outlines the controls that will be implemented to manage the risks associated with the Project.*

## 7.1 MINE PLANNING AND DESIGN

As described in **Section 2.2**, the mine plan for the Project was re-designed to avoid causing significant risks to water resources and upland swamps. The risk of significant impacts to water resources has been minimised by avoiding secondary extraction beneath the 3rd and 4th order reaches of Cataract Creek and maintaining a lateral setback from Cataract Reservoir. The minimum lateral setback is equivalent to 0.7 times the overburden depth, which is greater than the minimum setback prescribed by the DSC (see **Appendix D**).

The re-design of the mine plan also sought to minimise the extent of secondary extraction beneath upland swamps. As a result, only one swamp (CCUS4) remains at a 'high' risk of impact.

## 7.2 MONITORING AND ADAPTIVE MANAGEMENT

WCL currently implements a program of subsidence and water monitoring to detect impacts to water resources and upland swamps. WCL has developed Trigger Action Response Plans (TARPs) which outline the adaptive management measures that will be implemented if an impact is detected. These TARPs are included in the *Russell Vale East – Longwall 6 (365 m) Extraction Plan* (WCL, 2015).

The existing monitoring program for the Russell Vale East domain is summarised in **Table 8**. Groundwater and surface water monitoring locations are shown in **Figure 14** and **Figure 15**, respectively. Further monitoring locations will be established as required.

**Table 8**
**Water Monitoring Program**

| Aspect | Equipment | Purpose |
|---|---|---|
| Mine Inflows | V-notch Weirs | Abnormally high inflow rates may indicate hydraulic connectivity with Cataract Reservoir or the overlying catchment. |
| Groundwater Levels | 19 open standpipe and vibrating wire piezometers | To measure depressurisation of the regional aquifer due to mining. |
| Swamp Water Levels | 25 open standpipe piezometers | To measure changes in perched water levels within swamps. A decline in water level may indicate the presence of cracking in the bedrock beneath the swamp. |
| Stream flows and pool levels | 13 weirs | To detect changes in stream flow in Cataract Creek (including its tributaries) and Cataract River. Decreases in stream flow may indicate the presence of stream bed fracturing. |
| Groundwater Quality | Field and laboratory analyses for 12 open standpipe piezometers | To measure changes in groundwater quality. |

| Aspect | Equipment | Purpose |
|---|---|---|
| Surface Water Quality | Field and laboratory analyses for 19 monitoring sites | To measure changes in surface water quality. WCL operates monitoring stations immediately upstream of and within Cataract Reservoir to determine if there are any consequences for drinking water quality. |
| Valley Closure | High resolution surveys at 4 locations | To measure closure movements along Cataract Creek for the purposes of adaptive management. The TARP requires mining of the active longwall panel to cease if valley closure exceeds 200 mm. This safeguard reduces the risk of stream bed cracking and any associated reductions in stream flow. |

WCL's existing Extraction Plan commits to ceasing mining of the active longwall panel if mining results in greater than 200 mm of valley closure. This limit was determined based on previous experiences in the Southern Coalfield. Streams at other Southern Coalfield sites are generally hosted within Hawkesbury Sandstone strata. In contrast, the third and fourth order reaches of Cataract Creek are generally hosted within the Bald Hill Claystone.

Previous experience at Russell Vale Colliery indicates that the 200mm closure limit will be sufficient to prevent significant impacts to Cataract Creek. During mining of LW 11 in the Balgownie Seam, 14 mm/m of compressive strain was measured between pegs spaced 18 m apart and 4 mm/m of compressive strain was measured between the next two pegs spaced 15 m apart. These strain measurements imply a total closure of 310 mm. This level of closure would be expected to result in fracturing of Hawkesbury Sandstone. However, there is no apparent cracking in the bed of Cataract Creek. The lack of physical disturbance resulting from previous mining is attributed to the presence of the Bald Hill Claystone in the bed of Cataract Creek (SCT, 2014).

WCL was required under the conditions of its Subsidence Management Plan approval to prepare End of Panel reports. End of Panel reports were prepared following the completion of LWs 4 & 5 (Gujarat NRE Coking Coal Ltd, 2013; WCL, 2014). The End of Panel reports presented the measured subsidence values for that particular longwall panel and reviewed the monitoring results against the original predictions.

Future mining operations will be undertaken in accordance with Extraction Plans, which require six-monthly reporting. The six-monthly reports will also provide a comparison of measured impacts with predicted impacts.

### 7.3 COMPENSATORY MEASURES

Although the re-design of the mine plan has minimised the risks to water resources and upland swamps, additional measures will be undertaken to compensate for any residual impacts to water resources and upland swamps.

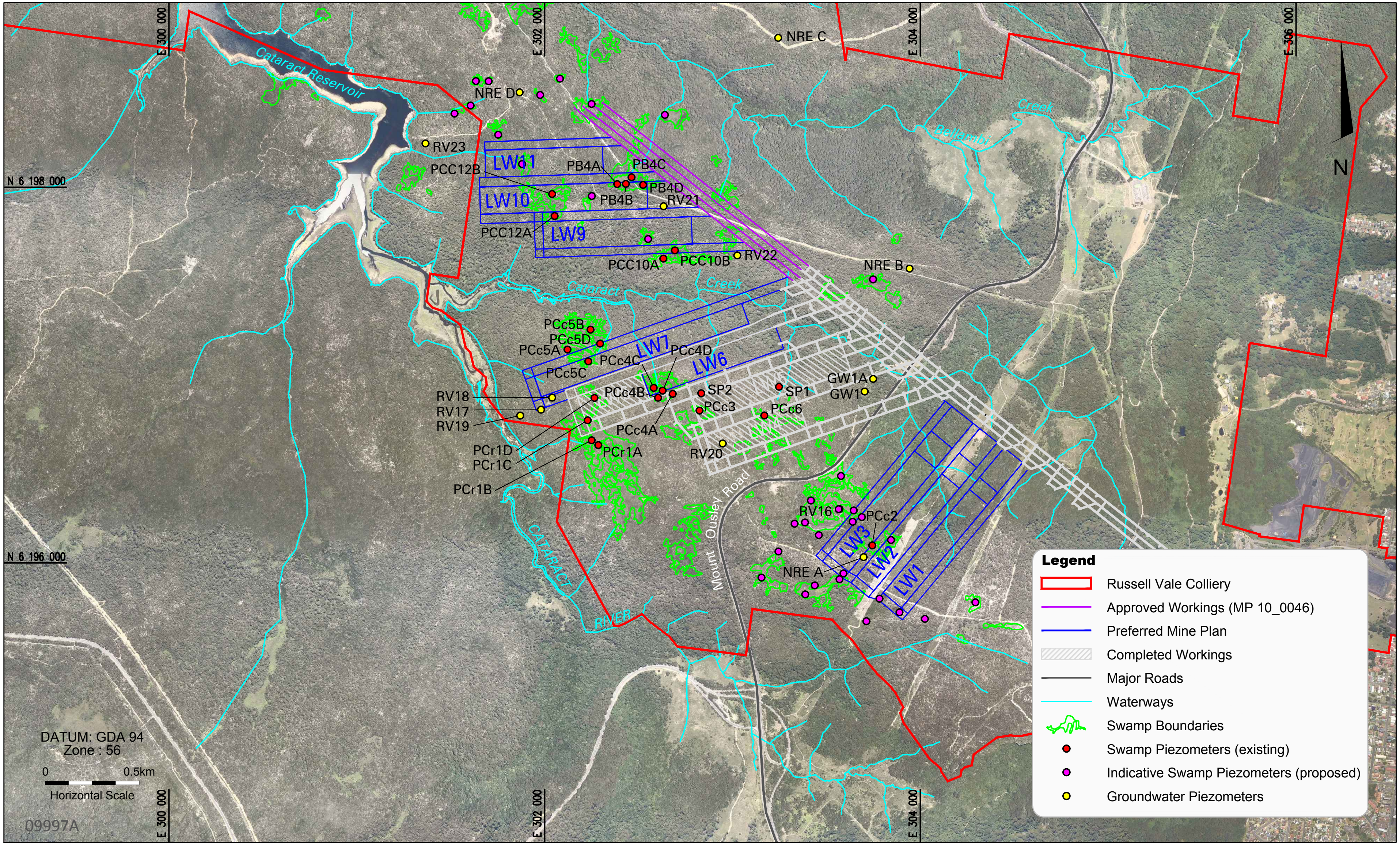
WCL will obtain the necessary water access licences in accordance with the *Water Management Act 2000* (WM Act) to account for water taken by Russell Vale Colliery. The WM Act facilitates the development of Water Sharing Plans (WSPs).

There are two WSPs that are relevant to the Project:

- *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011*; and
- *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011*.

WSPs establish limits on the volumes of water that can be taken from a water source to ensure that there are sufficient environmental flows. Therefore, obtaining the appropriate water access licences will ensure that there is sufficient water for environmental purposes.

The re-design of the mine plan has reduced the risk of impact to upland swamps, such that only CCUS4 is considered to be at a high risk of impact. If impacts to upland swamps occur as a result of the Project, WCL will obtain suitable offsets in accordance with the relevant offsetting policies.

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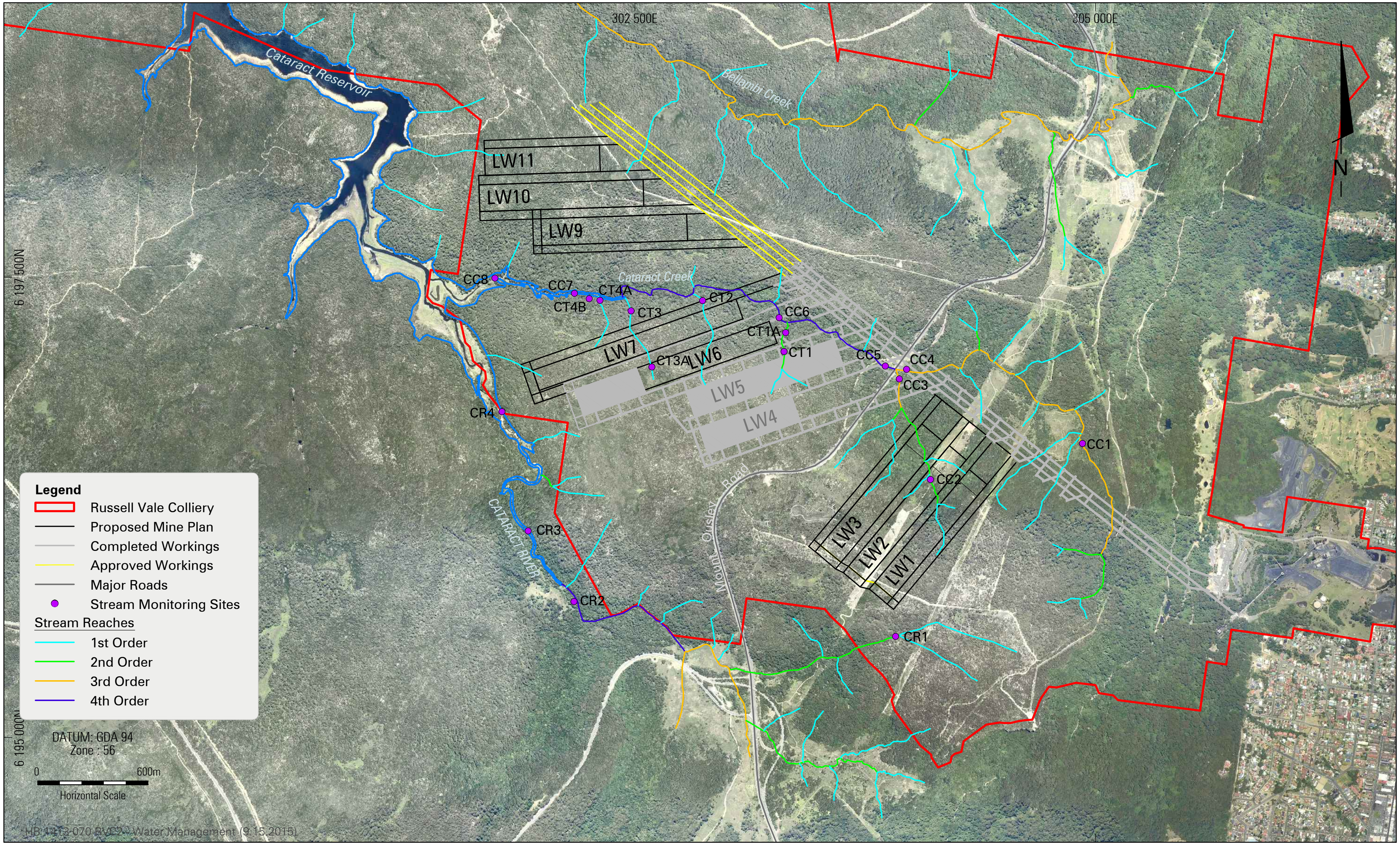
Groundwater Monitoring

**FIGURE 14**

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Surface Water Monitoring

**FIGURE 15**

# 8 ACTION PLAN

**Table 9** provides a summary of the additional management actions and commitments which have been identified by WCL during the Risk Assessment process.

The Statement of Commitments for the Project will be updated to include these commitments.

**Table 9**
**Additional Statement of Commitments**

| Ref | Action | Source |
|---|---|---|
| 1. | If required by the DSC, the panel length of LW 7 will be truncated if the Corrimal Fault is intersected during the development of the gateroads for LW 7 | DSC requirement |
| 2. | Conduct inspections of the Bulli Seam workings overlying LW 7 to confirm the accuracy of the record tracings (subject to the ability to safely access these workings) | IRAP recommendation |
| 3. | Drilling of exploration boreholes to confirm the accuracy of the record tracings for the Bulli Seam workings overlying LW 7 | IRAP recommendation |
| 4. | Consult with the IRAP during the development of management plans (following approval of the Project) | IRAP recommendation |

# 9 CONCLUSION

Should you have any queries in relation to this Document or have any further questions regarding the Project, please do not hesitate to contact the undersigned on (02) 6575 2000.

* * *

For
**HANSEN BAILEY**

Andrew Wu
*Environmental Engineer*

Dianne Munro
*Principal*

# 10 TERMINOLOGY

*This section defines the Project specific terminology used in the Risk Assessment.*

| Term | Definition |
|---|---|
| Gujarat NRE | The previous owner and operator of the colliery. The project application for the UEP was initiated by Gujarat NRE. |
| LW | Longwall |
| LW 6 (365 m) | The western-most 365 m of Longwall 6. This is approved under the Preliminary Works Project (10_0046) |
| NRE No. 1 Colliery | Previous name of the Russell Vale Colliery, when the mine was owned by Gujarat NRE. |
| Original Mine Plan | The mine plan proposed in the EA (ERM, 2012). This mine plan included 11 longwall panels in the Russell Vale East domain and 8 longwall panels in the Russell Vale West domain |
| Preferred Mine Plan | The mine plan proposed in the PPR (Gujarat NRE Coking Coal Ltd, 2013). This mine plan consists of 8 longwall panels in the Russell Vale East domain. This is the mine plan for which approval is being sought. |
| Preliminary Works Project (PWP) | The PWP is an approved project that authorises the development of the main headings in the Russell Vale East domain and the extraction of LWs 4, 5 and 6 (365 m). |
| Russell Vale East | The area of the mining domain located to the east of Cataract Reservoir |
| Russell Vale Site | The main surface facilities for the Russell Vale Colliery |
| Russell Vale West | The area of the mining domain located to the west of Cataract Reservoir |
| South Bulli Colliery | Previous name of the Russell Vale Colliery, prior to Gujarat NRE's tenure |
| Underground Expansion Project (UEP) | The Project. The subject of the current project application (09_0013). The UEP includes longwall mining of 8 panels in the Russell Vale East domain. |
| Wonga East | Previous term for Russell Vale East |
| Wonga Mains | The main headings for the longwall panels in the Russell Vale East domain. These headings were approved as part of the Preliminary Works Project (10_0046). |
| Wonga West | Previous term for Russell Vale West |

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## *APPENDIX A*

## Broadleaf Risk Assessment

# Broadleaf

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# Final report: Integrated risk assessment for the UEP

## Wollongong Coal, Russell Vale Underground Expansion Project

Prepared by:

**Dr Dale F Cooper**

Director

Version 8, 24 September 2015

Broadleaf

# Contents



# Tables

Broadleaf



# Figures

# 0 Executive summary

Wollongong Coal Limited (WCL) seeks Project Approval under the *Environmental Planning & Assessment Act 1979* for the Underground Expansion Project (UEP) at the Russell Vale Colliery.

The NSW Planning Assessment Commission (PAC) conducted a review of the UEP (PAC, 2015). Recommendation 1 stated that WCL should undertake an Integrated Risk Assessment of the UEP, with a particular focus on matters related to subsidence and water, to be overseen by an Independent Risk Assessment Panel (IRAP).

The scope of the risk assessment as stipulated in the Terms of Reference (TOR) of the IRAP is to address the impacts of underground mining on the quantity and quality of underground and surface water, and on environmental values associated with streams and swamps. It does not consider other pit top water related issues (e.g. discharges of stormwater and treated mine water to Bellambi Gully).

The risk assessment was aligned with the relevant national and international standard AS/NZS ISO 31000:2009 *Risk management – Principles and guidance*. The general approach was tailored for the UEP, with a particular focus on establishing the context and the three components of risk assessment: risk identification, risk analysis and risk evaluation. The WCL project team:

- Developed a set of event trees to map feasible pathways from mining activities to endpoints of interest: water quantity, water quality and environmental effects
- Used qualitative analysis, with rating scales specifically tailored for this risk assessment.

The WCL project team and its specialist advisers, including specialists in subsidence, groundwater and ecology, provided information for the risk assessment. The IRAP reviewed the risk assessment process and its outcomes.

Outcomes from the analysis are summarised in Section 6.

- The risk assessment considered a total of 110 risks.
- The mine plan has been modified to minimise secondary extraction beneath sensitive environmental features (third and fourth order streams, upland swamps).
- Most of the risks were classified as negligible risks (61) or low risks (18).

- The risk assessment identified 29 medium risks. Most of the medium risks have very low or low consequences.
- The two risks with high consequences, BS1113 and BS1213, are both related to impacts on swamp CCUS4, due to a potential for cracking of the bedrock beneath the swamp (BS1113) or the controlling rockbar (BS1213). The ecological consequences are almost certain to occur: loss of habitat for threatened species and changes of vegetation communities within the swamp. An offset strategy will be implemented.

This document should be read with the following documents:

- Technical information is included in the document 'Russell Vale Colliery Underground Expansion – Integrated Risk Assessment' (Hansen Bailey, 2015).
- The risk register is provided in the document 'Russell Vale Colliery Underground Expansion Project – Risk Register' (Broadleaf, 2015).

# 1 Introduction

## Background

Wollongong Coal Limited (WCL) seeks Project Approval under the *Environmental Planning & Assessment Act 1979* for the Underground Expansion Project (UEP) at the Russell Vale Colliery.

The NSW Planning Assessment Commission (PAC) conducted a review of the UEP (PAC, 2015). Recommendation 1 stated that WCL should undertake an Integrated Risk Assessment of the UEP, with a particular focus on matters related to subsidence and water, to be overseen by an Independent Risk Assessment Panel (IRAP).

## Scope of the risk assessment

The risk assessment discussed in this document is designed to address the PAC's Recommendation 1.

> ***Water/Subsidence***
>
> *1. The establishment of a risk assessment panel, constituted by an independent chair, Water NSW, the Dams Safety Committee, the Division of Resources and Energy and the proponent to oversee an integrated risk assessment, particularly focusing on links between subsidence and water (both groundwater and surface water) impacts of the proposal. This risk assessment, including associated work rerunning the groundwater modelling as recommended by Dr Mackie, and addressing the issues raised by the relevant agencies and experts (as highlighted in this report), needs to be completed before the application can be determined.*

The scope of the risk assessment as stipulated in the Terms of Reference (TOR) of the IRAP is to address the impacts of underground mining on the quantity and quality of underground and surface water, and on environmental values associated with streams and swamps. It does not consider discharges of stormwater and treated mine water to Bellambi Gully.

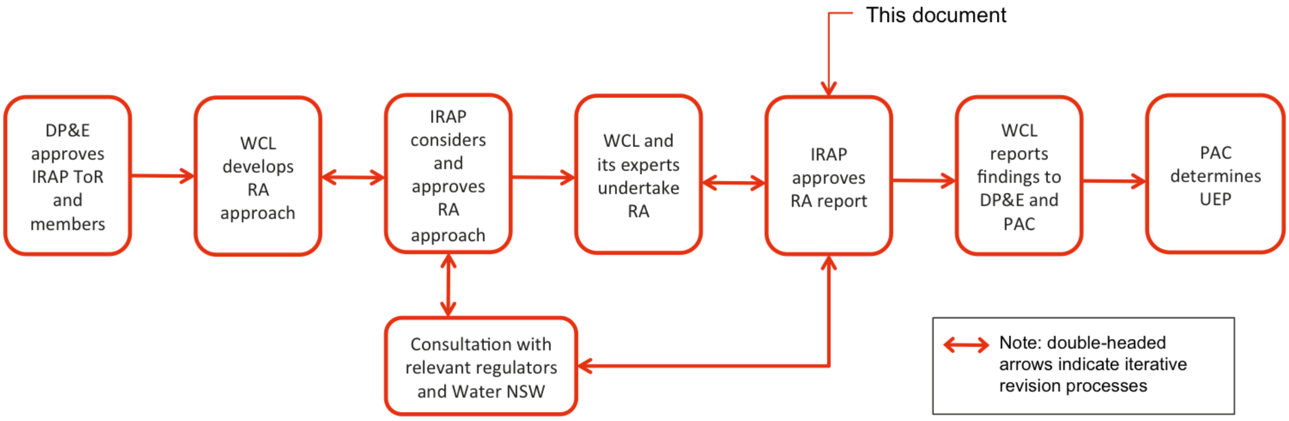
We have interpreted the requirement for an integrated risk assessment as one that takes a holistic view of risks from all sources and the effects of them all on the outcomes of interest.

## Purpose of this document

This document describes our approach to addressing the risks relating to subsidence and water for the UEP and the outcomes from our risk assessment.

Figure 1 illustrates the flowchart from the ToR and indicates where this report fits into the process.

## Figure 1: Project approval process




## Acknowledgements

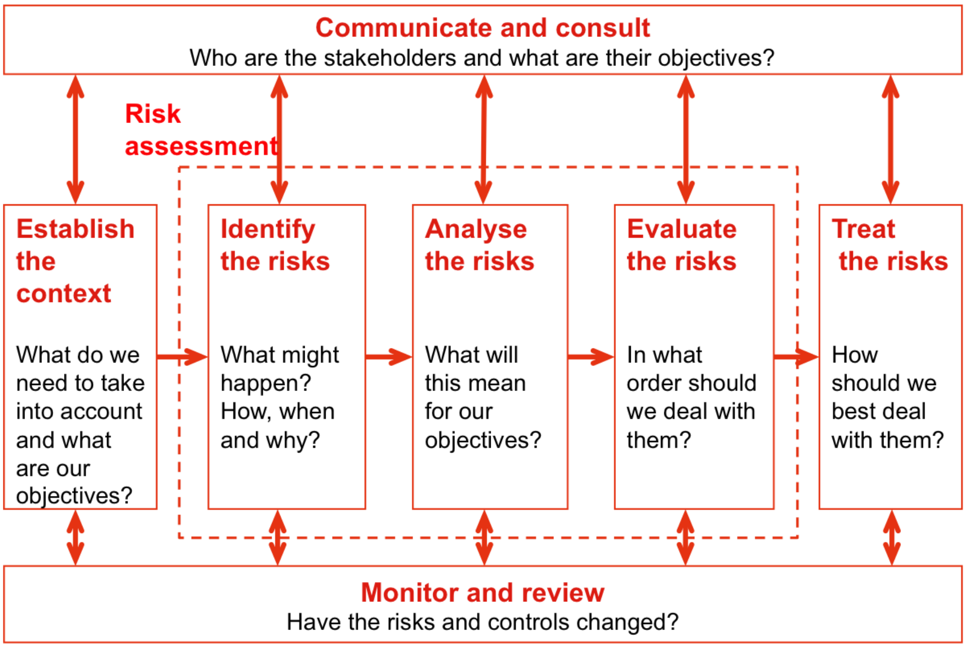
We wish to thank Professor Ismet Canbulat, Chair of the IRAP, and the members of the Panel for their helpful comments throughout this risk assessment process.

# 2 Risk management overview

## General approach

Our general approach to risk management is based on the relevant Standard, AS/NZS ISO 31000:2009 *Risk management – Principles and guidance*. The process is illustrated in Figure 2.

## Figure 2: Risk management process




## Tailoring for this project

The general approach has been tailored for the UEP.

The following sections describe the steps in the risk management process and how they were addressed for the UEP, with a particular focus on establishing the context and the three parts of risk assessment: risk identification, risk analysis and risk evaluation.

Section 3 lists the key stakeholders and summarises the context for the risk assessment. This is based on work undertaken in earlier stages of the UEP.

Section 4 describes the risk identification process and the event trees that specify the details of their causes and consequences (called endpoints here).

We undertook both a qualitative and a quantitative approach to the risk analysis. Section 5 describes the qualitative risk analysis process that was followed for all the identified risks and all endpoints.

We also examined a quantitative process for those risks that affect the quantity of water flowing into and from Cataract Reservoir and the mine void, but we determined that detailed analysis would not add value to the risk assessment. There were two related reasons for this:

- Groundwater modelling indicated that the potential effects on water volumes due to groundwater depressurisation were negligible. The primary impacts on water volumes are expected to occur via re-direction of surface flows through streambed cracking (AH 2121, BH 2121 and CH 2121). Given that potential impacts on water volumes occur primarily via one mechanism, further quantitative analysis is not justified.
- The numerical models used in the technical assessments did not allow us to develop all the required quantitative estimates for the disaggregated risks we were examining. The quantitative analysis that was proposed previously required predictions of a range of impacts. However, the numerical models were not suitable for this purpose, as they are designed to provide a best estimate of the potential impacts, rather than a range.

Section 6 shows the risk analysis outcomes and their implications for risk evaluation.

## Assessment workshops

We facilitated and recorded several risk assessment workshops with the WCL project team and its technical specialists.

We formulated a set of pathways to structure and set the agenda for the risk assessment activity. This was an important step if we were to conduct the assessment efficiently and effectively, and to ensure the key elements covered all matters of concern. They are discussed in detail in Section 4 below.

During the workshops we:

- Identified relevant risks and their associated controls
- Analysed the risks, using an analysis process tailored for this project
- Evaluated the risks to specify priorities for further attention.

## Participants in the risk assessment

The participants in the main risk assessment workshops and reviews, their roles and activities are shown in Table 1. Details of all discussions and reviews are provided in the Integrated Risk Assessment report (Hansen Bailey, 2015).

### Table 1: Participants

| Participant | Organisation | Role | Context & event tree review 22-26 June 15 | First workshop 17 July 15 | Second workshop 28 July 15 | Review workshop 5 August 15 | Review discussion 14 August 15 |
|---|---|---|---|---|---|---|---|
| Rhys Brett | WCL | Project team | ✓ | ✓ | ✓ | ✓ | |
| David Clarkson | WCL | Project team | ✓ | ✓ | ✓ | ✓ | ✓ |
| Andrew Dawkins | GeoTerra | Groundwater, surface water | ✓ | | ✓ | ✓ | ✓ |
| Nathan Garvey | Biosis | Ecology | ✓ | | | ✓ | |
| Dr Ken Mills | SCT Operations | Subsidence | ✓ | ✓ | | ✓ | |
| Dianne Munro | Hansen Bailey | Environment | ✓ | ✓ | ✓ | ✓ | ✓ |
| Andrew Wu | Hansen Bailey | Environment | ✓ | ✓ | ✓ | ✓ | ✓ |

Notes to Table 1:

1. The context and event tree review between 22 and 26 June focused on ensuring the context statement was appropriate and the initial trees were comprehensive. Parts of the trees were 'pruned' during the subsequent workshops.
2. The workshop on 17 July focused on risks that might affect water quantities. It involved both qualitative and quantitative assessments.
3. The workshop on 28 July focused on risks with effects on water quality and the environment. It also reviewed the outcomes from 17 July.

4. The review workshop on 5 August examined the risk assessment as a whole and confirmed the information in the risk register.
5. A final review took place by teleconference on 14 August. At the time of the final review, the key findings of the technical assessment had been determined. The revisions to the technical reports after the final review were typographical in nature and did not change the outcomes of the risk assessment.

## Supporting documents

The risk assessment relied on the information contained in technical reports prepared by WCL's experts. They are listed in Section 10.3.

# 3 Establishing the context

For this assessment, we included the ‘Communicate and consult’ step in the ‘Establish the context’ step of the process.

## Stakeholders

There are many external and internal stakeholders with an interest in the UEP. Some of the major stakeholders and issues that relate to Recommendation 1 are noted in Table 2.

WCL held a meeting with the Department of Planning & Environment (DP&E) on 15 May 2015 to discuss the formation of the IRAP. DP&E advised that the IRAP should be constituted of independent technical specialists approved by DP&E and consultation should be undertaken with relevant regulatory agencies.

## Table 2: Stakeholders

| Stakeholder group | Stakeholders | Interests and objectives relevant to this Risk Assessment |
|---|---|---|
| Company | Jindal Steel and Power; Wollongong Coal Limited | Approval of the UEP with acceptable conditions; acceptable return on capital invested |
| | Workforce at Russell Vale Colliery | Continuation of mining and associated employment for up to 5 years |
| Community | Local businesses; Illawarra Business Chamber; Port Kembla Coal Terminal (PKCT) | Economic multiplier benefits from employment at the mine and continuing mining activities; increased volumes of coal through PKCT (currently underutilised) |
| | Wollongong City Council; Wollondilly Shire Council | Minimised disruption to local residents and the environment; economic multiplier benefits |
| | Community groups and individuals; special interest groups | Protection of drinking water quality and quantity; maintenance of biodiversity |

| Stakeholder group | Stakeholders | Interests and objectives relevant to this Risk Assessment |
|---|---|---|
| Regulators | Department of Planning and Environment; Office of Environment and Heritage; Planning Assessment Commission; Environment Protection Authority; Division of Resources and Energy | Predicted environmental effects and uncertainty about those effects; potential long-term effects; biodiversity offset policy, efficacy of an adaptive management regime |
| | Dams Safety Committee | Structural integrity of the dam wall of Cataract Dam; impact on the stored waters of the Cataract Reservoir; existence, location and impact of the Corrimal Fault on Longwall 7 (one of the closest longwalls to the reservoir) |
| Water utility, land owner and catchment manager | Water NSW | Protection of drinking water quality and quantity; impacts on upland swamps; continuing objection to the longwalls extending into the Cataract Dam Notification Area; uncertainty about subsidence predictions; nature and extent of the Corrimal Fault and Dyke D8; potential for a connection between the Cataract Reservoir and the mine workings |
| Government | State of NSW | Royalty revenues; economic prosperity in the Illawarra |

## External and internal context

General aspects of the current context for the UEP are summarised in Table 3. Specific features that are important for the risk assessment are discussed in detail in the Integrated Risk Assessment report (Hansen Bailey, 2015) and in the detailed notes to the risk register (Broadleaf, 2015) that accompany this report.

## Table 3: Context summary

| External factor | Implications |
|---|---|
| The region includes important water resources | The area forms part of the drinking water catchment for Sydney; the mine is located within a declared catchment area, the Metropolitan Special Area; the majority of the area proposed to be mined is owned by Water NSW; mining is proposed near to but not directly under Cataract Reservoir, but mining could potentially impact tributaries of the streams that drain to the reservoir |
| Drying of swamps may affect water quality | If upland swamps dry out and begin to erode, water quality in the catchment may be compromised |
| The region includes important ecological resources | These are primarily upland swamps, which could be impacted |
| Geological features | The Corrimal Fault and Dyke D8 intersect some of the area covered by the mine plan |

# 4 Risk identification

## Pathways

We developed a set of the main risks and the main uncertainties that could affect the quantity or quality of water flowing into Cataract Reservoir, flowing into the regional aquifer, or affecting sensitive environmental areas on the Woronora Plateau. We expressed these in the form of pathways that begin with proposed mining activities and extend to consequences that are to be considered by the IRAP as part of its TOR. They provided a starting point for discussion in the risk assessment workshops.

The project team and its specialist technical advisers on subsidence, groundwater and ecology reviewed the initial event trees before the first workshop, and they were revised during the workshop process (see Table 1).

Consistent with the TOR, Table 4 summarises the features that have a potential to be impacted by longwall mining. Figure 3 shows a summary of the pathways. Predictions have not been made for individual longwalls: the mine plan has been grouped into three sets of related longwalls to enable the assessment to be undertaken.

## Table 4: Longwalls and associated features

| Longwall | Feature |
|---|---|
| LW1-LW3 | Cataract Creek, groundwater systems, CCUS1 (LW3), CCUS2 (LW2 and LW3), CRUS3 |
| LW6-LW7 | Cataract Reservoir, Cataract Creek, Cataract River, Corrimal Fault (F1), Dyke D8, groundwater systems, CCUS4 (LW6 and LW7), CCUS5 (LW7), CRUS1 |
| LW9-LW11 | Cataract Reservoir, Cataract Creek (LW9), Dyke D8, groundwater systems, CCUS10 (LW9), CCUS11 (LW9), CCUS12 (LW9 and LW10), CCUS24 (LW9), BCUS4 (LW10), BCUS11 (LW10), CRUS6 (LW11) |

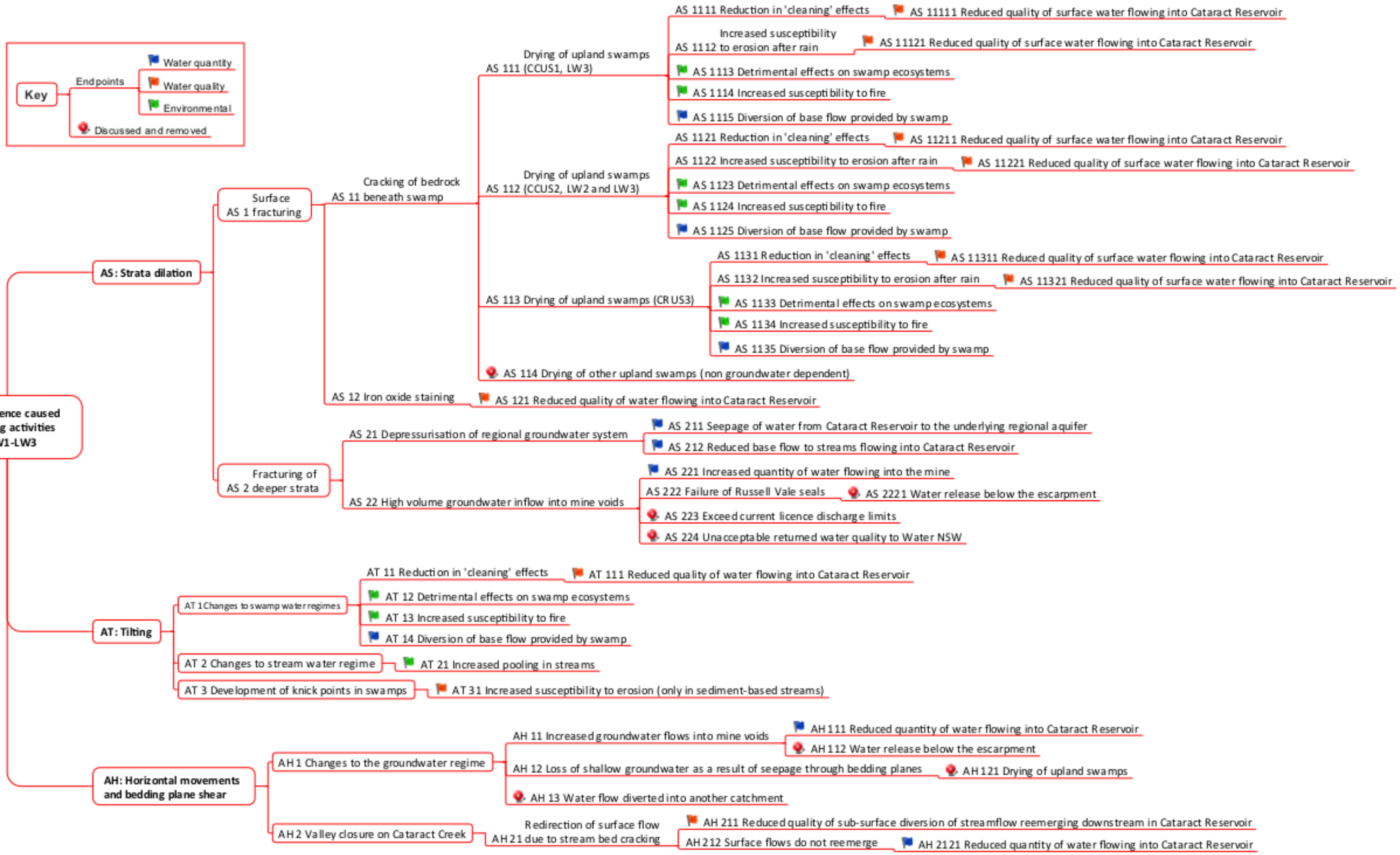
The detailed trees for each of the three groups of longwalls are shown in Figure 4 (LW1-LW3), Figure 5 (LW6-LW7) and Figure 6 (LW9-LW11), with pathway elements numbered for ease of reference. The nomenclature in the figures and the risk register is noted in Table 5.

## Table 5: Nomenclature for risks

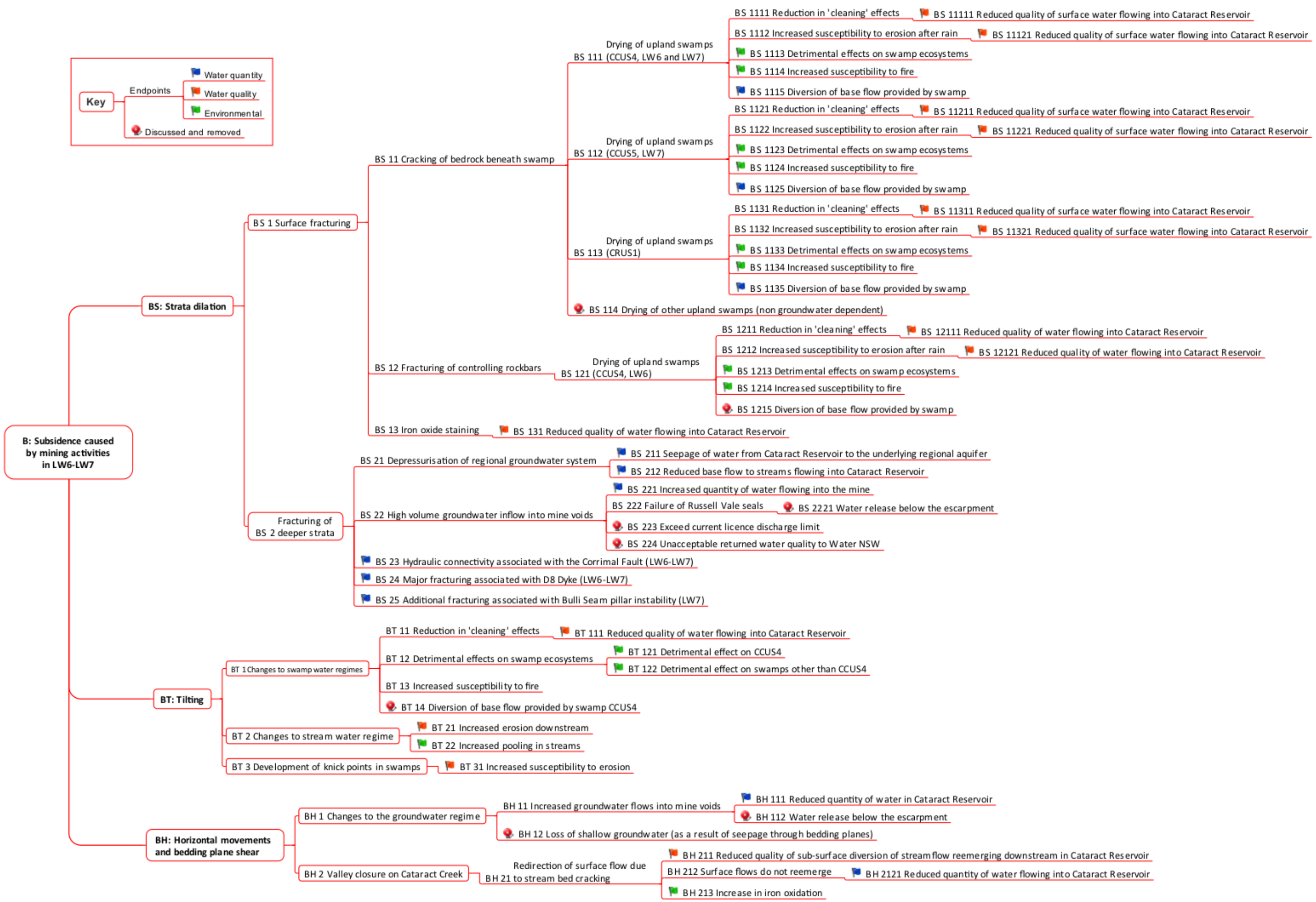
| Part | Detail | Interpretation |
|---|---|---|
| First letter | | The first letter indicates the group of longwalls |
| | A | LW1-LW3 |
| | B | LW6-LW7 |
| | C | LW9-LW11 |
| Second letter | | The second letter indicates the primary mechanism that follows from mining the relevant longwalls and leads ultimately to an endpoint of interest |
| | S | Strata dilation: fracturing of strata as a result of mining |
| | T | Tilting of the surface |
| | H | Horizontal ground movements and bedding plane shear |
| Subsequent digits | | Detailed pathway indicators, in the hierarchical structure set out in the event trees |

## Figure 3: Summary event tree

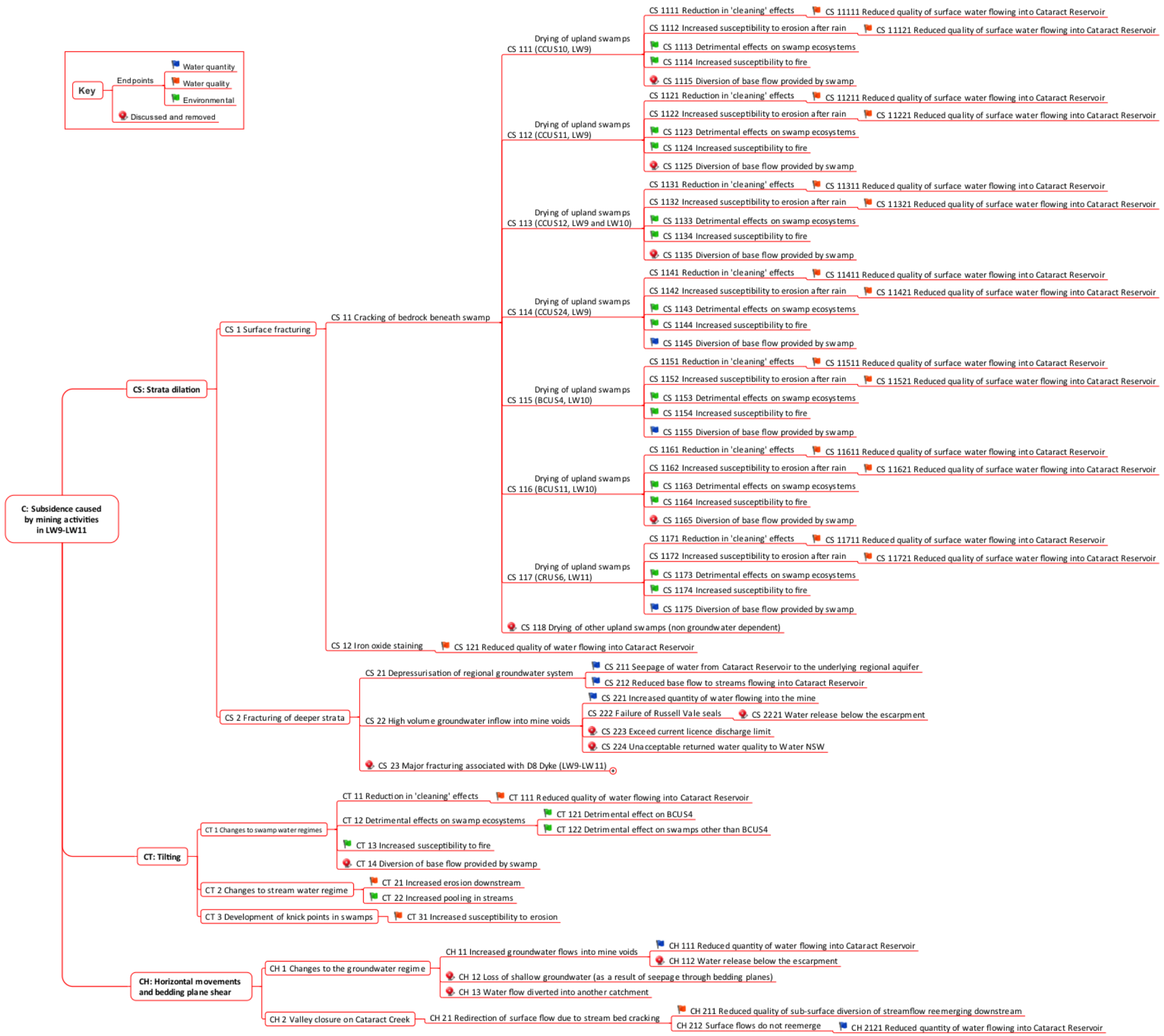
## Figure 4: Event tree, LW1-LW3



## Figure 5: Event tree, LW6-LW7



## Figure 6: Event tree, LW9-LW11



## Endpoints

The primary endpoints of interest are:

- Quantity of water available for drinking water purposes in Cataract Reservoir;
- Quality of water available for drinking water purposes in Cataract Reservoir; and
- Ecosystem effects of water quantity and quality on water dependent species, with a particular emphasis on upland swamps.

We used qualitative scales for the endpoints, taking into account the indicators in Table 6; colour-coded flags are used in Figure 3 to Figure 6 to indicate the endpoints.

## Table 6: Endpoint indicators

| Endpoint | Measures and indicators |
|---|---|
| Water quantity | Water flows into or from Cataract Reservoir, ML/day |
| Water quality | Iron content; low or high pH; low or high dissolved oxygen (DO); turbidity; manganese content; water hardness<br><br>The primary focus of the assessment was on changes to the overall water quality in Cataract Reservoir rather than localised effects in streams and swamps; localised effects are taken into account as part of the environmental consequences analysis where relevant |
| Swamp health | Severity and area of impact on upland swamp ecosystems |
| Creek health | Stream flow; water quality impacts as noted above |

## Risk register

An initial risk register was prepared from the event trees. Risks were presented in the form of sequences of causes, corresponding to the branches of the tree, that lead to consequences at the endpoints of the branches. As an example, Table 7 shows a risk description derived from the tree associated with mining LW1-LW3, following a pathway that leads in this case to a reduced quantity of water flowing into Cataract Reservoir.

## Table 7: Example risk description

| Causes … | | | | Consequence |
|---|---|---|---|---|
| A Subsidence caused by mining activities in LW1-LW3 | AH Horizontal movements and bedding plane shear | AH 1 Changes to the groundwater regime | AH 11 Increased groundwater flows into mine voids | AH 111 Reduced quantity of water flowing into Cataract Reservoir |

When we identified additional risks during the workshops, we included them in the risk register.

For each risk we noted the current controls that are expected to be in place in the UEP. These included controls that are:

- Included already in the preferred project mine plan
- Commitments already made
- Part of WCL's standard approach to good mining practice at Russell Vale.

The risk register is provided as a separate document (Broadleaf, 2015).

## Risks that were removed

Figure 3 to Figure 6 show the risks that were considered in the workshops, with those that were deemed not relevant or duplications marked by a red bell. The detailed reasons for removing a risk from the assessment are noted in the risk register.

# 5 Risk analysis

## Overview

We analysed each risk using the scales summarised in Table 8. The detailed scales are provided below.

### Table 8: Risk rating scales and their purpose

| Scale | Purpose |
|---|---|
| Control effectiveness (Table 9) | This measures the adequacy of the design of the controls and the effectiveness of their implementation, relative to industry best practice |
| Consequences (Table 10) | This measures the effects of a risk on the endpoints, taking into account the controls and their effectiveness |
| Likelihood (Table 11) | This measures the chance of the consequences arising at the indicated level, again taking into account the controls and their effectiveness |
| Level of risk (Table 12) | This combines the consequence and likelihood measures into a single measure of risk |
| Potential exposure (Table 10) | This measures the maximum consequences for the objectives if all the controls were to fail |

## Analysis and evaluation scales

Control effectiveness (Table 9) measures the adequacy of the design of the controls and the effectiveness of their implementation, relative to industry best practice. It is a broad indicator of management capability rather than a measure of the absolute effectiveness of the controls.

## Table 9: Control effectiveness

| | Descriptor | Guide |
|---|---|---|
| A | **Fully effective** | Nothing more to be done except review and monitor the existing controls. Controls are well designed for the risk, address the root causes and management believes that they are effective and reliable at all times. |
| B | **Substantially effective** | Most controls are designed correctly and are in place and effective. Some more work to be done to improve operating effectiveness or management has doubts about operational effectiveness and reliability. |
| C | **Partially effective** | While the design of controls may be largely correct in that they treat most of the root causes of the risk, they are not currently very effective.<br><br>or<br><br>Some of the controls do not seem correctly designed in that they do not treat root causes, those that are correctly designed are operating effectively. |
| D | **Largely ineffective** | Significant control gaps. Either controls do not treat root causes or they do not operate at all effectively. |
| E | **None or totally ineffective** | Virtually no credible control. Management has no confidence that any degree of control is being achieved due to poor control design and/or very limited operational effectiveness. |

The consequence scales (Table 10) are used to measure the effects of a risk on the endpoints and related objectives, taking into account the controls and their effectiveness. They were tailored for this specific risk assessment.

## Table 10: Consequences

| | Descriptor | Water volume | Water quality (see notes below) | Environment (see notes below) | Community & reputation | Legal & compliance |
|---|---|---|---|---|---|---|
| 5 | **Very high** | Very large reduction in water volumes flowing into or from Cataract Reservoir; immediate WCL action required by Water NSW; Water NSW launches enquiry; large water charges imposed | Significant long-term reduction in water quality; very high sustained turbidity in Cataract Reservoir; very low DO; very high or very low pH; very high iron content, manganese or hardness | Disastrous environmental impact with long term effect | Prominent negative international media coverage over several days | Major litigation or prosecution with high damages and significant costs; custodial sentence for an executive; prolonged closure of operations by regulator |
| 4 | **High** | Large reduction in water volumes flowing into or from Cataract Reservoir; WCL action required by Water NSW; water charges imposed | Major long term reduction in water quality; low DO; high or low pH; high iron content, manganese or hardness | Serious environmental impact with medium term effect | National media coverage over several days; community or NGO legal actions; impact on local economy | Major litigation and investigation by regulator; long term interruption to operations; possible custodial sentence |
| 3 | **Moderate** | Moderate reduction in water volumes flowing into or from Cataract Reservoir, beyond seasonal variations; WCL action required by Water NSW | Moderate long-term reduction in water quality; reduced DO; slightly high or slightly low pH; elevated iron content, manganese or hardness | Moderate reversible environmental impact with short term effect | Local media coverage over several days; negative impact on local economy; persistent community complaints | Major breach of regulation with punitive fine; significant litigation involving many weeks of senior management time |
| 2 | **Low** | Small reduction in water volumes flowing into or from Cataract Reservoir | Small, short-term reduction in water quality; slightly reduced DO; slightly high or slightly low pH; slightly elevated iron content, manganese or hardness | Minor reversible environmental impact | Local media coverage; complaint to site or regulator | Breach of regulation with investigation or report to regulator; prosecution or moderate fine possible |

| | Descriptor | Water volume | Water quality (see notes below) | Environment (see notes below) | Community & reputation | Legal & compliance |
|---|---|---|---|---|---|---|
| 1 | **Very low** | Negligible effect on water volumes flowing into or from Cataract Reservoir | Minimal reduction in water quality; DO, pH, iron content, manganese and hardness within normal ranges | Negligible reversible environmental impact | No media coverage; no community complaints | Minor legal issues, non-compliances and breaches of regulation |

Notes to Table 10:

1. Where appropriate, ratings associated with changes in water quality are interpreted in terms of base levels of the relevant characteristic.
2. Water quality and environmental ratings take account of recovery times and geographic scope, in the sense that long-term or wide-ranging effects are rated more highly than short-term or localised effects.

The likelihood scale (Table 11) measures the chance of the consequences arising at the indicated level, again taking into account the controls and their effectiveness. The scale was tailored for this specific risk assessment. In particular, the highest-likelihood part of the scale was set to rate outcomes that might arise annually or more frequently as more detailed disaggregation was not needed. The lowest-likelihood rating was set to rate outcomes that might arise with recurrence rates of less than one in one thousand years, such as are sometimes observed in environmental and ecological risk analyses.

## Table 11: Likelihoods

| | Descriptor | Annual probability | Recurrence |
|---|---|---|---|
| A | **Almost certain** | 1 | Once a year or more frequently |
| B | **Likely** | 0.1 | Every 1 to 10 years |
| C | **Possible** | 0.01 | Every 10 to 100 years |
| D | **Unlikely** | 0.001 | Every 100 to 1,000 years |
| E | **Rare** | 0.0001 | Less than once in 1,000 years |

A five-by-five matrix (Table 12) was used to combine the consequence and likelihood measures into a set of levels of risk, in five categories.

## Table 12: Level of risk

| | | | | | | |
|---|---|---|---|---|---|---|
| Likelihood rating | A | | | | | |
| | B | | | | | |
| | C | | | | | |
| | D | | | | | |
| | E | | | | | |
| | | 1 | 2 | 3 | 4 | 5 |
| | | Consequence rating | | | | |

| Classification: | Negligible risk | Low risk | Medium risk | High risk | Extreme risk |
|---|---|---|---|---|---|

## Potential exposure (PE)

Potential exposure is the plausible worst-case impact arising from a risk assuming all current controls fail. The potential exposure for each risk is rated using the consequence scale in Table 10. When combined with the level of risk, it provides an indication of the key controls that should be monitored and reviewed.

# 6 Risk evaluation: outcomes

## 6.1 Overview

The technical detail that supports the conclusions in this section is provided in the Integrated Risk Assessment report (Hansen Bailey, 2015) and in the detailed notes to the risk register (Broadleaf, 2015) that accompany this report.

Table 13 shows the consequences and likelihoods for all risks considered in the risk assessment, across all endpoints.

## Table 13: Overview of all risks

| Likelihood rating | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | A | AH111, AH211, AH2121, AS121, AS211, AS221, BS1115, BS131, BS211, BS221, CH111, CS1155, CS121, CS211, CS221 | AS212, BH111, BS212, CS212 | | BS1113, BS1213 | |
| | B | | | | | |
| | C | AS11121, AS1115, BH211, BH213, BS11121, BS11221, BS11123, BS1124, CH211, CS11121, CS11221, CS1133, CS11521, CS11621, CS11721 | AS1113, AS1124, BH2121, BS1114, BS1214, BT121, CH2121, CS1153, CS1154 | CT121 | | |
| | D | AS11111, AS1114, AS11211, AS11221, AS1123, AS1125, AS1133, AS1134, AS1135, AT14, AT21, AT31, BS11111, BS11211, BS1125, BS11311, BS11321, BS1133, BS1134, BS1135, BS12111, BS12121, BT111, BT122, BT13, BT21, BT22, BT31, CS11111, CS1113, CS1114, CS11211, CS1123, CS1124, CS11311, CS11321, CS1134, CS11411, CS11421, CS1143, CS1144, CS1145, CS11511, CS11611, CS1163, CS1164, CS11711, CS1173, CS1174, CS1175, CT111, CT122, CT13, CT21, CT22, CT31 | BS23, BS24, BS25 | | | |
| | E | AS11311, AS11321, AT111, AT12, AT13 | | | | |
| | | Consequence rating | | | | |

| Classification: | Negligible risk | Low risk | Medium risk | High risk | Extreme risk |
|---|---|---|---|---|---|

There are several features evident in Table 13:

- The risks tend to be clustered along the left-hand edge of the table. Most risks are associated with very low or low consequences for the endpoints of interest.
- There are many risks in the top-left corner of the table. Many of the consequences are almost certain to arise as an outcome of mining activities.

- There are only two high risks BS1113 and BS1213, both associated with environmental impacts on swamp CCUS4; and one with moderate impacts, CT121, associated with swamp BCUS4. They are discussed in more detail in Sections 6.4 and 6.6.

It is worth noting that the outcomes from the risk assessment presented in this section are conservative, in several ways.

- The consequence and likelihood ratings developed in the workshops were themselves conservative. Where there was uncertainty or doubt, higher consequence or higher likelihood ratings were selected.
- The risks that were analysed and their consequences cannot all arise at the same time. Each longwall will affect a relatively small part of the overall catchment of Cataract Reservoir. However, they are presented here 'en masse' as if they were all related to one another.
- The consequences for both water quantity and water quality are dependent on the levels of flow from time to time. In times of low or base flow, the localised consequence of streambed cracking can appear to be severe, but in times of increased flow, the consequence is diminished. The approach adopted in the workshops was broadly conservative, addressing the effects of individual risks on an annual basis, taking into account both short-term and long-term impacts. The consequences scales in Table 10, particularly for environmental impacts, include explicitly the duration of an adverse impact and the ability of the ecosystem to recover.
- A number of the technical experts assessing and informing the risk assessment have adopted conservative assumptions. For example, impacts on water quantity due to streambed and surface cracking have been determined based on the conservative assumption that catchment flows will not re-emerge downstream after they have been re-directed to the subsurface via cracks.

More detailed breakdowns of the risk assessment outcomes are provided in the following sub-sections.

## 6.2 Effects on water quantity

Table 14 shows the effects of risks that are associated with water flows into or from Cataract Reservoir, across all groups of longwalls. The pattern noted in Section 6.1 is evident: there are no risks with large consequences, and some effects are almost certain.

### Table 14: Qualitative outcomes: water quantity

| | | | | | | |
|---|---|---|---|---|---|---|
| Likelihood rating | A | **AH111, AH2121, AS211, AS221, BS1115, BS211, BS221, CH111, CS1155, CS211, CS221** | **AS212, BH111, BS212, CS212** | | | |
| | B | | | | | |
| | C | **AS1115** | **BH2121, CH2121** | | | |
| | D | **AS1125, AS1135, AT14, BS1125, BS1135, CS1145, CS1175** | **BS23, BS24, BS25** | | | |
| | E | | | | | |
| | | 1 | 2 | 3 | 4 | 5 |
| | | **Consequence rating** | | | | |

| Classification: | Negligible risk | Low risk | Medium risk | High risk | Extreme risk |
|---|---|---|---|---|---|

## 6.3 Effects on water quality

Table 15 shows the effects of risks that are associated with water quality in Cataract Reservoir, across all groups of longwalls. The pattern noted in Section 6.1 is evident: there are no risks with any but very low consequences, and some effects are almost certain.

In most cases the very low consequences are due to attenuation effects between the place where initial consequences are observed and Cataract Reservoir where the endpoint is applied. Where water quality is affected by a risk, the effects are almost always localised within the immediate vicinity of a specific 'source' site, although there may be many such sources along a length of stream. It should be noted that this discussion applies to water quality consequences only; any environmental consequences are considered under the corresponding environmental endpoints.

**Table 15: Qualitative outcomes: water quality**

| | | | | | | |
|---|---|---|---|---|---|---|
| Likelihood rating | A | AH211, AS121, BS131, CS121 | | | | |
| | B | | | | | |
| | C | AS11121, BH211, BS11121, BS11221, CH211, CS11121, CS11221, CS11521, CS11621, CS11721 | | | | |
| | D | AS11111, AS11211, AS11221, AT21, AT31, BS11111, BS11211, BS11311, BS11321, BS12111, BS12121, BT111, BT21, BT22, BT31, CS11111, CS11211, CS11311, CS11321, CS11411, CS11421, CS11511, CS11611, CS11711, CT111, CT21, CT22, CT31 | | | | |
| | E | AS11311, AS11321, AT111 | | | | |
| | | 1 | 2 | 3 | 4 | 5 |
| | | Consequence rating | | | | |

| Classification: | Negligible risk | Low risk | Medium risk | High risk | Extreme risk |
|---|---|---|---|---|---|

## 6.4 Effects on the environment

Table 16 shows the effects of risks that are associated with environmental and ecological consequences, across all groups of longwalls. Apart from three risks, the pattern noted in Section 6.1 is evident: most risks have low or very low consequences, and some effects are almost certain to occur.

## Table 16: Qualitative outcomes: environment

| Likelihood rating | | | | | | |
|---|---|---|---|---|---|---|
| | A | | | | BS1113, BS1213 | |
| | B | | | | | |
| | C | BH213, BS1123, BS1124, CS1133 | AS1113, AS1124, BS1114, BS1214, BT121, CS1153, CS1154 | CT121 | | |
| | D | AS1114, AS1123, AS1133, AS1134, BS1133, BS1134, BT122, BT13, CS1113, CS1114, CS1123, CS1124, CS1134, CS1143, CS1144, CS1163, CS1164, CS1173, CS1174, CT122, CT13 | | | | |
| | E | AT12, AT13 | | | | |
| | | 1 | 2 | 3 | 4 | 5 |
| | | **Consequence rating** | | | | |

| Classification: | Negligible risk | Low risk | Medium risk | High risk | Extreme risk |
|---|---|---|---|---|---|

Three of the risks are described in more detail in

Table 17 (and see Section 6.6).

- The two risks with high consequences, BS1113 and BS1213, are both related to impacts on swamp CCUS4, due to a potential for cracking of the bedrock beneath the swamp (BS1113) or the controlling rockbar (BS1213). The ecological consequences are almost certain to occur: loss of habitat for threatened species and changes of vegetation communities within the swamp. An offset strategy will be implemented.
- Risk CT121, with moderate consequences, is related to the effects of predicted tilting on swamp BCUS4 above LW10. The maximum amount of tilting above LW10 is predicted to be 24 mm/m (SCT, 2014). Modelling predicts that only about half the swamp is likely to be affected; 1.14 ha of the total swamp area of 2.23 ha is within the 200 mm subsidence contour.

## Table 17: Risks with moderate or high consequences

| Risk | Pathways … | | | | | |
|---|---|---|---|---|---|---|
| BS1113 | B Mining activities in LW6-LW7 | BS Strata dilation | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 111 Drying of upland swamps (CCUS4, LW6 and LW7) | BS 1113 Detrimental effects on swamp ecosystems |
| BS1213 | B Mining activities in LW6-LW7 | BS Strata dilation | BS 1 Surface fracturing | BS 12 Fracturing of controlling rockbars | BS 121 Drying of upland swamps (CCUS4, LW6) | BS 1213 Detrimental effects on swamp ecosystems |
| CT121 | C Mining activities in LW9-LW11 | CT Tilting | CT 1 Changes to swamp water regimes | CT 12 Detrimental effects on swamp ecosystems | CT 121 Detrimental effect on BCUS4 | |

## 6.5 Risks for each group of longwalls

Table 18, Table 19 and Table 20 show the consequences and likelihoods of the risks for each group of longwalls, across all endpoints.

## Table 18: Risks associated with LW1-LW3

| Likelihood rating | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | A | **AH111, AH211, AH2121, AS121, AS211, AS221** | **AS212** | | | |
| | B | | | | | |
| | C | **AS11121, AS1115** | **AS1113, AS1124** | | | |
| | D | **AS11111, AS1114, AS11211, AS11221, AS1123, AS1125, AS1133, AS1134, AS1135, AT14, AT21, AT31** | | | | |
| | E | **AS11311, AS11321, AT111, AT12, AT13** | | | | |
| | | **Consequence rating** | | | | |

| Classification: | **Negligible risk** | **Low risk** | **Medium risk** | **High risk** | **Extreme risk** |
|---|---|---|---|---|---|

## Table 19: Risks associated with LW6-LW7

| | | | | | | |
|---|---|---|---|---|---|---|
| Likelihood rating | A | BS1115, BS131, BS211, BS221 | BH111, BS212 | | BS1113, BS1213 | |
| | B | | | | | |
| | C | BH211, BH213, BS11121, BS11221, BS1123, BS1124 | BH2121, BS1114, BS1214, BT121 | | | |
| | D | BS11111, BS11211, BS1125, BS11311, BS11321, BS1133, BS1134, BS1135, BS12111, BS12121, BT111, BT122, BT13, BT21, BT22, BT31 | BS23, BS24, BS25 | | | |
| | E | | | | | |
| | | 1 | 2 | 3 | 4 | 5 |
| | | Consequence rating | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Classification: | Negligible risk | Low risk | Medium risk | High risk | Extreme risk |

## Table 20: Risks associated with LW9-LW11

| | | | | | | |
|---|---|---|---|---|---|---|
| Likelihood rating | A | CH111, CS1155, CS121, CS211, CS221 | CS212 | | | |
| | B | | | | | |
| | C | CH211, CS11121, CS11221, CS1133, CS11521, CS11621, CS1172 | CH2121, CS1153, CS1154 | CT121 | | |
| | D | CS11111, CS1113, CS1114, CS11211, CS1123, CS1124, CS11311, CS11321, CS1134, CS11411, CS11421, CS1143, CS1144, CS1145, CS11511, CS11611, CS1163, CS1164, CS11711, CS1173, CS1174, CS1175, CT111, CT122, CT13, CT21, CT22, CT31 | | | | |
| | E | | | | | |
| | | 1 | 2 | 3 | 4 | 5 |
| | | Consequence rating | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Classification: | Negligible risk | Low risk | Medium risk | High risk | Extreme risk |

## 6.6 Risks for each swamp

Most swamps have several associated risks, affecting water quantities, water quality or ecosystem function. The risk register contains a 'Swamps' sheet that lists the risks for each swamp. For most of the swamps, the consequences of the risks are either very low or low (Table 21). There are only two swamps, BCUS4 and CCUS4, having associated risks with consequences that are moderate or high (Table 17). The individual risks for these two swamps are shown in Table 22 and Table 23. A detailed analysis of the overall risk to key upland swamps is provided in the Integrated Risk Assessment (Hansen Bailey, 2015).

### Table 21: Swamps and the consequences of risks

| Swamp | Number of risks with each consequence rating | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| **BCUS4** | 3 | 2 | **1** | | |
| BCUS11 | 4 | | | | |
| CCUS1 | 4 | 1 | | | |
| CCUS2 | 4 | 1 | | | |
| **CCUS4** | 5 | 3 | | **2** | |
| CCUS5 | 5 | | | | |
| CCUS10 | 4 | | | | |
| CCUS11 | 4 | | | | |
| CCUS12 | 4 | | | | |
| CCUS24 | 4 | | | | |
| CRUS1 | 5 | | | | |
| CRUS3 | 5 | | | | |
| CRUS6 | 4 | | | | |

## Table 22: Risks associated with swamp BCUS4

| Identifier | Risk summary ... | Consequence | Impact | Cons | L'hood | Classification |
|---|---|---|---|---|---|---|
| CS 11511 | Surface fracturing with cracking of bedrock beneath swamp | CS 11511 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| CS 11521 | Surface fracturing with cracking of bedrock beneath swamp | CS 11521 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | C | Low |
| CS 1153 | Surface fracturing with cracking of bedrock beneath swamp | CS 1153 Detrimental effects on swamp ecosystems | E | 2 | C | Medium |
| CS 1154 | Surface fracturing with cracking of bedrock beneath swamp | CS 1154 Increased susceptibility to fire | E | 2 | C | Medium |
| CS 1155 | Surface fracturing with cracking of bedrock beneath swamp | CS 1155 Diversion of base flow provided by swamp | V | 1 | A | Medium |
| CT 121 | Tilting leading to changes to swamp water regimes | CT 121 Detrimental effect on BCUS4 ecosystems | E | 3 | C | Medium |

## Table 23: Risks associated with swamp CCUS4

| Identifier | Risk summary ... | Consequence | Impact | Cons | L'hood | Classification |
|---|---|---|---|---|---|---|
| BS 11111 | Surface fracturing with cracking of bedrock beneath swamp | BS 11111 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| BS 11121 | Surface fracturing with cracking of bedrock beneath swamp | BS 11121 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | C | Low |
| BS 1113 | Surface fracturing with cracking of bedrock beneath swamp | BS 1113 Detrimental effects on swamp ecosystems | E | 4 | A | High |
| BS 1114 | Surface fracturing with cracking of bedrock beneath swamp | BS 1114 Increased susceptibility to fire | E | 2 | C | Medium |
| BS 1115 | Surface fracturing with cracking of bedrock beneath swamp | BS 1115 Diversion of base flow provided by swamp | V | 1 | A | Medium |
| BS 12111 | Surface fracturing with fracturing of controlling rockbars | BS 12111 Reduced quality of water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| BS 12121 | Surface fracturing with fracturing of controlling rockbars | BS 12121 Reduced quality of water flowing into Cataract Reservoir | Q | 1 | D | Negligible |

| Identifier | Risk summary ... | Consequence | Impact | Cons | L'hood | Classification |
|---|---|---|---|---|---|---|
| BS 1213 | Surface fracturing with fracturing of controlling rockbars | BS 1213 Detrimental effects on swamp ecosystems | E | 4 | A | High |
| BS 1214 | Surface fracturing with fracturing of controlling rockbars | BS 1214 Increased susceptibility to fire | E | 2 | C | Medium |
| BT 121 | Tilting leading to changes to swamp water regimes | BT 121 Detrimental effects on CCUS4 ecosystems | E | 2 | C | Medium |

# 7 Risk treatment

Wollongong Coal has developed action plans to address major risks and areas of residual uncertainty. Many of these are noted in the Integrated Risk Assessment report (Hansen Bailey, 2015) and risk register (Broadleaf, 2015).

# 8 Contact

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# 9 Appendix: Glossary

## Table 24: Glossary

| Term | Description |
|---|---|
| Balgownie Seam | The middle coal seam at Russell Vale |
| Bulli Seam | The top-most coal seam at Russell Vale |
| CE | Control effectiveness, a measure of the adequacy of the design of the controls and the effectiveness of their implementation, in relation to the best the company could achieve |
| DO | Dissolved oxygen |
| DP&E | NSW Department of Planning and Environment |
| EEC | Endangered ecological community |
| EPBC Act | Environment Protection and Biodiversity Conservation Act 1999 |
| IRAP | Independent Risk Assessment Panel |
| LW | Longwall |
| Mode | The peak value of a distribution when displayed in density form |
| P10 value | The distribution value for which the chance of being lower is one in ten |
| P90 value | The distribution value for which the chance of being higher is one in ten |
| PAC | Planning Assessment Commission |
| PE | Potential exposure, the maximum consequences for the objectives if all the controls were to fail |
| PKCT | Port Kembla Coal Terminal |
| RA | Risk assessment, including risk identification, risk analysis and risk evaluation |

| | |
|---|---|
| ROM coal | Run-of-mine coal, the coal delivered from the mine before coal preparation and processing |
| ToR | Terms of reference |
| UEP | Underground Expansion Project |
| WCL | Wollongong Coal Limited |
| Wongawilli Seam | The lowest coal seam intended to be mined by the UEP |

# 10 Appendix: References

## 10.1 Risk assessment references

Barrett, DJ, CA Couch, DJ Metcalfe, L Lytton, DP Adhikary and RK Schmidt (2013). *Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources.* Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, Department of Environment.

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Cooper, DF, PM Bosnich, SJ Grey, G Purdy, GA Raymond, PR Walker and MJ Wood (2014) Project Risk Management Guidelines: Managing Risk with ISO 31000 and UEC 62198. Chichester, UK: John Wiley & Sons, Ltd.

Hilyard, D, W Zeigler and H Middleton (2012) *Risk assessment for managing impacts of mining on dam*s. Australian National Committee on Large Dams (ANCOLD) Conference, Perth WA.

ISO 31000:2009. *Risk management – Principles and guidelines*. International Organization for Standardization, Geneva. Published in Australia as AS/NZS ISO 31000:2009, *Risk management – Principles and guidelines*, Standards Australia, Sydney, and Standards New Zealand, Wellington.

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Water NSW (2015) *Risk Management Framework*. CD2011/13, Water NSW, February.

## 10.2 Supporting documents

Broadleaf Capital International (2015) *Russell Vale Colliery Underground Expansion Project – Risk Register*.

Hansen Bailey (2015) *Russell Vale Colliery Underground Expansion Project – Integrated Risk Assessment.*

## 10.3 Expert reports

Biosis (2014) *Coastal Upland Swamp Impact Assessment Report.*

Biosis (2015) *Underground Expansion Project Independent Risk Assessment - Addendum Report.*

GeoTerra (2014a) *Swamp piezometer monitoring in associated with extraction of Longwalls 4, 5 and 6 (365m).*

GeoTerra (2014b) *End of Longwall 4 & Longwall 5 Groundwater & Surface Water Monitoring Assessment.*

GeoTerra (2014c) *End of Longwall 4 & Longwall 5 Groundwater & Surface Water Monitoring Assessment.*

GeoTerra (2014d) *Russell Vale Colliery Underground Expansion Project Preferred Project Report Groundwater & Surface Water Response to Submissions Residual Matters Addendum.*

GeoTerra / GES (2015) Russell Vale Colliery Underground Expansion Project Russell Vale East Revised Groundwater Assessment.

SCT (2015a) *Response to Galvin and Associates Pty Ltd Report dated 3 March 2015.*

SCT (2015b) *Review of Barrier to Protect Stored Waters of Cataract Reservoir.*

SCT (2015c) *Assessment of Corrimal Fault and Dyke D8 at Russell Vale East as Risks to the Stored Waters of Cataract Reservoir.*

SCT (2015d) *Response to Residual Matters from Independent Risk Assessment Panel Comments.*

WRM (2015) *Russell Vale Colliery Underground Expansion Project - Surface Water Modelling: Response to Planning Assessment Commission.*

## *APPENDIX B*

## Broadleaf Risk Register

Broadleaf

**Creating value from uncertainty**
Broadleaf Capital International Pty Ltd
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# Risk register:
# Integrated risk assessment for the UEP

## Wollongong Coal, Russell Vale Underground Expansion Project

Prepared by:
**Dr Dale F Cooper**
Director

Version 10, 24 September 2015

Broadleaf

# 1 Combined risk register

| Identifier | Risk … | | | | | Impact | Current controls and factors that reduce the risk | QUALITATIVE ASSESSMENT | | | | | Notes | References | Additional controls and treatments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | CE | C | L | Risk | PE | | | |
| **A** | **A Subsidence caused by mining activities in LW1-LW3** | | | | | | | | | | | | | | |
| **AH** | **AH Horizontal movements and bedding plane shear** | | | | | | | | | | | | | | |
| AH 111 | AH 1 Changes to the groundwater regime | AH 11 Increased groundwater flows into fractured strata or mine voids | AH 111 Reduced quantity of water flowing into Cataract Reservoir | | | V | Monitoring will continue to be undertaken to detect abnormal flows (high or low), allowing adaptive management intervention to adjust mining activities; Water Access Licences will be obtained | E | 1 | A | 3 | 1 | First and second order streams above LW1-LW3; Management measures have not been adopted for stream reaches lower than 3rd order.<br>Horizontal shear zones do not provide hydraulic connectivity to the mine workings. It may provide connectivity to the zone of depressurisation above the longwall panels.<br>4% of rainfall recharges the overburden.<br>Conservative estimate of 4% of the total inflow of 0.1ML/day entering the mine workings (from LW1-LW3) (GW report). | *LW 6 & 7 Groundwater Management Plan* (WCL, 2015)<br>Section 10.7 of *Russell Vale Colliery Underground Expansion Project Russell Vale East Revised Groundwater Assessment* (GeoTerra / GES, 2015). | Sch 3, Condition 8 of the Draft Development Consent conditions (Draft DA) requires an Extraction Plan (EP) with significant inclusions to be prepared in consultation with DP&E, NSW Trade & Investment and the owners of affected infrastructure. The EP also requires the inclusion of a Water Management Plan, to be prepared in consultation with SCA and NOW. |
| AH 211 | AH 2 Valley closure on Cataract Creek | AH 21 Redirection of surface flow due to stream bed cracking | AH 211 Reduced quality of sub-surface diversion of streamflow re-emerging downstream into Cataract Reservoir | | | Q | Two phases of mining have already occurred beneath the creek, with a significant impact on iron hydroxide precipitation and an associated increase in metalliferous content in the creek water quality at and downstream of seepage points. | E | 1 | A | 3 | 1 | Primarily a localised impact downstream of each seepage point (there may be multiple seepage points), but for bulk water impact to reservoir it is negligible.<br>Incremental change in quality will not be observable. | Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| AH 2121 | AH 2 Valley closure on Cataract Creek | AH 21 Redirection of surface flow due to stream bed cracking | AH 212 Surface flows do not re-emerge but divert into the groundwater system or the mine | AH 2121 Reduced quantity of water flowing into Cataract Reservoir | | V | Impacts are limited to 1st and 2nd order reaches. | E | 1 | A | 3 | 1 | The worst case scenario is that all runoff in catchments overlying and upstream of longwall panels will be captured by the mine (i.e. stream flows do not re-emerge).<br>Mining of LWs 1-3 affects the catchments of Cataract Creek and Cataract River. Assuming no re-emergence of surface flow, total flow to these streams would decrease by 2.35 ML/day. | Section 5 of *Russell Vale Colliery Underground Expansion Project Surface Water Modelling: Response to Planning Assessment Commission* (WRM, 2015) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| **AS** | **AS Strata dilation** | | | | | | | | | | | | | | |
| AS 11111 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 111 Drying of upland swamps (CCUS1, LW3) | AS 1111 Reduction in 'cleaning' effects | AS 11111 Reduced quality of surface water flowing into Cataract Reservoir | Q | LW1-LW3 were re-orientated so that there was no secondary extraction beneath CCUS1.<br>Swamp not located above the longwalls (i.e. no secondary extraction beneath the swamp), with approximately 0.15 ha (3.14%) of the swamp and 8.99% of the catchment of the swamp located within the 200mm subsidence zone. | B | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwall panels (rather than a typical subsidence bowl).<br>A small area (0.15 ha) of CCUS1 is located within the 200mm subsidence zone. There is no secondary extraction beneath CCUS1.<br>Filtration effect would not change due to limited subsidence impacts on this swamp. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| AS 11121 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 111 Drying of upland swamps (CCUS1, LW3) | AS 1112 Increased susceptibility to erosion after rain | AS 11121 Reduced quality of surface water flowing into Cataract Reservoir | Q | LW1-LW3 were re-orientated so that there was no secondary extraction beneath CCUS1.<br>Swamp not located above the longwalls (i.e. no secondary extraction beneath the swamp), with approximately 0.15 ha (3.14%) of the swamp and 8.99% of the catchment of the swamp located within the 200mm subsidence zone. | B | 1 | C | 4 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>A small area (0.15 ha) of CCUS1 overlies the chain pillar. There is no secondary extraction beneath CCUS1.<br>The small area affected is unlikely to result in a significant increase in erosion potential.<br>Filtration effect would not change due to limited subsidence impacts on this swamp. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| AS 1113 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 111 Drying of upland swamps (CCUS1, LW3) | AS 1113 Detrimental effects on swamp ecosystems | | E | LW1-LW3 were re-orientated so that there was no secondary extraction beneath CCUS1.<br>Swamp not located above the longwalls (i.e. no secondary extraction beneath the swamp), with approximately 0.15 ha (3.14%) of the swamp and 8.99% of the catchment of the swamp located within the 200mm subsidence zone. | B | 2 | C | 3 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>A small area (0.15 ha) of CCUS1 overlies the chain pillar. There is no secondary extraction beneath CCUS1.<br>Given the small area affected, mining is unlikely to result in significant changes in water levels within the swamp, and unlikely to impact on the species and communities reliant on this swamp. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Sch 3, Condition 9 of the Draft DA requires an Upland Swamp Monitoring Program prepared in consultation with OEH, NOW and SCA to determine compliance with Sch 3 Condition 1 in relation to performance measures for swamps and biodiversity.<br>Sch 3, Condition 3 provides for 'Offsets' to be required if the performance measures are exceeded. DP&E is preparing a Swamp Offsets Policy, which is currently being considered in response to public submissions to its exhibition. Once finalised, WCL will be likely be required to adhere to this Swamp Offsets Policy. |
| AS 1114 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 111 Drying of upland swamps (CCUS1, LW3) | AS 1114 Increased susceptibility to fire | | E | LW1-LW3 were re-orientated so that there was no secondary extraction beneath CCUS1.<br>Swamp not located above the longwalls (i.e. no secondary extraction beneath the swamp), with approximately 0.15 ha (3.14%) of the swamp and 8.99% of the catchment of the swamp located within the 200mm subsidence zone. | B | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>A small area (0.15 ha) of CCUS1 overlies the chain pillar. There is no secondary extraction beneath CCUS1.<br>Given the small area affected mining is unlikely to result in significant changes in water levels within the swamp, and unlikely to result in drying of soils to the extent that this swamp would be susceptible to increased fire potential. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| AS 1115 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 111 Drying of upland swamps (CCUS1, LW3) | AS 1115 Reduction in base flow provided by swamp | | V | LW1-LW3 were re-orientated so that there was no secondary extraction beneath CCUS1.<br>Swamp not located above the longwalls (i.e. no secondary extraction beneath the swamp), with approximately 0.15 ha (3.14%) of the swamp and 8.99% of the catchment of the swamp located within the 200mm subsidence zone. | B | 1 | C | 4 | 1 | Flow occurs as two separate pathways in the eastern and western sections of the swamp, with the western pathway being more substantial. Only the eastern pathway will be affected.<br>Only 8.99% of the swamp catchment is located within the 200mm subsidence zone. Baseflow from CCUS1 occurs as a diffuse flow across a broad area at the base of the swamp, and is difficult to accurately measure. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | A flow monitoring station will be installed downstream of CCUS1 at a point where flow can be reliably measured. |
| AS 11211 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 112 Drying of upland swamps (CCUS2, LW2 and LW3) | AS 1121 Reduction in 'cleaning' effects | AS 11211 Reduced quality of surface water flowing into Cataract Reservoir | Q | There are existing powerlines and bike tracks in this swamp with associated clearing and erosion of trails. | A | 1 | D | 5 | 1 | This swamp is small (1.21ha) with a relatively small catchment area (4.08ha) due to this swamp's location at the top of the catchment area.<br>Currently this swamp does not provide a significant contribution to overall catchment yield.<br>Filtration effect would not change due to limited subsidence impacts on this swamp. | Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| AS 11221 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 112 Drying of upland swamps (CCUS2, LW2 and LW3) | AS 1122 Increased susceptibility to erosion after rain | AS 11221 Reduced quality of surface water flowing into Cataract Reservoir | Q | There are existing powerlines and bike tracks in this swamp with associated clearing and erosion of trails. | A | 1 | D | 5 | 1 | This swamp is small (1.21ha) with a relatively small catchment area (4.08ha) due to this swamp's location at the top of the catchment area.<br>Currently this swamp does not provide a significant contribution to overall catchment yield.<br>It is unlikely that drying of this swamp would result in significant increased erosion potential as flow velocity of sufficient magnitude unlikely to occur due to the small catchment size and resulting small amount of in-flow. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |

| Identifier | Risk … | | | | | Impact | Current controls and factors that reduce the risk | QUALITATIVE ASSESSMENT | | | | | Notes | References | Additional controls and treatments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | CE | C | L | Risk | PE | | | |
| AS 1123 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 112 Drying of upland swamps (CCUS2, LW2 and LW3) | AS 1123 Detrimental effects on swamp ecosystems | | E | There are existing powerlines and bike tracks in this swamp with associated clearing and erosion of trails. | A | 1 | D | 5 | 1 | This swamp is small (1.21ha) with a relatively small catchment area (4.08ha) due to this swamp's location at the top of the catchment area.<br>Currently this swamp does not provide a significant contribution to overall catchment yield.<br>Vegetation associated with this swamp is very dry and not groundwater-dependent. Minor changes only could be expected to occur. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| AS 1124 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 112 Drying of upland swamps (CCUS2, LW2 and LW3) | AS 1124 Increased susceptibility to fire | | E | There are existing powerlines and bike tracks in this swamp with associated clearing and erosion of trails. | A | 2 | C | 3 | 1 | This swamp is small (1.21ha) with a relatively small catchment area (4.08ha) due to this swamps location at the top of the catchment area.<br>Currently this swamp does not provide a significant contribution to overall catchment yield.<br>Vegetation associated with this swamp is very dry and not groundwater-dependent. Whilst drying may result in a small increase in the susceptibility of this swamp to fire, vegetation is already fire-prone. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Sch 3, Condition 9 of the Draft DA requires an Upland Swamp Monitoring Program prepared in consultation with OEH, NOW and SCA to determine compliance with Sch 3 Condition 1 in relation to performance measures for swamps and biodiversity.<br>Sch 3, Condition 3 provides for 'Offsets' to be required if the performance measures are exceeded. DP&E is preparing a Swamp Offsets Policy, which is currently being considered in response to public submissions to its exhibition. Once finalised, WCL will be likely be required to adhere to this Swamp Offsets Policy. |
| AS 1125 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 112 Drying of upland swamps (CCUS2, LW2 and LW3) | AS 1125 Reduction in base flow provided by swamp | | V | There are existing powerlines and bike tracks in this swamp with associated clearing and erosion of trails. | A | 1 | D | 5 | 1 | Baseflow from this swamp occurs as a diffuse flow that is difficult to measure. Currently this swamp does not provide a significant contribution to overall catchment yield. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| AS 11311 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 113 Drying of upland swamps (CRUS3) | AS 1131 Reduction in 'cleaning' effects | AS 11311 Reduced quality of surface water flowing into Cataract Reservoir | Q | Restrictions on lengths of LWs 1-3 were imposed during mine planning to avoid longwall mining beneath swamp CRUS3.<br>As a result, none of this swamp is located within the 200mm subsidence zone, with approximately 0.62 ha (4.91%) of the catchment of the swamp located within the 200mm subsidence zone. | A | 1 | E | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>No subsidence will occur within this swamp.<br>Filtration effect would not change due to no subsidence impacts on this swamp. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| AS 11321 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 113 Drying of upland swamps (CRUS3) | AS 1132 Increased susceptibility to erosion after rain | AS 11321 Reduced quality of surface water flowing into Cataract Reservoir | Q | Restrictions on lengths of LWs 1-3 were imposed during mine planning to avoid longwall mining beneath swamp CRUS3.<br>As a result, none of this swamp is located within the 200mm subsidence zone, with approximately 0.62 ha (4.91%) of the catchment of the swamp located within the 200mm subsidence zone. | A | 1 | E | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>No subsidence will occur within this swamp.<br>Based on the small area affected there is a negligible likelihood of increased erosion potential within this swamp. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| AS 1133 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 113 Drying of upland swamps (CRUS3) | AS 1133 Detrimental effects on swamp ecosystems | | E | Restrictions on lengths of LWs 1-3 were imposed during mine planning to avoid longwall mining beneath swamp CRUS3.<br>As a result, none of this swamp is located within the 200mm subsidence zone, with approximately 0.62 ha (4.91%) of the catchment of the swamp located within the 200mm subsidence zone. | A | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>No subsidence will occur within this swamp.<br>Given the small area affected and negligible changes to in-flows, mining is unlikely to result in significant changes in water levels within the swamp, and unlikely to impact on the species and communities reliant on this swamp. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| AS 1134 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 113 Drying of upland swamps (CRUS3) | AS 1134 Increased susceptibility to fire | | E | Restrictions on lengths of LWs 1-3 were imposed during mine planning to avoid longwall mining beneath swamp CRUS3.<br>As a result, none of this swamp is located within the 200mm subsidence zone, with approximately 0.62 ha (4.91%) of the catchment of the swamp located within the 200mm subsidence zone. | A | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>No subsidence will occur within this swamp.<br>Given the small area affected mining is unlikely to result in significant changes in water levels within the swamp, and unlikely to result in drying of soils to the extent that this swamp would be susceptible to increased fire potential. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| AS 1135 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 113 Drying of upland swamps (CRUS3) | AS 1135 Reduction in base flow provided by swamp | | V | Restrictions on lengths of LWs 1-3 were imposed during mine planning to avoid longwall mining beneath swamp CRUS3.<br>As a result, none of this swamp is located within the 200mm subsidence zone, with approximately 0.62 ha (4.91%) of the catchment of the swamp located within the 200mm subsidence zone. | A | 1 | D | 5 | 1 | Baseflow from this swamp occurs via diffuse flow across the rockbar at the base of the swamp and cannot be reliably measured. There is no secondary extraction beneath the swamp and only a small section of the catchment of this swamp is located within the 200mm subsidence zone. The impact to the swamp is negligible. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| AS 121 | AS 1 Surface fracturing | AS 12 Iron oxide staining | AS 121 Reduced quality of water flowing into Cataract Reservoir | | | Q | Two phases of mining have already occurred beneath the creek, with a significant impact on iron hydroxide precipitation and an associated increase in metalliferous content in the creek water quality at and downstream of seepage points.<br>No controls. | E | 1 | A | 3 | 1 | Primarily a localised impact downstream of each seepage point (there may be multiple seepage points), but for bulk water impact to reservoir it is negligible.<br>Incremental change in quality will not be observable. | Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| AS 211 | AS 2 Fracturing of deeper strata | AS 21 Depressurisation of the regional groundwater system | AS 211 Seepage of water from Cataract Reservoir to the underlying regional aquifer | | | V | Regional groundwater is below the RL of the base of the Reservoir and therefore does not contribute to Reservoir storage. At the location of the reservoir, the regional groundwater table is in the Bulgo Sandstone. The base of Cataract Reservoir occurs in the overlying Bald Hill Claystone. | E | 1 | A | 3 | 1 | Negligible (0.00024 ML/day) seepage resulting from extraction of all LWs. | Section 10.5 of *Russell Vale Colliery Underground Expansion Project Russell Vale East Revised Groundwater Assessment* (GeoTerra / GES, 2015) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| AS 212 | AS 2 Fracturing of deeper strata | AS 21 Depressurisation of the regional groundwater system | AS 212 Reduced baseflow to streams flowing to Cataract Reservoir (Cataract Creek, Cataract River and Bellambi Creek) | | | V | Avoidance of longwall mining beneath 3rd and 4th order reaches of Cataract Creek | E | 2 | A | 3 | 2 | Drawdown of the regional aquifer is predicted to reduce baseflow to Cataract Creek, Cataract River and Bellambi Creek by 0.041 ML/day. However, the re-directed water is expected to flow to the reservoir via subterranean pathways. | Section 10.4 of *Russell Vale Colliery Underground Expansion Project Russell Vale East Revised Groundwater Assessment* (GeoTerra / GES, 2015) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |

| Identifier | Risk ... | | | | | Impact | Current controls and factors that reduce the risk | QUALITATIVE ASSESSMENT | | | | | Notes | References | Additional controls and treatments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | CE | C | L | Risk | PE | | | |
| AS 221 | AS 2 Fracturing of deeper strata | AS 22 Groundwater inflow into mine voids (primarily during a high rainfall event; note there is a time lag between the rainfall event and the consequences being seen underground) | AS 221 Increased quantity of water flowing into the mine | | | V | There is ample underground storage capacity in the mine to manage inflows. The infrastructure to return water to the catchment is largely in place. Water Access Licences will be obtained.<br>Regional groundwater currently does not contribute to the Reservoir as it is below the Reservoir level. At the location of the reservoir, the regional groundwater table is in the Bulgo Sandstone. The base of Cataract Reservoir occurs in the overlying Bald Hill Claystone. | A | 1 | A | 3 | 1 | Predicted incremental increase in mine inflows of 0.1 ML/day after extraction of LWs 1-3. The regional aquifer is below the reservoir. Therefore, this does not affect reservoir capacity except for the minor additional seepage resulting from depressurisation (0.00024 ML/day). | Section 10.7 of *Russell Vale Colliery Underground Expansion Project Russell Vale East Revised Groundwater Assessment* (GeoTerra / GES, 2015) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| **AT** | **AT Tilting** | | | | | | | | | | | | | | |
| AT 111 | AT 1 Changes to swamp water regimes | AT 11 Reduction in 'cleaning' effects | AT 111 Reduced quality of water flowing into Cataract Reservoir | | | Q | Re-design of mine plan to avoid longwall mining beneath swamps CCUS1 and CRUS3. | A | 1 | E | 5 | 1 | No observable effect would be felt. Quantum of predicted tilting will have no observable effect (max. 51 mm/m over LW3). Filtration effect would not change. Although CCUS2 will be subject to significant levels of tilt, the flow velocity in this swamp is low due to the small catchment and thefore unlikely to result in increased erosion potential.<br>Primary impact to swamps is from cracking rather than tilting. Tilting will not have an impact and it is being included here for completeness. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| AT 12 | AT 1 Changes to swamp water regimes | AT 12 Detrimental effects on swamp ecosystems | | | | E | Re-design of mine plan to avoid longwall mining beneath swamps CCUS1 and CRUS3. | A | 1 | E | 5 | 1 | No observable effect would be felt. Quantum of predicted tilting will have no observable effect (max. 51 mm/m over LW3). Filtration effect would not change.<br>Primary impact to swamps is from cracking rather than tilting. Tilting will not have an impact and it is being included here for completeness. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| AT 13 | AT 1 Changes to swamp water regimes | AT 13 Increased susceptibility to fire | | | | E | Re-design of mine plan to avoid longwall mining beneath swamps CCUS1 and CRUS3. | A | 1 | E | 5 | 1 | No observable effect would be felt. Quantum of predicted tilting will have no observable effect (max. 51 mm/m over LW3). Filtration effect would not change.<br>Primary impact to swamps is from cracking rather than tilting. Tilting will not have an impact and it is being included here for completeness. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| AT 14 | AT 1 Changes to swamp water regimes | AT 14 Reduction in base flow provided by swamp | | | | V | Re-design of mine plan to avoid longwall mining beneath swamps CCUS1 and CRUS3. | A | 1 | D | 5 | 1 | Tilting may alter the distribution of water within a swamp, but does not result in loss of runoff from the catchment. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| AT 21 | AT 2 Changes to stream water regime | AT 21 Increased pooling in streams | | | | Q | No controls. | E | 1 | D | 5 | 1 | There are no rockbar constrained pools in the upper headwaters of Cataract Creek due to the steepness of the catchment. | Section 2.2 of *Russell Vale Colliery Underground Expansion Project Preferred Project Report Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| AT 31 | AT 3 Development of knick points in swamps | AT 31 Increased susceptibility to erosion (only in sediment-based streams) | | | | Q | No controls. Knick points only develop in sediment based streams, so not applicable here. | E | 1 | D | 5 | 1 | No observable effect would be felt. Quantum of predicted tilting will have no observable effect (max. 51 mm/m over LW3). Filtration effect would not change.<br>Primary impact to swamps is from cracking rather than tilting. Tilting will not have an impact and it is being included here for completeness. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| **B** | **B Subsidence caused by mining activities in LW6-LW7** | | | | | | | | | | | | | | |
| **BH** | **BH Horizontal movements and bedding plane shear** | | | | | | | | | | | | | | |
| BH 111 | BH 1 Changes to the groundwater regime | BH 11 Increased groundwater flows into deeper strata or mine voids | BH 111 Reduced quantity of water in Cataract Reservoir | | | V | Mine design with 0.7 depth of cover offset from full supply level of Cataract Reservoir (which is well within the DSC guidelines) | B | 2 | A | 3 | 3 | Monitoring will be in place to detect abnormal flows (high or low), allowing adaptive management to adjust mining activities. Horizontal shear zones do not provide hydraulic connectivity to the mine workings. It may provide connectivity to the zone of depressurisation above the longwall panels.<br>Mine inflows take water from the regional aquifer, which is below the reservoir. The only impact on the reservoir is 0.00024 ML/day of seepage. | *LW 6 & 7 Groundwater Management Plan* (WCL, 2015)<br>Section 10.5 of *Russell Vale Colliery Underground Expansion Project Russell Vale East Revised Groundwater Assessment* (GeoTerra / GES, 2015). | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| BH 211 | BH 2 Valley closure on Cataract Creek | BH 21 Redirection of surface flow due to stream bed cracking | BH 211 Reduced quality of sub-surface diversion of streamflow re-emerging downstream in Cataract Reservoir | | | Q | Significant mining has already occurred beneath the creek, with an observable impact on current water quality. The existing water quality in the Creek is highly ferruginous and contains elevated metals.<br>Trigger Action Response Plan (TARP) requires monitoring of valley closure. To avoid impacts to Cataract Creek, extraction of the active longwall will cease if the trigger value for valley closure is exceeded.<br>LW8 was removed from the mine plan to minimise impacts on the main channel of Cataract Creek. | B | 1 | C | 4 | 1 | Primarily a localised impact downstream of each seepage point (there may be multiple seepage points), but for bulk water impact to reservoir it is negligible.<br>Incremental change in quality will not be observable.<br>This particular bedrock has not cracked from previous mining. | Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| BH 2121 | BH 2 Valley closure on Cataract Creek | BH 21 Redirection of surface flow due to stream bed cracking | BH 212 Surface flows do not re-emerge but divert into the shear plane | BH 2121 Reduced quantity of water flowing into Cataract Reservoir | | V | TARP requires monitoring of valley closure. To avoid impacts to Cataract Creek, extraction of the active longwall will cease if the trigger value for valley closure is exceeded.<br>LW8 was removed from the mine plan to minimise impacts on the main channel of Cataract Creek. | B | 2 | C | 3 | 3 | It has been assumed that all runoff in catchments overlying and upstream of longwall panels will be captured by the mine (i.e. stream flows do not re-emerge).<br>Mining of LWs 6-7 affects the catchments of Cataract Creek and Cataract River. Assuming no re-emergence of surface flow, total flow in Cataract Creek would decrease by 3.60 ML/day. Note that this is a conservative assumption that is not expected to be this magnitude - it is used as an upper bound. | Section 5 of *Russell Vale Colliery Underground Expansion Project Surface Water Modelling: Response to Planning Assessment Commission* (WRM, 2015) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| BH 213 | BH 2 Valley closure on Cataract Creek | BH 21 Redirection of surface flow due to stream bed cracking | BH 213 Increase in iron oxidation | | | E | Significant mining has already occurred beneath the creek, with an observable impact on current water quality. The existing water quality in the Creek is highly ferruginous and contains elevated metals.<br>TARP requires monitoring of valley closure. To avoid impacts to Cataract Creek, extraction of the active longwall will cease if the trigger value for valley closure is exceeded.<br>LW8 was removed from the mine plan to minimise impacts on the main channel of Cataract Creek. | B | 1 | C | 4 | 1 | Primarily a localised impact downstream of each seepage point (there may be multiple seepage points), but for bulk water impact to reservoir it is negligible<br>Incremental change in quality will not be observable.<br>The streambed has not observably cracked from previous mining. | Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not required |
| **BS** | **BS Strata dilation** | | | | | | | | | | | | | | |

| Identifier | Risk … | | | | | Impact | Current controls and factors that reduce the risk | QUALITATIVE ASSESSMENT | | | | | Notes | References | Additional controls and treatments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | CE | C | L | Risk | PE | | | |
| BS 11111 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 111 Drying of upland swamps (CCUS4, LW6 and LW7) | BS 1111 Reduction in 'cleaning' effects | BS 11111 Reduced quality of surface water flowing into Cataract Reservoir | Q | Water quality monitoring is undertaken at the base of CCUS4 (CT3A) and downstream, prior to Cataract Creek (CT3) | E | 1 | D | 5 | 1 | Mining beneath swamp CCUS4 is likely to result in fracturing of bedrock and decreased water levels within the swamp. However, monitoring of flows from CCUS4 indicate that this swamp provides negligible baseflow, with flow only after significant rainfall and ceasing within a short timeframe. Vegetation within the swamp and downstream environment will continue to provide cleaning effects, and impacts to the quality of water entering the reservoir are likely to be negligible. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>*Swamp piezometer monitoring in associated with extraction of Longwalls 4, 5 and 6 (365m)* (GeoTerra, 2015) | Not applicable |
| BS 11121 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 111 Drying of upland swamps (CCUS4, LW6 and LW7) | BS 1112 Increased susceptibility to erosion after rain | BS 11121 Reduced quality of surface water flowing into Cataract Reservoir | Q | Water quality monitoring is undertaken at the base of CCUS4 (CT3A) and downstream, prior to Cataract Creek (CT3) | E | 1 | C | 4 | 1 | Mining beneath swamp CCUS4 is likely to result in fracturing of bedrock and decreased water levels within the swamp. Drying of the sediments within the swamp may result in a small increase in the potential for erosion; however flow velocities within this swamp are low and unlikely to be sufficient to result in a significant increase in erosion potential such that the quality of water entering the reservoir would be affected. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>*Swamp piezometer monitoring in associated with extraction of Longwalls 4, 5 and 6 (365m)* (GeoTerra, 2015) | Not applicable |
| BS 1113 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 111 Drying of upland swamps (CCUS4, LW6 and LW7) | BS 1113 Detrimental effects on swamp ecosystems | | E | No controls. | E | 4 | A | 2 | 1 | Fracturing of bedrock and subsequent changes in water levels have the potential to result in changes in swamp vegetation and habitat for threatened species. Drying may result in transition of vegetation from wetter to drier swamp types through the centre/downstream extent of the swamp and increased potential for encroachment of woodland. In addition, drying of swamp sediments may reduce the suitability of this swamp for the Giant Dragonfly, resulting in loss of habitat for this species. Impacts likely at a local scale, but unlikely to affect the swamps or the Giant Dragonfly at a regional scale. Effects likely to be long-term. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Condition 4, Schedule 3 of the draft Project Approval requires offsets for any impacts to CCUS4 that are greater than negligible. |
| BS 1114 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 111 Drying of upland swamps (CCUS4, LW6 and LW7) | BS 1114 Increased susceptibility to fire | | E | No controls. | E | 2 | C | 3 | 1 | Vegetation within the upstream and outer margins of the swamp is already fire-prone. However, drying of swamp sediments and potential transition of vegetation from wetter to drier swamp types through the downstream/centre of the swamp may increase the susceptibility of these areas to fire. In addition, drying of sediments in these areas may increase the potential for fire to burn into these sediments. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Condition 4, Schedule 3 of the draft Project Approval requires offsets for any impacts to CCUS4 that are greater than negligible. |
| BS 1115 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 111 Drying of upland swamps (CCUS4, LW6 and LW7) | BS 1115 Reduction in base flow provided by swamp | | V | No controls. | E | 1 | A | 3 | 1 | Flow from this swamp occurs as a concentrated flow, with some potenial for a diffuse flow outside this flow point. CCUS4 only provides flow for short periods after rain. Maximum peak outflow of 0.1 ML/day recorded after extreme rainfall. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Sch 3, Condition 9 of the Draft DA requires an Upland Swamp Monitoring Program prepared in consultation with OEH, NOW and SCA to determine compliance with Sch 3 Condition 1 in relation to performance measures for swamps and biodiversity. Sch 3, Condition 3 provides for 'Offsets' to be required if the performance measures are exceeded. DP&E is preparing a Swamp Offsets Policy, which is currently being considered in response to public submissions to its exhibition. Once finalised, WCL will be likely be required to adhere to this Swamp Offsets Policy. |
| BS 11211 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 112 Drying of upland swamps (CCUS5, LW7) | BS 1121 Reduction in 'cleaning' effects | BS 11211 Reduced quality of surface water flowing into Cataract Reservoir | Q | LW8 was removed from mine plan and LW7 was narrowed to reduce extent of longwall mining beneath CCUS5.<br>As a result, approximately 0.51 ha (14.71%) of the swamp and 52.21% of the catchment of the swamp is located within the 200mm subsidence zone. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>A small area (0.51 ha) of CCUS5 is located within the 200mm subsidence zone, with only a small section of the swamp located above the longwall. The majority of the swamp will not experience significant subsidence.<br>Filtration effect would not change due to limited subsidence impacts on this swamp. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| BS 11221 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 112 Drying of upland swamps (CCUS5, LW7) | BS 1122 Increased susceptibility to erosion after rain | BS 11221 Reduced quality of surface water flowing into Cataract Reservoir | Q | LW8 was removed from mine plan and LW7 was narrowed to reduce extent of longwall mining beneath CCUS5.<br>As a result, approximately 0.51 ha (14.71%) of the swamp and 52.21% of the catchment of the swamp is located within the 200mm subsidence zone. | E | 1 | C | 4 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>A small area (0.51 ha) of CCUS5 is located within the 200mm subsidence zone, with only a small section of the swamp located above the longwall. The majority of the swamp will not experience significant subsidence.<br>The small area affected is unlikely to result in a significant increase in erosion potential.<br>Filtration effect would not change due to limited subsidence impacts on this swamp. | Section 4 of Coastal Upland Swamp Impact Assessment Report (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| BS 1123 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 112 Drying of upland swamps (CCUS5, LW7) | BS 1123 Detrimental effects on swamp ecosystems | | E | LW8 was removed from mine plan and LW7 was narrowed to reduce extent of longwall mining beneath CCUS5.<br>As a result, approximately 0.51 ha (14.71%) of the swamp and 52.21% of the catchment of the swamp is located within the 200mm subsidence zone. | E | 1 | C | 4 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>A small area (0.51 ha) of CCUS5 is located within the 200mm subsidence zone, with only a small section of the swamp located above the longwall. The majority of the swamp will not experience significant subsidence.<br>Given the small area affected mining is unlikely to result in significant changes in water levels within the swamp, and unlikely to impact on the species and communities reliant on this swamp. Some localised effects may occur in upstream extent. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| BS 1124 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 112 Drying of upland swamps (CCUS5, LW7) | BS 1124 Increased susceptibility to fire | | E | LW8 was removed from mine plan and LW7 was narrowed to reduce extent of longwall mining beneath CCUS5.<br>As a result, approximately 0.51 ha (14.71%) of the swamp and 52.21% of the catchment of the swamp is located within the 200mm subsidence zone. | E | 1 | C | 4 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>A small area (0.51 ha) of CCUS1 is located within the 200mm subsidence zone, with only a small section of the swamp located above the longwall. The majority of the swamp will not experience significant subsidence.<br>Given the small area affected mining is unlikely to result in significant changes in water levels within the swamp, and unlikely to result in drying of soils to the extent that this swamp would be susceptible to increased fire potential. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |

| Identifier | Risk … | | | | | Impact | Current controls and factors that reduce the risk | QUALITATIVE ASSESSMENT CE | C | L | Risk | PE | Notes | References | Additional controls and treatments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BS 1125 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 112 Drying of upland swamps (CCUS5, LW7) | BS 1125 Reduction in base flow provided by swamp | | V | LW8 was removed from mine plan and LW7 was narrowed to reduce extent of longwall mining beneath CCUS5.<br>As a result, approximately 0.51 ha (14.71%) of the swamp and 52.21% of the catchment of the swamp is located within the 200mm subsidence zone. | E | 1 | D | 5 | 1 | Flow from this swamp occurs as a diffuse flow, and is difficult to measure. Only the upstream extent of the swamp will be affected by mining, primarily dry areas; 14.7% affected (0.5 Ha); water flows not measured, but very low and similar to CCUS4; Outflows from CCUS4 have been adopted. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| BS 11311 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 113 Drying of upland swamps (CRUS1) | BS 1131 Reduction in 'cleaning' effects | BS 11311 Reduced quality of surface water flowing into Cataract Reservoir | Q | No controls.<br>Mining by LW6 has occurred beneath this swamp in the past with no observable impacts. The remaining length of LW6 is located over 225m from the margins of CRUS1. The extraction of the remaining length of LW6 is not expected to result in any further subsidence of CRUS1.<br>Mining of LW7 may result in minor additional subsidence, but the magnitude is unlikely to result in negative environmental consequences. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>Piezometric data indicates that previous mining has not resulted in changes in water levels within this swamp. Future mining will not subside either the swamp or the catchment of the swamp.<br>No change in the filtration effect will occur. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>*Swamp piezometer monitoring in associated with extraction of Longwalls 4, 5 and 6 (365m)* (GeoTerra, 2015) | Not applicable |
| BS 11321 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 113 Drying of upland swamps (CRUS1) | BS 1132 Increased susceptibility to erosion after rain | BS 11321 Reduced quality of surface water flowing into Cataract Reservoir | Q | No controls.<br>Mining by LW6 has occurred beneath this swamp in the past with no observable impacts. The remaining length of LW6 is located over 225m from the margins of CRUS1. The extraction of the remaining length of LW6 is not expected to result in any further subsidence of CRUS1.<br>Mining of LW7 may result in minor additional subsidence, but the magnitude is unlikely to result in negative environmental consequences. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>Piezometric data indicates that previous mining has not resulted in changes in water levels within this swamp. Future mining will not subside either the swamp or the catchment of the swamp.<br>Negligible potential for increased erosion of this swamp. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>*Swamp piezometer monitoring in associated with extraction of Longwalls 4, 5 and 6 (365m)* (GeoTerra, 2015) | Not applicable |
| BS 1133 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 113 Drying of upland swamps (CRUS1) | BS 1133 Detrimental effects on swamp ecosystems | | E | No controls.<br>Mining by LW6 has occurred beneath this swamp in the past with no observable impacts. The remaining length of LW6 is located over 225m from the margins of CRUS1. The extraction of the remaining length of LW6 is not expected to result in any further subsidence of CRUS1.<br>Mining of LW7 may result in minor additional subsidence, but the magnitude is unlikely to result in negative environmental consequences. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>Piezometric data indicates that previous mining has not resulted in changes in water levels within this swamp. Future mining will not subside either the swamp or the catchment of the swamp.<br>Given this, there is negligible potential for detrimental effects on swamp ecosystem. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>*Swamp piezometer monitoring in associated with extraction of Longwalls 4, 5 and 6 (365m)* (GeoTerra, 2015) | Not applicable |
| BS 1134 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 113 Drying of upland swamps (CRUS1) | BS 1134 Increased susceptibility to fire | | E | No controls.<br>Mining by LW6 has occurred beneath this swamp in the past with no observable impacts. The remaining length of LW6 is located over 225m from the margins of CRUS1. The extraction of the remaining length of LW6 is not expected to result in any further subsidence of CRUS1.<br>Mining of LW7 may result in minor additional subsidence, but the magnitude is unlikely to result in negative environmental consequences. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>Piezometric data indicates that previous mining has not resulted in changes in water levels within this swamp. Future mining will not subside either the swamp or the catchment of the swamp.<br>Given this, there is negligible likelihood of any increase in susceptibility to fire. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>*Swamp piezometer monitoring in associated with extraction of Longwalls 4, 5 and 6 (365m)* (GeoTerra, 2015) | Not applicable |
| BS 1135 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 113 Drying of upland swamps (CRUS1) | BS 1135 Reduction in base flow provided by swamp | | V | No controls.<br>Mining by LW6 has occurred beneath this swamp in the past with no observable impacts. The remaining length of LW6 is located over 225m from the margins of CRUS1. The extraction of the remaining length of LW6 is not expected to result in any further subsidence of CRUS1.<br>Mining of LW7 may result in minor additional subsidence, but the magnitude is unlikely to result in negative environmental consequences. | E | 1 | D | 5 | 1 | Flow from this swamp occurs as a diffuse flow with multiple exit points from the swamp, making measurement difficult. In addition, only a small portion of the catchment of this swamp (8.64%) is within the 200mm subsidence zone. The areas of CRUS1 that have been mined beneath are dry. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| BS 12111 | BS 1 Surface fracturing | BS 12 Fracturing of controlling rockbars | BS 121 Drying of upland swamps (CCUS4, LW6) | BS 1211 Reduction in 'cleaning' effects | BS 12111 Reduced quality of water flowing into Cataract Reservoir | Q | No controls. | E | 1 | D | 5 | 1 | There is no surface pooling behind the rockbar.<br>Filtration effect would not change as a result of fracturing of the rockbar, as it does not play a critical role in water quality. Vegetation within the swamp and downstream environment will contunue to provide cleaning effects, and impacts to the quality of water entering the reservoir are likely to be negligible. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>*Swamp piezometer monitoring in associated with extraction of Longwalls 4, 5 and 6 (365m)* (GeoTerra, 2015) | Not applicable |
| BS 12121 | BS 1 Surface fracturing | BS 12 Fracturing of controlling rockbars | BS 121 Drying of upland swamps (CCUS4, LW6) | BS 1212 Increased susceptibility to erosion after rain | BS 12121 Reduced quality of water flowing into Cataract Reservoir | Q | No controls. | E | 1 | D | 5 | 1 | There is no surface pooling behind the rockbar.<br>Filtration effect would not change.<br>The impacts will be the same as cracking beneath the swamps. Fracturing of the rockbar has the potential to result in a decrease in water retention within the swamp, and resultant drying of swamp sediments. Drying of the sediments within the swamp may result in a small increase in the potential for erosion; however flow velocities within this swamp are low and unlikely to be sufficient to result in a significant increase in erosion potential such that the quality of water entering the reservoir would be affected. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014)<br>*Swamp piezometer monitoring in associated with extraction of Longwalls 4, 5 and 6 (365m)* (GeoTerra, 2015) | Not applicable |
| BS 1213 | BS 1 Surface fracturing | BS 12 Fracturing of controlling rockbars | BS 121 Drying of upland swamps (CCUS4, LW6) | BS 1213 Detrimental effects on swamp ecosystems | | E | No controls. | E | 4 | A | 2 | 1 | Fracturing of the rockbar has the potential to result in a decrease in water retention within the swamp, and resultant drying of the swamp sediments. Drying may result in transition of vegetation from wetter to drier swamp types through the centre/downstream extent of the swamp and increased potential for encroachment of woodland. In addition, drying of swamp sediments may reduce the suitability of this swamp for the Giant Dragonfly, resulting in loss of habitat for this species. Impacts are likely at a local scale, but unlikely to affect the swamps or the Giant Dragonfly at a regional scale. Effects are likely to be long-term. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Condition 4, Schedule 3 of the draft Project Approval requires offsets for any impacts to CCUS4 that are greater than negligible. |
| BS 1214 | BS 1 Surface fracturing | BS 12 Fracturing of controlling rockbars | BS 121 Drying of upland swamps (CCUS4, LW6) | BS 1214 Increased susceptibility to fire | | E | No controls. | E | 2 | C | 3 | 1 | Vegetation within the upstream and outer margins of the swamp is already fire-prone. However, drying of swamp sediments and potential transition of vegtetation from wetter to drier swamp types through the downstream/centre of the swamp may increase the susceptibility of these areas to fire. In addition, drying of sediments in these areas may increase the potential for fire to burn into these sediments. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Condition 4, Schedule 3 of the draft Project Approval requires offsets for any impacts to CCUS4 that are greater than negligible. |

| Identifier | Risk … | | | | | Impact | Current controls and factors that reduce the risk | QUALITATIVE ASSESSMENT | | | | | Notes | References | Additional controls and treatments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | CE | C | L | Risk | PE | | | |
| BS 131 | BS 1 Surface fracturing | BS 13 Iron oxide staining | BS 131 Reduced quality of water flowing into Cataract Reservoir | | | Q | Significant mining has already occurred beneath the creek, with an observable impact on current water quality. The existing water quality in the Creek is highly ferruginous and contains elevated metals.<br>TARP requires monitoring of valley closure. To avoid impacts to Cataract Creek, extraction of the active longwall will cease if the trigger value for valley closure is exceeded.<br>LW8 was removed from the mine plan to minimise impacts on the main channel of Cataract Creek. | E | 1 | A | **3** | 1 | Primarily a localised impact downstream of each seepage point (there may be multiple seepage points), but for bulk water impact to reservoir it is negligible.<br>Incremental change in quality will not be observable. | Section 9.2 of *End of Longwall 4 & Longwall 5 Groundwater & Surface Water Monitoring Assessment* (GeoTerra, 2014) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| BS 211 | BS 2 Fracturing of deeper strata | BS 21 Depressurisation of the regional groundwater system | BS 211 Seepage of water from Cataract Reservoir to the underlying regional aquifer | | | V | Regional groundwater currently does not contribute to the Reservoir as it is below the Reservoir level. At the location of the reservoir, the regional groundwater table is in the Bulgo Sandstone. The base of Cataract Reservoir occurs in the overlying Bald Hill Claystone. | E | 1 | A | **3** | 1 | Negligible (0.00024 ML/day) seepage resulting from extraction of all LWs. | Section 10.5 of *Russell Vale Colliery Underground Expansion Project Russell Vale East Revised Groundwater Assessment* (GeoTerra / GES, 2015) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| BS 212 | BS 2 Fracturing of deeper strata | BS 21 Depressurisation of the regional groundwater system | BS 212 Reduced baseflow to streams flowing to Cataract Reservoir (Cataract Creek, Cataract River and Bellambi Creek) | | | V | Avoidance of longwall mining beneath 3rd and 4th order reaches of Cataract Creek | E | 2 | A | **3** | 2 | Drawdown of the regional aquifer is predicted to reduce baseflow to Cataract Creek, Cataract River and Bellambi Creek by 0.041 ML/day. However, the re-directed water is expected to flow to the reservoir via subterranean pathways. | Section 10.4 of *Russell Vale Colliery Underground Expansion Project Russell Vale East Revised Groundwater Assessment* (GeoTerra / GES, 2015) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| BS 221 | BS 2 Fracturing of deeper strata | BS 22 Groundwater inflow into mine voids | BS 221 Increased quantity of water flowing into the mine | | | V | There is ample underground storage capacity in the mine to manage inflows. The infrastructure to return water to the catchment is largely in place. Water Access Licences will be obtained.<br>Regional groundwater currently does not contribute to the Reservoir as it is below the Reservoir level. At the location of the reservoir, the regional groundwater table is in the Bulgo Sandstone. The base of Cataract Reservoir occurs in the overlying Bald Hill Claystone. | B | 1 | A | **3** | 1 | Predicted incremental increase to mine inflows of 1.0 ML/day after extraction of LWs 6-7. The regional aquifer is below the reservoir. Therefore, this does not affect reservoir capacity except for the minor additional seepage resulting from depressurisation (0.00024 ML/day). | Section 10.7 of *Russell Vale Colliery Underground Expansion Project Russell Vale East Revised Groundwater Assessment* (GeoTerra / GES, 2015) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. Additionally, as per DSC requirements dated 26 March, 2015 "The presence or absence of the Corrimal Fault will be proved by the development of MG7 first workings. If the Fault is intercepted then the DSC will not recommend approval of the western end of LW7 and will request that the longwall be set back from the Fault, leaving a hydraulic barrier of solid coal against the fault for protection against ingress. If the Corrimal Fault is absent from LW7, the DSC has no concerns with the extraction of LW7 regarding this fault." This requirement will be added to the UEP's Statement of Commitment (SOC). |
| BS 23 | BS 2 Fracturing of deeper strata | BS 23 Hydraulic connectivity associated with the Corrimal Fault (LW6-LW7) | | | | V | There is not considered to be a credible risk of elevated inflows via the Corrimal Fault. Nevertheless, WCL has developed a plan to manage inflows. | B | 2 | D | **4** | 2 | The Corrimal Fault does not provide hydraulic connectivity; there are no credible mechanisms for this to occur. The nearest goaf (LW7) is 540 m from the FSL of Cataract Reservoir along the projection of the fault and the throw of the fault is less than 1 m at this location at a depth below surface of 305 m. | *Response to Galvin and Associates Pty Ltd Report dated 3 March 2015* (SCT, 2015); *Review of Barrier to Protect Stored Waters of Cataract Reservoir* (SCT, 2015): and *Assessment of Corrimal Fault and Dyke D8 at Russell Vale East as Risks to the Stored Waters of Cataract Reservoir* (SCT, 2015). | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. Additionally, as per DSC requirements dated 26 March, 2015 "The presence or absence of the Corrimal Fault will be proved by the development of MG7 first workings. If the Fault is intercepted then the DSC will not recommend approval of the western end of LW7 and will request that the longwall be set back from the Fault, leaving a hydraulic barrier of solid coal against the fault for protection against ingress. If the Corrimal Fault is absent from LW7, the DSC has no concerns with the extraction of LW7 regarding this fault." This requirement will be added to the UEP's Statement of Commitment (SOC). |
| BS 24 | BS 2 Fracturing of deeper strata | BS 24 Hydraulic connectivity associated with D8 Dyke (LW6-LW7) | | | | V | There is not considered to be a credible risk of elevated inflows via Dyke D8. Nevertheless, WCL has developed a plan to manage inflows. | B | 2 | D | **4** | 2 | Dyke D8 does not provide a credible pathway for inflow from the reservoir to the mine workings. The dyke is present below the reservoir but the point where the dyke intersects the edge of Cataract Reservoir is 1.7km west of the nearest goaf intersection (LW7) at a depth of 330 m below surface. Previous intersections closer to the reservoir do not indicate any intersection. Mining is not expected to cause any change in the hydraulic conductivity of the dyke adjacent to the reservoir. | *Response to Galvin and Associates Pty Ltd Report dated 3 March 2015* (SCT, 2015); *Review of Barrier to Protect Stored Waters of Cataract Reservoir* (SCT, 2015): and *Assessment of Corrimal Fault and Dyke D8 at Russell Vale East as Risks to the Stored Waters of Cataract Reservoir* (SCT, 2015). | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. Additionally, as per DSC requirements dated 26 March, 2015 "The presence or absence of the Corrimal Fault will be proved by the development of MG7 first workings. If the Fault is intercepted then the DSC will not recommend approval of the western end of LW7 and will request that the longwall be set back from the Fault, leaving a hydraulic barrier of solid coal against the fault for protection against ingress. If the Corrimal Fault is absent from LW7, the DSC has no concerns with the extraction of LW7 regarding this fault." This requirement will be added to the UEP's Statement of Commitment (SOC). |
| BS 25 | BS 2 Fracturing of deeper strata | BS 25 Additional fracturing associated with Bulli Seam pillar instability (LW7), resulting in hydraulic connectivity | | | | V | Lateral setback from Cataract Reservoir (0.7 times depth) for Wongawilli seam workings | B | 2 | D | **4** | 2 | The Bulli Seam pillars near Cataract Reservoir have large width to height ratios (ranging from 5 to 14). For large pillars, load bearing capacity is a function of frictional resistance rather than cohesive strength of the coal. Large pillars will compress (rather than collapse) when loaded beyond their load capacity. The large pillars in the Bulli Seam are expected to increase in strength as they compress. | Section 5.5 of *Response to Galvin and Associates Pty Ltd Report dated 3 March 2015* (SCT, 2015)<br>Section 1 of *Response to Residual Matters from Independent Risk Assessment Panel Comments (SCT, 2015)* | Not applicable |
| **BT** | **BT Tilting** | | | | | | | | | | | | | | |

| Identifier | Risk … | | | | | Impact | Current controls and factors that reduce the risk | QUALITATIVE ASSESSMENT | | | | | Notes | References | Additional controls and treatments |
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| | | | | | | | | CE | C | L | Risk | PE | | | |
| BT 111 | BT 1 Changes to swamp water regimes | BT 11 Reduction in 'cleaning' effects | BT 111 Reduced quality of water flowing into Cataract Reservoir | | | Q | LW8 was removed from mine plan and LW7 was narrowed to reduce the extent of longwall mining beneath CCUS5.<br>Mining by LW6 has occurred beneath CRUS1 in the past with no observable impacts. Future mining will not occur beneath or within the catchment of this swamp, and no further impacts are anticipated. | A | 1 | D | 5 | 1 | No observable effect would be felt. Quantum of predicted tilting will have no observable effect (max. 38 mm/m over LW6).<br>Filtration effect would not change.<br>Primary impact to swamps is from cracking rather than tilting.<br>Tilting will not have a significant impact on these swamps and it is being included here for completeness. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| BT 121 | BT 1 Changes to swamp water regimes | BT 12 Detrimental effects on swamp ecosystems | BT 121 Detrimental effects on CCUS4 | | | E | No controls. | A | 2 | C | 3 | 1 | Flow accumulation modelling indicates a small (4.77%) overall decline in in-flows through the swamp. Re-distribution of water will result in increased flows through the western section of this upland swamp, including vegetation reliant on waterlogging, and decreases in the eastern section, in areas supporting vegetation communities not reliant on waterlogging. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Condition 4, Schedule 3 of the draft Project Approval requires offsets for any impacts to CCUS4 that are greater than negligible. |
| BT 122 | BT 1 Changes to swamp water regimes | BT 12 Detrimental effects on swamp ecosystems | BT 122 Detrimental effects on swamps other than CCUS4 | | | E | No controls. | A | 1 | D | 5 | 1 | No observable effect would be felt. Quantum of predicted tilting will have no observable effect (max. 38 mm/m over LW6).<br>Filtration effect would not change.<br>Primary impact to swamps is from cracking rather than tilting.<br>Tilting will not have a significant impact on these swamps and it is being included here for completeness. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| BT 13 | BT 1 Changes to swamp water regimes | BT 13 Increased susceptibility to fire | | | | E | No controls. | A | 1 | D | 5 | 1 | No observable effect would be felt. Quantum of predicted tilting will have no observable effect (max. 38 mm/m over LW6).<br>Filtration effect would not change.<br>Primary impact to swamps is from cracking rather than tilting.<br>Tilting will not have a significant impact on these swamps and it is being included here for completeness. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| BT 21 | BT 2 Changes to stream water regime | BT 21 Increased erosion downstream | | | | Q | No controls. | E | 1 | D | 5 | 1 | No observable effect would be felt as tilting in the stream bed is predicted to be minimal. Quantum of predicted tilting will have no observable effect (max. 38 mm/m over LW6).<br>Filtration effect would not change.<br>Primary impact to streams is from cracking rather than tilting.<br>Tilting will not have an impact as the stream bed comprises boulders, sand and exposed bedrock. | | Not applicable |
| BT 22 | BT 2 Changes to stream water regime | BT 22 Increased pooling in streams | | | | Q | No controls. | E | 1 | D | 5 | 1 | No adverse effects on stream flow continuity or stream ponding due to previous mining activities have been observed. No mining induced cracking or compressional buckling of rock bars, or loss of pool holding capacity has been observed to date. | Section 2.2 of *Russell Vale Colliery Underground Expansion Project Preferred Project Report Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| BT 31 | BT 3 Development of knick points in swamps | BT 31 Increased susceptibility to erosion | | | | Q | No controls. Knick points only happen in sediment based streams, so not applicable here. | E | 1 | D | 5 | 1 | No observable effect would be felt. Quantum of predicted tilting will have no observable effect (max. 38 mm/m over LW6).<br>Given the small catchment for swamps in this area, flow velocities are unlikely to be sufficient to increase erosion potential.<br>Primary impact to swamps is from cracking rather than tilting.<br>Tilting will not have an impact and it is being included here for completeness. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| **C** | **C Subsidence caused by mining activities in LW9-LW11** | | | | | | | | | | | | | | |
| **CH** | **CH Horizontal movements and bedding plane shear** | | | | | | | | | | | | | | |
| CH 111 | CH 1 Changes to the groundwater regime | CH 11 Increased groundwater flows into fractured strata or mine voids | CH 111 Reduced quantity of water flowing into Cataract Reservoir | | | V | The mine design has adopted relatively narrow longwall panels and maintained an offset from Cataract Reservoir of at least 0.7 times the depth of cover. This offset is consistent with the DSC guidelines | B | 1 | A | 3 | 1 | Monitoring will be in place to detect abnormal flows (high or low), allowing adaptive management intervention to adjust mining activities; water flows modelled.<br>Horizontal shear zones do not provide hydraulic connectivity to the mine workings. It may provide connectivity to the zone of depressurisation above the longwall panels.<br>Mine inflows take water from the regional aquifer, which is below the reservoir. The only impact on the reservoir is 0.00024 ML/day of seepage. | *LW 6 & 7 Groundwater Management Plan* (WCL, 2015)<br>Section 10.7 of *Russell Vale Colliery Underground Expansion Project Russell Vale East Revised Groundwater Assessment* (GeoTerra / GES, 2015). | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| CH 211 | CH 2 Valley closure on Cataract Creek | CH 21 Redirection of surface flow due to stream bed cracking | CH 211 Reduced quality of sub-surface diversion of streamflow re-emerging downstream into Cataract reservoir | | | Q | Significant mining has already occurred beneath the creek, with an observable impact on current water quality. The existing water quality in the creek is highly ferruginous and contains elevated metals.<br>TARP requires monitoring of valley closure. To avoid impacts to Cataract Creek, extraction of the active longwall will cease if the trigger value for valley closure is exceeded. | B | 1 | C | 4 | 1 | Primarily a localised impact downstream of each seepage point (there may be multiple seepage points), but for bulk water impact to reservoir it is negligible.<br>Incremental change in quality will not be observable.<br>This particular creek bedrock has not cracked from previous mining. | Section 9.2 of *End of Longwall 4 & Longwall 5 Groundwater & Surface Water Monitoring Assessment* (GeoTerra, 2014) | Not applicable |
| CH 2121 | CH 2 Valley closure on Cataract Creek | CH 21 Redirection of surface flow due to stream bed cracking | CH 212 Surface flows do not re-emerge | CH 2121 Reduced quantity of water flowing into Cataract Reservoir | | V | TARP requires monitoring of valley closure. To avoid impacts to Cataract Creek, extraction of the active longwall will cease if the trigger value for valley closure is exceeded. | B | 2 | C | 3 | 3 | The worst case is that all runoff in catchments overlying and upstream of longwall panels will be captured by the mine (i.e. stream flows do not re-emerge).<br>Mining of LWs 9-11 affects the catchments of Cataract Creek, Cataract River and Bellambi Creek. Assuming that surface flows do not re-emerge, flow to these streams is predicted to decrease by 1.39 ML/day. Note that this is a conservative assumption that is not expected to be this magnitude - it is used as an upper bound. | Section 5 of *Russell Vale Colliery Underground Expansion Project Surface Water Modelling: Response to Planning Assessment Commission* (WRM, 2015) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| **CS** | **CS Strata dilation** | | | | | | | | | | | | | | |
| CS 11111 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 111 Drying of upland swamps (CCUS10, LW9) | CS 1111 Reduction in 'cleaning' effects | CS 11111 Reduced quality of surface water flowing into Cataract Reservoir | Q | LW 9 was re-aligned to reduce secondary extraction beneath CCUS10.<br>As a result, approximately 0.16 ha (9.99%) of the swamp and 45.80% of the catchment of the swamp is located within the 200mm subsidence zone. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>A small area (0.16ha) of CCUS10 is located within the 200mm subsidence zone, with only a small section of the swamp located above the longwall. The majority of the swamp will not be subsided.<br>Filtration effect would not change due to limited subsidence impacts on this swamp. | Section 4 of Coastal Upland Swamp Impact Assessment Report (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| CS 11121 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 111 Drying of upland swamps (CCUS10, LW9) | CS 1112 Increased susceptibility to erosion after rain | CS 11121 Reduced quality of surface water flowing into Cataract Reservoir | Q | LW 9 was re-aligned to reduce secondary extraction beneath CCUS10.<br>As a result, approximately 0.16 ha (9.99%) of the swamp and 45.80% of the catchment of the swamp is located within the 200mm subsidence zone. | E | 1 | C | 4 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>A small area (0.16ha) of CCUS10 is located within the 200mm subsidence zone, with only a small section of the swamp located above the longwall. The majority of the swamp will not be subsided.<br>The small area affected is unlikely to result in a significant increase in erosion potential.<br>Filtration effect would not change due to limited subsidence impacts on this swamp. | Section 4 of Coastal Upland Swamp Impact Assessment Report (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |

| Identifier | Risk … | | | | | Impact | Current controls and factors that reduce the risk | QUALITATIVE ASSESSMENT | | | | | Notes | References | Additional controls and treatments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | CE | C | L | Risk | PE | | | |
| CS 1113 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 111 Drying of upland swamps (CCUS10, LW9) | CS 1113 Detrimental effects on swamp ecosystems | | E | LW 9 was re-aligned to reduce secondary extraction beneath CCUS10.<br>As a result, approximately 0.16 ha (9.99%) of the swamp and 45.80% of the catchment of the swamp is located within the 200mm subsidence zone. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>A small area (0.16ha) of CCUS10 is located within the 200mm subsidence zone, with only a small section of the swamp located above the longwall. The majority of the swamp will not be subsided.<br>Given the small area affected mining is unlikely to result in significant changes in water levels within the swamp, and unlikely to impact on the species and communities reliant on this swamp. Some localised effects may occur in upstream extent. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| CS 1114 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 111 Drying of upland swamps (CCUS10, LW9) | CS 1114 Increased susceptibility to fire | | E | LW 9 was re-aligned to reduce secondary extraction beneath CCUS10.<br>As a result, approximately 0.16 ha (9.99%) of the swamp and 45.80% of the catchment of the swamp is located within the 200mm subsidence zone. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>A small area (0.16ha) of CCUS10 is located within the 200mm subsidence zone, with only a small section of the swamp located above the longwall. The majority of the swamp will not be subsided.<br>Given the small area affected mining is unlikely to result in significant changes in water levels within the swamp, and unlikely to result in drying of soils to the extent that this swamp would be susceptible to increased fire potential. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| CS 11211 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 112 Drying of upland swamps (CCUS11, LW9) | CS 1121 Reduction in 'cleaning' effects | CS 11211 Reduced quality of surface water flowing into Cataract Reservoir | Q | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CCUS11 is a small swamp (0.34 ha) with a small catchment (1.18ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out as a result of fracturing of bedrock.<br>Filtration effect would not change due to limited current levels of filtration and small in-flows and out-flow. | Section 4 of Coastal Upland Swamp Impact Assessment Report (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| CS 11221 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 112 Drying of upland swamps (CCUS11, LW9) | CS 1122 Increased susceptibility to erosion after rain | CS 11221 Reduced quality of surface water flowing into Cataract Reservoir | Q | No controls. | E | 1 | C | 4 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CCUS11 is a small swamp (0.34 ha) with a small catchment (1.18ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out as a result of fracturing of bedrock. Given the small catchment area, flow velocity is unlikely to be sufficient to result in an increase in erosion potential.<br>Filtration effect would not change due to limited current levels of filtration and small in-flows and out-flow. | Section 4 of Coastal Upland Swamp Impact Assessment Report (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| CS 1123 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 112 Drying of upland swamps (CCUS11, LW9) | CS 1123 Detrimental effects on swamp ecosystems | | E | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CCUS11 is a small swamp (0.34 ha) with a small catchment (1.18ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out as a result of fracturing of bedrock. As a result, impacts to the swamp ecosystem are unlikely to occur to this dry swamp. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| CS 1124 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 112 Drying of upland swamps (CCUS11, LW9) | CS 1124 Increased susceptibility to fire | | E | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CCUS11 is a small swamp (0.34 ha) with a small catchment (1.18ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out further as a result of fracturing of bedrock. In addition, vegetation within this swamp is already "fire prone". Swamp sediments are not at increased risk of fire. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| CS 11311 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 113 Drying of upland swamps (CCUS12, LW9 and LW10) | CS 1131 Reduction in 'cleaning' effects | CS 11311 Reduced quality of surface water flowing into Cataract Reservoir | Q | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CCUS12 is a relatively small swamp (1.84 ha) with a small catchment (3.49ha). Piezometer indicate that the upper section of the swamp is dry, whilst the lower sections support a perched water table, with water rising to near surface levels following rainfall.<br>Filtration effect would not change due to limited current levels of filtration and small in-flows and out-flow. | Section 4 of Coastal Upland Swamp Impact Assessment Report (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| CS 11321 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 113 Drying of upland swamps (CCUS12, LW9 and LW10) | CS 1132 Increased susceptibility to erosion after rain | CS 11321 Reduced quality of surface water flowing into Cataract Reservoir | Q | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CCUS12 is a relatively small swamp (1.84 ha) with a small catchment (3.49ha). Piezometer indicate that the upper section of the swamp is dry, whilst the lower sections support a perched water table, with water rising to near surface levels following rainfall.<br>Given the small catchment area, flow velocity is unlikely to be sufficient to result in an increase in erosion potential.<br>Filtration effect would not change due to limited current levels of filtration and small in-flows and out-flow. | Section 4 of Coastal Upland Swamp Impact Assessment Report (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |

| Identifier | Risk ... | | | | | Impact | Current controls and factors that reduce the risk | QUALITATIVE ASSESSMENT CE | C | L | Risk | PE | Notes | References | Additional controls and treatments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CS 1133 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 113 Drying of upland swamps (CCUS12, LW9 and LW10) | CS 1133 Detrimental effects on swamp ecosystems | | E | No controls. | E | 1 | C | 4 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CCUS12 is a relatively small swamp (1.84 ha) with a small catchment (3.49ha). Piezometer indicate that the upper section of the swamp is dry, whilst the lower sections support a perched water table, with water rising to near surface levels following rainfall.<br>Whilst mining may result in some drying within this swamp, the swamp does not support ecological features reliant on a perched water table, and therefore the consequence of any drying is deemed low. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| CS 1134 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 113 Drying of upland swamps (CCUS12, LW9 and LW10) | CS 1134 Increased susceptibility to fire | | E | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CCUS12 is a relatively small swamp (1.84 ha) with a small catchment (3.49ha). Piezometer indicate that the upper section of the swamp is dry, whilst the lower sections support a perched water table, with water rising to near surface levels following rainfall.<br>Whilst some drying may occur, vegetation within this swamp is already "fire prone". Swamp sediments are not at increased risk of fire. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| CS 11411 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 114 Drying of upland swamps (CCUS24, LW9) | CS 1141 Reduction in 'cleaning' effects | CS 11411 Reduced quality of surface water flowing into Cataract Reservoir | Q | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CCUS24 is a very small swamp (0.08ha) with a very small catchment (0.54ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out as a result of fracturing of bedrock.<br>Filtration effect would not change due to limited current levels of filtration and small in-flows and out-flow. | Section 3.3 of *Underground Expansion Project Independent Risk Assessment - Addendum Report* (Biosis, 2015) | Not applicable |
| CS 11421 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 114 Drying of upland swamps (CCUS24, LW9) | CS 1142 Increased susceptibility to erosion after rain | CS 11421 Reduced quality of surface water flowing into Cataract Reservoir | Q | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CCUS24 is a very small swamp (0.08ha) with a very small catchment (0.54ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out as a result of fracturing of bedrock.<br>Given the small catchment area, flow velocity is unlikely to be sufficient to result in an increase in erosion potential.<br>Filtration effect would not change due to limited current levels of filtration and small in-flows and out-flow. | Section 3.3 of *Underground Expansion Project Independent Risk Assessment - Addendum Report* (Biosis, 2015) | Not applicable |
| CS 1143 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 114 Drying of upland swamps (CCUS24, LW9) | CS 1143 Detrimental effects on swamp ecosystems | | E | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CCUS24 is a very small swamp (0.08ha) with a very small catchment (0.54ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out as a result of fracturing of bedrock. As a result, impacts to the swamp ecosystem are unlikely to occur to this dry swamp. | Section 3.3 of *Underground Expansion Project Independent Risk Assessment - Addendum Report* (Biosis, 2015) | Not applicable |
| CS 1144 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 114 Drying of upland swamps (CCUS24, LW9) | CS 1144 Increased susceptibility to fire | | E | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CCUS24 is a very small swamp (0.08ha) with a very small catchment (0.54ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out further as a result of fracturing of bedrock. In addition, vegetation within this swamp is already "fire prone". Swamp sediments are not at increased risk of fire. | Section 3.3 of *Underground Expansion Project Independent Risk Assessment - Addendum Report* (Biosis, 2015) | Not applicable |
| CS 11511 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 115 Drying of upland swamps (BCUS4, LW10) | CS 1151 Reduction in 'cleaning' effects | CS 11511 Reduced quality of surface water flowing into Cataract Reservoir | Q | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>1.14ha (51.38%) of this swamp and 80.81% of the catchment of the swamp are located within the 200mm subsidence zone, with only a small section of the swamp located above the longwall.<br>Vegetation within the swamp and downstream environment will contunue to provide cleaning effects, and impacts to the quality of water entering the reservoir are likely to be negligible. | Section 4 of Coastal Upland Swamp Impact Assessment Report (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| CS 11521 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 115 Drying of upland swamps (BCUS4, LW10) | CS 1152 Increased susceptibility to erosion after rain | CS 11521 Reduced quality of surface water flowing into Cataract Reservoir | Q | No controls. | E | 1 | C | 4 | 1 | Mining beneath swamp BCUS4, likely to result in tilts and strains of sufficient magnitude to result in fracturing, will be restricted to a small upper section of this upland swamp, and is unlikely to result in broader impacts to this upland swamp. Drying of the sediments within the swamp may result in a small increase in the potential for erosion; however flow velocities within this swamp are low and unlikely to be sufficient to result in a significant increase in erosion potential such that the quality of water entering the reservoir would be affected. | Section 4 of Coastal Upland Swamp Impact Assessment Report (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |

| Identifier | Risk ... | | | | | Impact | Current controls and factors that reduce the risk | QUALITATIVE ASSESSMENT CE | C | L | Risk | PE | Notes | References | Additional controls and treatments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CS 1153 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 115 Drying of upland swamps (BCUS4, LW10) | CS 1153 Detrimental effects on swamp ecosystems | | E | No controls. | E | 2 | C | 3 | 1 | Whilst subsidence of sufficient magnitude to result in fracturing may occur, it will be restricted to a small upper section of this upland swamp, and is unlikely to result in broader impacts to this upland swamp. In these areas, changes in groundwater levels may result in drying of the swamp; however, these areas are dominated by vegetation that is not reliant on a perched water table. Given the small area affected by mining, it is unlikely to significantly impact on the species and communities reliant on this swamp. Some localised effects may occur in upstream extent. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Sch 3, Condition 9 of the Draft DA requires an Upland Swamp Monitoring Program prepared in consultation with OEH, NOW and SCA to determine compliance with Sch 3 Condition 1 in relation to performance measures for swamps and biodiversity. Sch 3, Condition 3 provides for 'Offsets' to be required if the performance measures are exceeded. DP&E is preparing a Swamp Offsets Policy, which is currently being considered in response to public submissions to its exhibition. Once finalised, WCL will be likely be required to adhere to this Swamp Offsets Policy. |
| CS 1154 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 115 Drying of upland swamps (BCUS4, LW10) | CS 1154 Increased susceptibility to fire | | E | No controls. | E | 2 | C | 3 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>1.14ha (51.38%) of this swamp and 80.81% of the catchment of the swamp are located within the 200mm subsidence zone, with only a small section of the swamp located above the longwall. The majority of the swamp will not be subsided.<br>Vegetation within the areas that may see some drying is already fire-prone. Wetter sediments and vegetation reliant on a perched water table are unlikely to be subject to fracturing and drying. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Sch 3, Condition 9 of the Draft DA requires an Upland Swamp Monitoring Program prepared in consultation with OEH, NOW and SCA to determine compliance with Sch 3 Condition 1 in relation to performance measures for swamps and biodiversity. Sch 3, Condition 3 provides for 'Offsets' to be required if the performance measures are exceeded. DP&E is preparing a Swamp Offsets Policy, which is currently being considered in response to public submissions to its exhibition. Once finalised, WCL will be likely be required to adhere to this Swamp Offsets Policy. |
| CS 1155 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 115 Drying of upland swamps (BCUS4, LW10) | CS 1155 Reduction in base flow provided by swamp | | V | No controls. | B | 1 | A | 3 | 1 | Flow from this swamp occurs as a diffuse flow, and is difficult to measure. Whilst only the upstream extent of the swamp will be affected by mining, and these areas are primarily dry areas, there is some potential for a small reduction in baseflow. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Sch 3, Condition 9 of the Draft DA requires an Upland Swamp Monitoring Program prepared in consultation with OEH, NOW and SCA to determine compliance with Sch 3 Condition 1 in relation to performance measures for swamps and biodiversity. Sch 3, Condition 3 provides for 'Offsets' to be required if the performance measures are exceeded. DP&E is preparing a Swamp Offsets Policy, which is currently being considered in response to public submissions to its exhibition. Once finalised, WCL will be likely be required to adhere to this Swamp Offsets Policy. |
| CS 11611 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 116 Drying of upland swamps (BCUS11, LW10) | CS 1161 Reduction in 'cleaning' effects | CS 11611 Reduced quality of surface water flowing into Cataract Reservoir | Q | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>BCUS11 is a very small swamp (0.26ha) with a very small catchment (1.14ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out as a result of fracturing of bedrock.<br>Filtration effect would not change due to limited current levels of filtration and small in-flows and out-flow. | Section 4 of Coastal Upland Swamp Impact Assessment Report (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| CS 11621 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 116 Drying of upland swamps (BCUS11, LW10) | CS 1162 Increased susceptibility to erosion after rain | CS 11621 Reduced quality of surface water flowing into Cataract Reservoir | Q | No controls. | E | 1 | C | 4 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>BCUS11 is a very small swamp (0.26ha) with a very small catchment (1.14ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out as a result of fracturing of bedrock.<br>Given the small catchment area, flow velocity is unlikely to be sufficient to result in an increase in erosion potential.<br>Filtration effect would not change due to limited current levels of filtration and small in-flows and out-flow. | Section 4 of Coastal Upland Swamp Impact Assessment Report (Biosis, 2014)<br>Section 4 of *Russell Vale Colliery Underground Expansion Project Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| CS 1163 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 116 Drying of upland swamps (BCUS11, LW10) | CS 1163 Detrimental effects on swamp ecosystems | | E | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>BCUS11 is a very small swamp (0.26ha) with a very small catchment (1.14ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out as a result of fracturing of bedrock. As a result, impacts to the swamp ecosystem are unlikely to occur to this dry swamp. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| CS 1164 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 116 Drying of upland swamps (BCUS11, LW10) | CS 1164 Increased susceptibility to fire | | E | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>BCUS11 is a very small swamp (0.26ha) with a very small catchment (1.14ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out as a result of fracturing of bedrock. In addition, vegetation within this swamp is already "fire prone". Swamp sediments are not at increased risk of fire. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| CS 11711 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 117 Drying of upland swamps (CRUS6, LW11) | CS 1171 Reduction in 'cleaning' effects | CS 11711 Reduced quality of surface water flowing into Cataract Reservoir | Q | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CRUS6 is a very small swamp (0.49ha) with a very small catchment (2.99ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out as a result of fracturing of bedrock.<br>Filtration effects would not change due to limited current levels of filtration and small in-flows and out-flow. | Section 3.3 of *Underground Expansion Project Independent Risk Assessment - Addendum Report* (Biosis, 2015) | Not applicable |

| Identifier | Risk ... | | | | | Impact | Current controls and factors that reduce the risk | QUALITATIVE ASSESSMENT | | | | | Notes | References | Additional controls and treatments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | CE | C | L | Risk | PE | | | |
| CS 11721 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 117 Drying of upland swamps (CRUS6, LW11) | CS 1172 Increased susceptibility to erosion after rain | CS 11721 Reduced quality of surface water flowing into Cataract Reservoir | Q | No controls. | E | 1 | C | 4 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CRUS6 is a very small swamp (0.49ha) with a very small catchment (2.99ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out as a result of fracturing of bedrock.<br>Given the small catchment area, flow velocity is unlikely to be sufficient to result in an increase in erosion potential.<br>Filtration effects would not change due to limited current levels of filtration and small in-flows and out-flow. | Section 3.3 of *Underground Expansion Project Independent Risk Assessment - Addendum Report* (Biosis, 2015) | Not applicable |
| CS 1173 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 117 Drying of upland swamps (CRUS6, LW11) | CS 1173 Detrimental effects on swamp ecosystems | | E | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CRUS6 is a very small swamp (0.49ha) with a very small catchment (2.99ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out as a result of fracturing of bedrock. As a result, impacts to the swamp ecosystem are unlikely to occur to this dry swamp. | Section 3.3 of *Underground Expansion Project Independent Risk Assessment - Addendum Report* (Biosis, 2015) | Not applicable |
| CS 1174 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 117 Drying of upland swamps (CRUS6, LW11) | CS 1174 Increased susceptibility to fire | | E | No controls. | E | 1 | D | 5 | 1 | Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl).<br>CRUS6 is a very small swamp (0.49ha) with a very small catchment (2.99ha). As a result, this swamp does not support a significant perched water table, and is unlikely to dry out as a result of fracturing of bedrock. In addition, vegetation within this swamp is already "fire prone". Swamp sediments are not at increased risk of fire. | Section 3.3 of *Underground Expansion Project Independent Risk Assessment - Addendum Report* (Biosis, 2015) | Not applicable |
| CS 121 | CS 1 Surface fracturing | CS 12 Iron oxide staining | CS 121 Reduced quality of water flowing into Cataract Reservoir | | | Q | Significant mining has already occurred beneath the creek, with an observable impact on current water quality. Existing water quality in the creek is highly ferruginous and contains elevated metals.<br>TARP requires monitoring of valley closure. To avoid impacts to Cataract Creek, extraction of the active longwall will cease if the trigger value for valley closure is exceeded. | E | 1 | A | 3 | 1 | Primarily a localised impact downstream of each seepage point (there may be multiple seepage points, but for bulk water impact to reservoir it is negligible. High localised effect. Very steep, little drainage. Incremental change in quality will not be observable.<br>This particular area has only had mining occurring beneath it once before (Bulli workings) so levels are probably slightly higher than for LW6-LW7 (which have twice had mining occurring beneath it), but not above the "negligible" level. | Section 9.2 of *End of Longwall 4 & Longwall 5 Groundwater & Surface Water Monitoring Assessment* (GeoTerra, 2014) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| CS 211 | CS 2 Fracturing of deeper strata | CS 21 Depressurisation of regional groundwater system | CS 211 Seepage of water from Cataract Reservoir into the underlying regional aquifer | | | V | Regional groundwater currently does not contribute to the Reservoir as it is below the Reservoir level. At the location of the reservoir, the regional groundwater table is in the Bulgo Sandstone. The base of Cataract Reservoir occurs in the overlying Bald Hill Claystone. | E | 1 | A | 3 | 1 | Negligible (0.00024 ML/day) seepage resulting from extraction of all LWs. | Section 10.5 of *Russell Vale Colliery Underground Expansion Project Russell Vale East Revised Groundwater Assessment* (GeoTerra / GES, 2015) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| CS 212 | CS 2 Fracturing of deeper strata | CS 21 Depressurisation of the regional groundwater system | CS 212 Reduced baseflow to streams flowing to Cataract Reservoir (Cataract Creek, Cataract River and Bellambi Creek) | | | V | Avoidance of longwall mining beneath 3rd and 4th order reaches of Cataract Creek | E | 2 | A | 3 | 2 | Drawdown of the regional aquifer is predicted to reduce baseflow to Cataract Creek, Cataract River and Bellambi Creek by 0.041 ML/day. However, the re-directed water is expected to flow to the reservoir via subterranean pathways. | Section 10.4 of *Russell Vale Colliery Underground Expansion Project Russell Vale East Revised Groundwater Assessment* (GeoTerra / GES, 2015) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| CS 221 | CS 2 Fracturing of deeper strata | CS 22 Groundwater inflow into mine voids | CS 221 Increased quantity of water flowing into the mine | | | V | There is ample underground storage capacity in the mine to manage inflows. The infrastructure to return water to the catchment is largely in place. Water Access Licences will be obtained.<br>Regional groundwater currently does not contribute to the Reservoir as it is below the Reservoir level. At the location of the reservoir, the regional groundwater table is in the Bulgo Sandstone. The base of Cataract Reservoir occurs in the overlying Bald Hill Claystone. | B | 1 | A | 3 | 1 | Predicted incremental increase in mine inflows of 0.4 ML/day after extraction of LWs 9-11. The regional aquifer is below the reservoir. Therefore, this does not affect reservoir capacity except for the minor additional seepage resulting from depressurisation. | Section 10.7 of *Russell Vale Colliery Underground Expansion Project Russell Vale East Revised Groundwater Assessment* (GeoTerra / GES, 2015) | Sch 3, Condition 8 of the Draft DA requires the EP to include a detailed groundwater monitoring program to monitor and report on groundwater inflows to the underground mine, leakage from Cataract Reservoir, height of groundwater depressurisation between LW6 & 7 and the Cataract Reservoir, and other parameters to validate the surface water and groundwater models along with a plan to respond to any exceedances of the water criteria. Performance criteria are stipulated in Table 1. |
| CT | CT Tilting | | | | | | | | | | | | | | |
| CT 111 | CT 1 Changes to swamp water regimes | CT 11 Reduction in 'cleaning' effects | CT 111 Reduced quality of water flowing into Cataract Reservoir | | | Q | Re-design of mine plan to reduce impacts to swamps. LW 9 was re-aligned to reduce secondary extraction beneath CCUS10. | A | 1 | D | 5 | 1 | No observable effect would be felt. Quantum of predicted tilting will have no observable effect (max. 32 mm/m over LW9). Filtration effect would not change.<br>Primary impact to swamps is from cracking rather than tilting. Very small catchment size means that any tilting will have a very small impact on these swamps. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| CT 121 | CT 1 Changes to swamp water regimes | CT 12 Detrimental effects on swamp ecosystems | CT 121 Detrimental effect on BCUS4 | | | E | No controls. | A | 3 | C | 3 | 1 | 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 significantly decreased water flow through a patch of vegetation reliant on maintenance of water regimes. This may result in changes to vegetation composition in this area, with transition to drier vegetation types. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Sch 3, Condition 9 of the Draft DA requires an Upland Swamp Monitoring Program prepared in consultation with OEH, NOW and SCA to determine compliance with Sch 3 Condition 1 in relation to performance measures for swamps and biodiversity. Sch 3, Condition 3 provides for 'Offsets' to be required if the performance measures are exceeded. DP&E is preparing a Swamp Offsets Policy, which is currently being considered in response to public submissions to its exhibition. Once finalised, WCL will be likely be required to adhere to this Swamp Offsets Policy. |
| CT 122 | CT 1 Changes to swamp water regimes | CT 12 Detrimental effects on swamp ecosystems | CT 122 Detrimental effect on swamps other than BCUS4 | | | E | No controls. | A | 1 | D | 5 | 1 | No observable effect would be felt. Quantum of predicted tilting will have no observable effect (max. 32 mm/m over LW9). Filtration effect would not change.<br>Primary impact to swamps is from cracking rather than tilting. Very small catchment size means that any tilting will have a very small impact on these swamps (except for BCUS4). | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |

| Identifier | Risk ... | | | | | Impact | Current controls and factors that reduce the risk | QUALITATIVE ASSESSMENT | | | | | Notes | References | Additional controls and treatments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | CE | C | L | Risk | PE | | | |
| CT 13 | CT 1 Changes to swamp water regimes | CT 13 Increased susceptibility to fire | | | | E | Re-design of mine plan to reduce impacts to swamps. LW 9 was re-aligned to reduce secondary extraction beneath CCUS10. | A | 1 | D | 5 | 1 | No observable effect would be felt. Quantum of predicted tilting will have no observable effect (max. 32 mm/m over LW9). Filtration effect would not change. Primary impact to swamps is from cracking rather than tilting. Very small catchment size means that any tilting will have a very small impact on these swamps. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |
| CT 21 | CT 2 Changes to stream water regime | CT 21 Increased erosion downstream | | | | Q | No controls. | E | 1 | D | 5 | 1 | No observable effect would be felt as minimal tilting will occur in the stream bed. Tilting will not have an impact as the stream bed comprises boulders, sand or exposed bedrock. | | Not applicable |
| CT 22 | CT 2 Changes to stream water regime | CT 22 Increased pooling in streams | | | | Q | No controls. | E | 1 | D | 5 | 1 | No adverse effects on stream flow continuity or stream ponding due to previous mining activities have been observed. No mining induced cracking or compressional buckling of rock bars, or loss of pool holding capacity has been observed to date. | Section 2.2 of *Russell Vale Colliery Underground Expansion Project Preferred Project Report Groundwater & Surface Water Response to Submissions Residual Matters Addendum* (GeoTerra, 2014) | Not applicable |
| CT 31 | CT 3 Development of knick points in swamps | CT 31 Increased susceptibility to erosion | | | | Q | No controls. Knick points only happen in sediment based streams, so not applicable here. | E | 1 | D | 5 | 1 | No observable effect would be felt. Quantum of predicted tilting will have no observable effect (max. 32 mm/m over LW9). Given the small catchment for swamps in this area, flow velocities are unlikely to be sufficient to increase erosion potential. Primary impact to swamps is from cracking rather than tilting. Very small catchment size means that any tilting will have a very small impact on these swamps. Only a small potential for erosion. | Section 4 of *Coastal Upland Swamp Impact Assessment Report* (Biosis, 2014) | Not applicable |

# 3 Risks removed from the register

This section lists the risks that were discussed during the assessment process but removed subsequently from the register, with the reasons for their removal.

| Identifier | Risk ... | | | | Reasons for removal |
|---|---|---|---|---|---|
| | | | | | |
| A | A Subsidence caused by mining activities in LW1-LW3 | | | | |
| AH | AH Horizontal movements and bedding plane shear | | | | |
| AH 112 | AH 1 Changes to the groundwater regime | AH 11 Increased groundwater flows into mine voids | AH 112 Water release below the escarpment | | Outside scope |
| AH 12 | AH 1 Changes to the groundwater regime | AH 12 Loss of shallow groundwater (as a result of seepage through bedding planes) | AH 121 Drying of upland swamps | | Not relevant because shear happens under creeks, not under swamps |
| AH 13 | AH 1 Changes to the groundwater regime | AH 13 Water flow diverted into another catchment | | | Not relevant as there is no nearby catchment |
| AS | AS Strata dilation | | | | |
| AS 114 | AS 1 Surface fracturing | AS 11 Cracking of bedrock beneath swamp | AS 114 Drying of other upland swamps (non groundwater dependent) | | No other relevant swamps near the mining areas |
| AS 2221 | AS 2 Fracturing of deeper strata | AS 22 High volume groundwater inflow into mine voids | AS 222 Failure of Russell Vale seals | AS 2221 Water release below the escarpment | Sealing of the mine adits is included in the risk assessment as a control for managing inflows (risk BS23 and BS24) rather than as a risk in and of itself. |
| AS 223 | AS 2 Fracturing of deeper strata | AS 22 High volume groundwater inflow into mine voids | AS 223 Exceed current licence discharge limits | | Remove this scenario; out of scope |
| AS 224 | AS 2 Fracturing of deeper strata | AS 22 High volume groundwater inflow into mine voids | AS 224 Unacceptable returned water quality to Water NSW | | Currently do not return water to Water NSW.<br>Propose mechanism for massive inflow - not part of the UEP. Needs a response from WCL. |
| B | B Subsidence caused by mining activities in LW6-LW8 | | | | |
| BH | BH Horizontal movements and bedding plane shear | | | | |
| BH 112 | BH 1 Changes to the groundwater regime | BH 11 Increased groundwater flows into mine voids | BH 112 Water release below the escarpment | | Outside scope |
| BH 12 | BH 1 Changes to the groundwater regime | BH 12 Loss of shallow groundwater (as a result of seepage through bedding planes) | | | Not relevant because shear happens under creeks, not under swamps |
| BS | BS Strata dilation | | | | |
| BS 114 | BS 1 Surface fracturing | BS 11 Cracking of bedrock beneath swamp | BS 114 Drying of other upland swamps (non groundwater dependent) | | No other relevant swamps near the mining areas |
| BS 1215 | BS 1 Surface fracturing | BS 12 Fracturing of controlling rockbars | BS 121 Drying of upland swamps (CCUS4, LW6) | BS 1215 Diversion of base flow provided by swamp | There is no pooling behind the rockbar, which is just a rock ledge, so this is not relevant<br>Fracturing of the rock bar will not divert baseflow. It may increase seepage from the swamp but will not result in diversion of surface flow to subsurface or will not resulkt in decreased baseflow. |
| BS 2221 | BS 2 Fracturing of deeper strata | BS 22 High volume groundwater inflow into mine voids | BS 222 Failure of Russell Vale seals | BS 2221 Water release below the escarpment | Sealing of the mine adits is included in the risk assessment as a control for managing inflows (risk BS23 and BS24) rather than as a risk in and of itself. |
| BS 223 | BS 2 Fracturing of deeper strata | BS 22 High volume groundwater inflow into mine voids | BS 223 Exceed current licence discharge limit | | Outside scope. |
| BS 224 | BS 2 Fracturing of deeper strata | BS 22 High volume groundwater inflow into mine voids | BS 224 Unacceptable returned water quality to Water NSW | | Currently do not return water to Water NSW.<br>Propose mechanism for massive inflow - not part of the UEP. Needs a response from WCL. |
| BT | BT Tilting | | | | |

| Identifier | Risk ... | | | | Reasons for removal |
|---|---|---|---|---|---|
| | | | | | |
| BT 14 | BT 1 Changes to swamp water regimes | BT 14 Diversion of base flow provided by swamp CCUS4 | | | This only applies to CCUS4; it has no effect on flow to Cataract Reservoir. CCUS4 is the only swamp with a water regime. Tilting cannot make the water flow out of the catchment. Swamp is already sloped. 5% decrease in catchment area for CCUS4 is the upper bound.<br><br>Tilting will not result in change to baseflow from the majority of swamps. Whilst tilting may result in change in flow pathways, it will not result in in-flow to the reservoir. |
| **C** | **C Subsidence caused by mining activities in LW9-LW12** | | | | |
| **CH** | **CH Horizontal movements and bedding plane shear** | | | | |
| CH 112 | CH 1 Changes to the groundwater regime | CH 11 Increased groundwater flows into mine voids | CH 112 Water release below the escarpment | | Outside scope |
| CH 12 | CH 1 Changes to the groundwater regime | CH 12 Loss of shallow groundwater (as a result of seepage through bedding planes) | | | Not relevant because shear happens under creeks, not under swamps |
| CH 13 | CH 1 Changes to the groundwater regime | CH 13 Water flow diverted into another catchment | | | Not relevant as there is no nearby catchment |
| **CS** | **CS Strata dilation** | | | | |
| CS 1115 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 111 Drying of upland swamps (CCUS10, LW9) | CS 1115 Diversion of base flow provided by swamp | The base flow from CCUS10 is low and will not be changed; it only flows after rain |
| CS 1125 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 112 Drying of upland swamps (CCUS11, LW9) | CS 1125 Diversion of base flow provided by swamp | There is a negligible base flow from CCUS11; it only flows after rain |
| CS 1135 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 113 Drying of upland swamps (CCUS12, LW9 and LW10) | CS 1135 Diversion of base flow provided by swamp | There is a negligible base flow from CCUS12; it only flows after rain |
| CS 1145 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 114 Drying of upland swamps (CCUS24, LW9) | CS 1145 Diversion of base flow provided by swamp | There is a negligible base flow from CCUS24; it only flows after rain |
| CS 1165 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 116 Drying of upland swamps (BCUS11, LW10) | CS 1165 Diversion of base flow provided by swamp | There is a negligible base flow from BCUS11; it only flows after rain |
| CS 1175 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 117 Drying of upland swamps (CRUS6, LW11) | CS 1175 Diversion of base flow provided by swamp | There is a negligible base flow fromCRUS6; it only flows after rain |
| CS 118 | CS 1 Surface fracturing | CS 11 Cracking of bedrock beneath swamp | CS 118 Drying of other upland swamps (non groundwater dependent) | | No other relevant swamps near the mining areas |
| CS 2221 | CS 2 Fracturing of deeper strata | CS 22 High volume groundwater inflow into mine voids | CS 222 Failure of Russell Vale seals | CS 2221 Water release below the escarpment | Sealing of the mine adits is included in the risk assessment as a control for managing inflows (risk BS23 and BS24) rather than as a risk in and of itself. |
| CS 223 | CS 2 Fracturing of deeper strata | CS 22 High volume groundwater inflow into mine voids | CS 223 Exceed current licence discharge limit | | Outside scope |
| CS 224 | CS 2 Fracturing of deeper strata | CS 22 High volume groundwater inflow into mine voids | CS 224 Unacceptable returned water quality to Water NSW | | Currently do not return water to Water NSW.<br>Propose mechanism for massive inflow - not part of the UEP. Needs a response from WCL. |
| CS 23 | CS 2 Fracturing of deeper strata | CS 23 Major fracturing associated with D8 Dyke (LW9-LW11) | | | Dyke D8 does not provide hydraulic connectivity; there are no credible mechanisms for this to occur |
| **CT** | **CT Tilting** | | | | |
| CT 14 | CT 1 Changes to swamp water regimes | CT 14 Diversion of base flow provided by swamp | | | This only applies to BCUS4; it has no effect on flow to Cataract Reservoir. Removed for volume impact being low. |

# 4 Risk assessment scales

The risk assessment scales are provided here for completeness.

**Control effectiveness**

| CE | Descriptor | Guide |
|---|---|---|
| A | **Fully effective** | Nothing more to be done except review and monitor the existing controls. Controls are well designed for the risk, address the root causes and management believes that they are effective and reliable at all times. |
| B | **Substantially effective** | Most controls are designed correctly and are in place and effective. Some more work to be done to improve operating effectiveness or management has doubts about operational effectiveness and reliability. |
| C | **Partially effective** | While the design of controls may be largely correct in that they treat most of the root causes of the risk, they are not currently very effective.<br>or<br>Some of the controls do not seem correctly designed in that they do not treat root causes, those that are correctly designed are operating effectively. |
| D | **Largely ineffective** | Significant control gaps. Either controls do not treat root causes or they do not operate at all effectively. |
| E | **None or totally ineffective** | Virtually no credible control. Management has no confidence that any degree of control is being achieved due to poor control design and/or very limited operational effectiveness. |

**Likelihood**

| L | Descriptor | Annual probability |
|---|---|---|
| A | **Almost certain** | 1 |
| B | **Likely** | 0.1 |
| C | **Possible** | 0.01 |
| D | **Unlikely** | 0.001 |
| E | **Rare** | 0.0001 |

**Consequences**

| C | Descriptor | Water volume | Water quality | Environment | Community & reputation | Legal & compliance |
|---|---|---|---|---|---|---|
| 5 | **Very high** | Very large reduction in water volumes flowing into or from Cataract Reservoir; immediate WCL action required by Water NSW; Water NSW launches enquiry; large water charges imposed | Significant long-term reduction in water quality; very high sustained turbidity in Cataract Reservoir; very low DO; very high or very low pH; very high iron content, manganese or hardness | Disastrous environmental impact with long term effect | Prominent negative international media coverage over several days | Major litigation or prosecution with high damages and significant costs; custodial sentence for an executive; prolonged closure of operations by regulator |
| 4 | **High** | Large reduction in water volumes flowing into or from Cataract Reservoir; WCL action required by Water NSW; water charges imposed | Major long term reduction in water quality; low DO; high or low pH; high iron content, manganese or hardness | Serious environmental impact with medium term effect | National media coverage over several days; community or NGO legal actions; impact on local economy | Major litigation and investigation by regulator; long term interruption to operations; possible custodial sentence |
| 3 | **Moderate** | Moderate reduction in water volumes flowing into or from Cataract Reservoir, beyond seasonal variations; WCL action required by Water NSW | Moderate long-term reduction in water quality; reduced DO; slightly high or slightly low pH; elevated iron content, manganese or hardness | Moderate reversible environmental impact with short term effect | Local media coverage over several days; negative impact on local economy; persistent community complaints | Major breach of regulation with punitive fine; significant litigation involving many weeks of senior management time |
| 2 | **Low** | Small reduction in water volumes flowing into or from Cataract Reservoir | Small, short-term reduction in water quality; slightly reduced DO; slightly high or slightly low pH; slightly elevated iron content, manganese or hardness | Minor reversible environmental impact | Local media coverage; complaint to site or regulator | Breach of regulation with investigation or report to regulator; prosecution or moderate fine possible |
| 1 | **Very low** | Negligible effect on water volumes flowing into or from Cataract Reservoir | Minimal reduction in water quality; DO, pH, iron content, manganese and hardness within normal ranges | Negligible reversible environmental impact | No media coverage; no community complaints | Minor legal issues, non-compliances and breaches of regulation |

**Level of risk**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Likelihood** | A | 3 | 3 | 2 | 2 | 1 |
| | B | 4 | 3 | 2 | 2 | 1 |
| | C | 4 | 3 | 3 | 2 | 2 |
| | D | 5 | 4 | 3 | 3 | 2 |
| | E | 5 | 5 | 4 | 3 | 3 |
| | Consequences | 1 | 2 | 3 | 4 | 5 |
| | Classification: | **Negligible risk** | **Low risk** | **Medium risk** | **High risk** | **Extreme risk** |

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# Contact

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***APPENDIX C***

**IRAP and Regulatory Consultation**

**Table A**
**Summary of Consultation in Formulating Methodology and Risk Assessment**

| Ref | Date | Detail | Attendees |
|---|---|---|---|
| **IRAP Formation** | | | |
| 1. | 15 May 2015 | Preliminary meeting with DP&E to discuss the approach for the IRA | David Clarkson (DC), Rhys Brett (RB) |
| 2. | 20 May 2015 | Email to DP&E presenting draft ToRs (and supporting flowchart) for comment | DC, DP&E |
| 3. | 22 May 2015 | Meeting with WaterNSW to discuss the proposed ToRs | DC, RB |
| 4. | 15 June 2015 | Letter from DP&E endorsing the nominated IRAP members | DP&E, DC |
| 5. | 25 June 2015 | Email from DP&E outlining WaterNSW's suggested edits to the ToRs | DP&E, DC |
| **Methodology** | | | |
| 6. | 30 June 2015 | Draft Methodology distributed (via email) to IRAP members for comments | Dianne Munro (DM), Ismet Canbulat (IC) |
| 7. | 6 July 2015 | Meeting at UNSW to discuss the draft Methodology | IRAP, RB, DC, Andrew Wu (AWu), Andrew Dawkins (AD), Ken Mills (KM), Nathan Garvey (NG) |
| 8. | 15 July 2015 | IRAP provided minutes of meeting on 6 July 2015 provided by the IRAP. These minutes included recommended edits to the draft Methodology | IRAP, RB, DC |
| 9. | 21 July 2015 | Meeting with IRAP and regulatory authorities to discuss the draft Methodology | IRAP, RB, DC |
| 10. | 31 July 2015 | Letter from IRAP expressing in principle support for the proposed Methodology | IC, RB |
| **Risk Assessment** | | | |
| 11. | 17 July 2015 | Preliminary risk assessment session (subsidence issues) | WCL: RB, DC<br>HB: DM, AWu<br>Specialists: Dale Cooper (DCo), KM |
| 12. | 28 July 2015 | Preliminary risk assessment session (water and ecology issues) | WCL: RB, DC<br>HB: DM, AWu<br>Specialists: DCo, AD |
| 13. | 5 August 2015 | Risk Assessment Session (subsidence, water and ecology issues) | WCL: RB, DC<br>HB: DM, AWu<br>Specialists: DCo, KM, AD, NG |
| 14. | 14 August 2015 | Submission of draft risk assessment documents (Final Report and Risk Register) | DM, IC |
| 15. | 19 August 2015 | Submission of draft risk assessment documents (Supporting Technical Information) | DM, IC |
| 16. | 24 August 2015 | Meeting with IRAP to discuss draft risk assessment | IRAP, RB, DC, DM, AWu, KM, NG |
| 17. | 31 August 2015 | Meeting with IRAP to discuss draft risk assessment | IRAP, RB, DC, DM, AWu, KM, AD |
| 18. | 31 August 2015 | Meeting with WaterNSW to discuss draft risk | WaterNSW, DC, DM, |

| Ref | Date | Detail | Attendees |
|---|---|---|---|
| | | assessment | AWu |
| 19. | 10 September 2015 | Receipt of the IRAP's written response to the draft risk assessment | IRAP, WCL |
| 20. | 15 September 2015 | Submission of revised risk assessment documents after addressing the IRAP's recommendations | IC, DM |
| 21. | 21-22 September 2015 | Final IRAP comments | IRAP, RB, DC, DM, AWu |
| 22. | 28 September 2015 | IRAP approval of risk assessment | IRAP |

# IRAP Members

**Planning Services**
**Resource Assesssments & Compliance**

Contact: Howard Reed
Phone: (02) 9228 6308
Email: howard.reed@planning.nsw.gov.au

Mr Rhys Brett
Manager of Mining Engineering
Russell Vale Colliery
PO Box 281
FAIRY MEADOW NSW 2519

Dear ~~Mr Brett~~ Rhys

**Russell Vale Colliery Underground Expansion Project**
**Independent Risk Assessment Panel**

Thank you for contacting the Department regarding proposed members of Wollongong Coal Company's (WCL's) Independent Risk Assessment Panel (IRAP) for its Russell Vale Colliery Underground Expansion Project (MP 09_0013).

After careful consideration of the qualifications and experience of the nominated members, I would like to advise you that the Department supports WCL's proposal for the following membership of the IRAP:

- Professor Ismet Canbulat – Chair and rock mechanics expert;
- Arthur Waddington – subsidence expert;
- Dr David Robertson – ecology expert;
- Dr Steve Perrens – surface water expert; and
- Andrea Madden – groundwater expert.

If you have any queries about this letter, please contact me on the details above.

Yours sincerely

Howard Reed

Howard Reed
**Director Resource Assessments**
15·6·15

# Terms of Reference

# WOLLONGONG COAL LIMITED

**Operating Procedures for the Russell Vale Colliery – Independent Risk Assessment Panel**

## Purpose

In its review report, the NSW Planning Assessment Commission (PAC) made the following recommendations:

> *'The establishment of a risk assessment panel, constituted by an independent chair, Water NSW, the Dams Safety Committee, the Division of Resources and Energy and the proponent to oversee an integrated risk assessment, particularly focusing on links between subsidence and water (both groundwater and surface water) impacts of the proposal. This risk assessment, including associated work rerunning the groundwater modelling as recommended by Dr Mackie; and addressing the issues raised by the relevant agencies and experts (as highlighted in this report), needs to be completed before the application can be determined.*

In accordance with recommendations made by the PAC, and prior to longwall extraction beyond the approved 365m section of LW6 in the Russell Vale East area, WCL will constitute an Independent Risk Assessment Panel (IRAP) to conduct an ongoing assessment of risks to Cataract Reservoir, groundwater, surface water and Upland Swamps during the extraction of LWs 1, 2, 3, 6, 7, 9, 10 and 11.

The IRAP will have an Independent Chair, approved by the Department of Planning and Environment (DP&E), to ensure that the objectives of the IRAP are achieved. This proposed Operating Procedure documents the following for endorsement by the parties:

1. Objectives of the IRAP;
2. IRAP Process
3. Structure and membership of the IRAP; and
4. Financial arrangements.

## 1. Objectives of the IRAP

The objective of the IRAP is to give full effect to Recommendation 1 of the PAC Russell Vale Colliery Underground Expansion Project (UEP) Review Report.

## 2. IRAP Process

### *a. Project Approval Process*

- Assist in the development and approval of an appropriate risk assessment methodology;

- Utilise latest available data to identify and assess the risks related to the extraction of longwalls in the Russell Vale East area. At a minimum, this must include consideration of potential risks associated with the following mining activities:
  - Longwall 1 – groundwater systems, Cataract Creek;
  - Longwall 2 – groundwater systems, swamp CCUS2, Cataract Creek;
  - Longwall 3 – groundwater systems, swamps CCUS1 & CCUS2, Cataract Creek;
  - Longwall 6 *(365m to completion)* – Cataract Reservoir, Dyke D8, groundwater systems, swamp CCUS4, Cataract Creek, Cataract River;
  - Longwall 7 – Cataract Reservoir, Corrimal Fault, Dyke D8, groundwater systems, swamps CCUS4 & CCUS5, Cataract Creek, Cataract River;
  - Longwall 9 – Cataract Reservoir, Dyke D8, groundwater systems, swamps CCUS10, CCUS11, CCUS12 and CCUS24, Cataract Creek;
  - Longwall 10 – Cataract Reservoir, Dyke D8, groundwater systems, swamps CCUS12, BCUS4 and BCUS11; and
  - Longwall 11 – Cataract Reservoir, Dyke D8, groundwater systems, swamp CRUS6.
- Engage suitable experts to assist with and/or review the Risk Assessment Report and any other studies undertaken by WCL and its specialists; and
- Consultation with appropriate regulatory authorities and WaterNSW (as required) during its consideration of the risk assessment methodology and Risk Assessment Report.

### *b. Extraction Plan Process*

- Based on latest available data, review the risk assessment for the following longwall and make recommendations to WCL for revisions of the existing Extraction Plan; and
- Review the draft Extraction Plan (to be prepared by WCL) and provide recommendations prior to submission of the plan for approval by DP&E.

### *c. Post Approval Process*

- Based on latest available data and risk assessment outcomes, provide ongoing advice to WCL in consideration of findings from monitoring conducted during and following mining; and
- Advise on appropriate mitigation or remediation measures (by engaging suitable experts where necessary) to address any Extraction Plan triggers or exceedances of Performance Measures.

## 3. Structure and Membership of the IRAP

The **IRAP** will be comprised of:

- Independent Expert (IE) groundwater, surface water, upland swamp and subsidence specialists, as approved by DP&E, to provide advice and guidance on identifying and managing key risks;

- An Independent Chair.
- WCL representatives and specialists would attend meetings at the request of the IRAP to provide advice, as required.

The IRAP will consist of the following members as approved by DP&E.

| WCL IRAP | |
|---|---|
| **Chairperson** | Ismet Canbulat (Professor of Rock Mechanics UNSW); and |
| **IE Subsidence** | Arthur Waddington – Managing Director (Mine Subsidence Engineering Consultants) |
| **IE Groundwater** | Andrea Madden – Principal Hydrogeologist (WSP – Parsons Brinkerhoff) |
| **IE Surface Water** | Steve Perrens – Principal (Advisian, formerly Evans & Peck) |
| **IE Upland Swamps** | David Robertson – Director (Cumberland Ecology) |

## 4. Financial Arrangements

WCL agrees to fund the reasonable costs of:

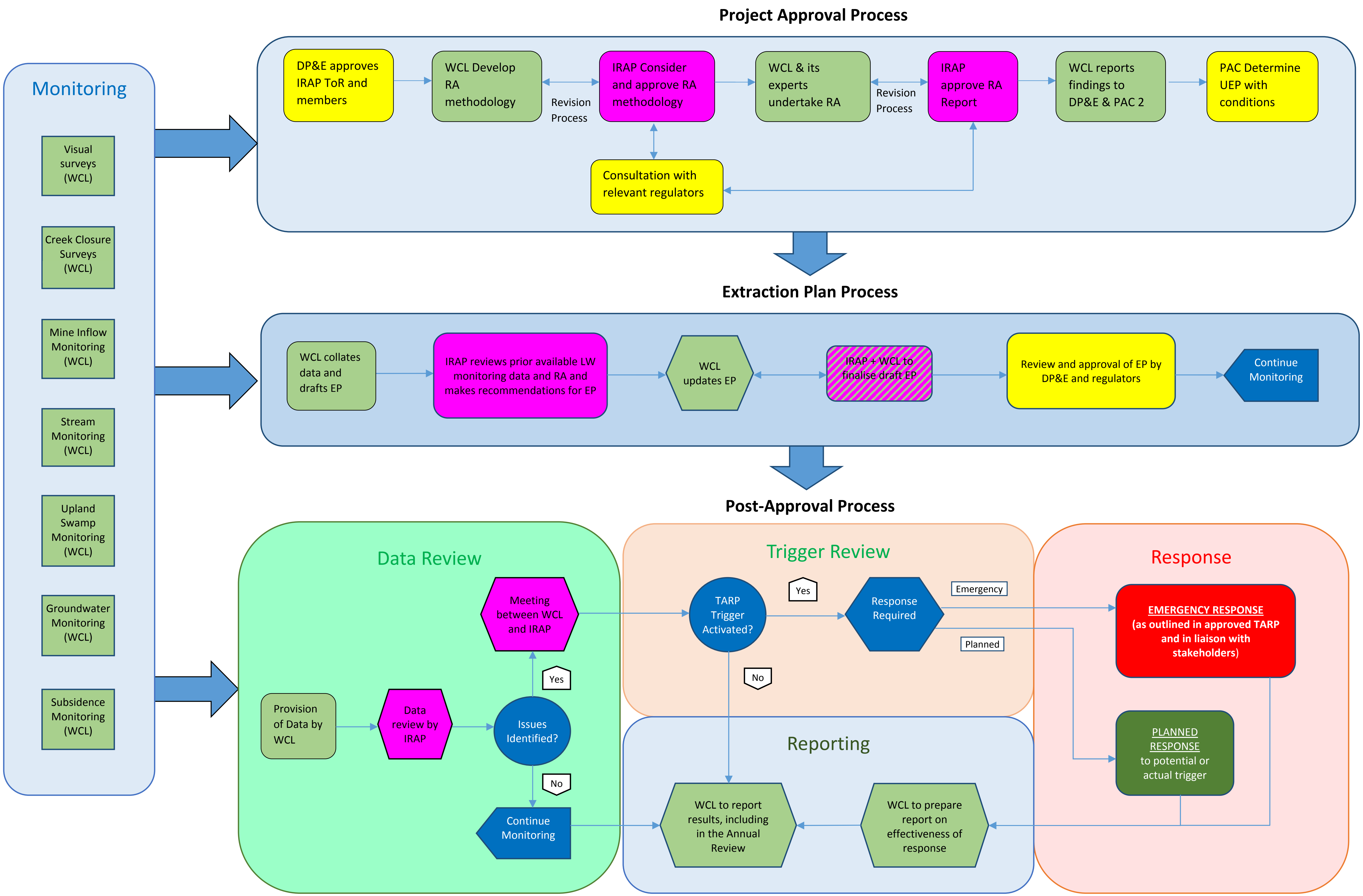
- The Independent Experts and Chair;
- any monitoring, investigatory or other preparatory work agreed to by WCL and the IRAP, or required by DP&E in liaison with the IRAP Independent Chair, to improve data for use in risk assessment, management and/or review of the Extraction Plan in relation to Cataract Reservoir, groundwater, surface water and upland swamps; and
- engagement of independent specialists, as required; and
- any other work required to further critical works associated with the implementation of Extraction Plans.

## 5 Endorsements

Signed and dated in agreement on behalf of:

Wollongong Coal Limited

Rhys Brett
Business Development Manager



Project Approval Process
Monitoring
Visual surveys (WCL)
Creek Closure Surveys (WCL)
Mine Inflow Monitoring (WCL)
Stream Monitoring (WCL)
Upland Swamp Monitoring (WCL)
Groundwater Monitoring (WCL)
Subsidence Monitoring (WCL)
DP&E approves IRAP ToR and members
WCL Develop RA methodology
Revision Process
IRAP Consider and approve RA methodology
WCL & its experts undertake RA
Revision Process
IRAP approve RA Report
WCL reports findings to DP&E & PAC 2
PAC Determine UEP with conditions
Consultation with relevant regulators
Extraction Plan Process
WCL collates data and drafts EP
IRAP reviews prior available LW monitoring data and RA and makes recommendations for EP
WCL updates EP
IRAP + WCL to finalise draft EP
Review and approval of EP by DP&E and regulators
Continue Monitoring
Post-Approval Process
Data Review
Provision of Data by WCL
Data review by IRAP
Issues Identified?
Yes
Meeting between WCL and IRAP
No
Continue Monitoring
Trigger Review
TARP Trigger Activated?
Yes
Response Required
No
Emergency
Planned
Response
EMERGENCY RESPONSE (as outlined in approved TARP and in liaison with stakeholders)
PLANNED RESPONSE to potential or actual trigger
Reporting
WCL to report results, including in the Annual Review
WCL to prepare report on effectiveness of response

# Risk Assessment Methodology

| | |
|---|---|
| To: | Rhys Brett<br>Business Development Manager<br>Wollongong Coal<br>Email: rbrett@wcl.net.au<br>P: 02 4223 849 |
| CC: | Dianne Munro and David Clarkson |
| From: | Independent Risk Assessment Panel |
| Date: | 31 July 2015 |

REVIEW OF THE RISK ASSESSMENT METHODOLOGY PROPOSED FOR THE RUSSELL VALE COLLIERY UNDERGROUND EXPANSION PROJECT

Dear Rhys,

The Independent Risk Assessment Review Panel (IRAP), which comprises Ismet Canbulat, Arthur Waddington, Andrea Madden, Steve Perrens and David Robertson, has conducted a review of the proposed integrated risk assessment methodology proposed by Wollongong Coal Limited (WCL) for the Russell Vale Colliery Underground Expansion Project (UEP). This note summarises the outcomes of the review.

The objective of the proposed integrated risk assessment methodology is to ensure that associated risks with underground mining on the quantity and quality of groundwater and surface water as well as upland swamps have been assessed and appropriate controls are implemented.

The objective of IRAP's review was to ensure that the proposed risk assessment methodology is technically sound and appropriate. A consideration was the acceptability of the risk assessment methodology by the relevant government agencies and the public.

The review by IRAP consisted of two stages. In the first stage, the risk assessment methodology reported by Dr Dale Cooper, entitled "Discussion paper: UEP – Integrated risk assessment approach Wollongong Coal Limited, Russell Vale Underground Expansion Project"; version 1, dated 2015 (Broadleaf, 2015a), was reviewed and recommendations were submitted to WCL to amend the proposed risk assessment methodology. A review report, entitled "Review of the Proposed Risk Assessment Methodology", dated 15 July 2015, was submitted to WCL by IRAP.

In the second stage of the review, IRAP reviewed WCL's revised risk assessment methodology summarised in a document entitled "Discussion paper: UEP – Integrated risk assessment approach Wollongong Coal, Russell Vale Underground Expansion Project, version 7a, prepared by Dr Dale Cooper, dated 2015 (Broadleaf, 2015b). As part of this review stage, WCL also provided written responses to IRAP's recommendations in a note entitled "IRAP review: Responses to IRAP recommendations on the risk assessment, version 4, dated 15 July 2015, prepared by Dr Dale Cooper (Broadleaf, 2015c). An additional document, entitled "Water NSW comments: Responses to comments on the risk assessment dated 24 July 2015 Wollongong Coal, Russell Vale UEP", version 1, prepared by Dr Dale Cooper, dated 2015 (Broadleaf, 2015d), was also reviewed as part of the second stage of the review.

Based on our review of the revised risk assessment methodology and the relevant documentation, including the WaterNSW Risk Management Framework, IRAP, in principle, support the overall risk assessment methodology proposed for the Russell Vale Colliery UEP, recognising that IRAP will be able to review the draft risk assessment, upon its completion. In order to ensure that the risk assessment methodology and the risk assessment are well understood and accepted by all parties, suggested considerations are provided in the following tables.

Please note that David Robertson was part of the initial review meeting on 6 July 2015 and provided comments on Broadleaf (2015a). Although David has been unable to provide further review of the methodology, he will continue to be part of IRAP in the review process of the risk assessment.

Yours Sincerely

Ismet Canbulat
On Behalf of the Independent Risk Assessment Panel

Table 1. Suggested considerations in the discussion and IRAP review documents.

*Discussion Paper*

| Paragraph | Comment |
|---|---|
| Page 5, end of paragraph 2 | The last sentence 'It does not consider water discharges' is unclear and should be reworded. For example, 'It does not consider discharges of stormwater and treated mine water to Bellambi Gully.' |
| Page 8, last dot point | For clarity, 'Upgrade of **pit top** water management facilities' is suggested. |
| Page 10, last paragraph | It is considered that the flow issue is broader than just the quantity of water flowing to Cataract Reservoir. One possibility would be that subsidence impacts lead to low flows drying up – which could significantly impact the riparian and aquatic ecology of the creek even if it has negligible effect on the total quantity of water flowing into the reservoir. |
| Page 11, paragraphs 1 and 4.<br>Also pages 11, 13, 21, 25, 26, 28, 29 | First paragraph refers to 'workshops' (plural), but paragraph 4 refers to 'the workshop' (singular).<br>It would be useful to clarify the workshop process. It is envisaged that at least two will be needed with much of the quantitative risk analysis undertaken following an initial workshop (Context; Risk Identification/Review and Qualitative Risk Analysis). The subsequent workshop would then review and confirm the quantitative risk assessment and consequence/mitigation assessment.<br>This is not clear from the Discussion Paper. |
| Page 14, Table 4 | It is stated that there has been no evidence of reactivation of the Corrimal Fault during the mining of Longwall 4 or Longwall 5. It is our understanding that Longwalls 4 and 5 did not intersect the fault, with proposed Longwall 6 the first longwall to intersect the fault. If the fault was intersected by the maingates of Longwalls 4 and 5, then this should be clarified. A plan of the fault (and D8) would have been helpful. |
| Pages 17-19, detailed event tress | It is unclear how the drying of upland swamps can result in the loss of baseflow provided by a swamp (for example, refer to AS1145). Perhaps the wording can be changed to "loss of recharge to groundwater and/or surface water". |
| Page 20, 'Endpoints' | Timing of flow is also important for the creek. Flow duration needs to be considered. Similarly, hydrologic regime in the swamps needs to be considered (rate of drying after a rainfall event) in the risk assessment. |
| Page 20, Table 5 | <u>Severity</u> of impact on upland swamps is also important – not just area affected. |
| General, e.g. page 20 | When referring to water quality or water quantity, to avoid confusion, it is preferable to refer to the type of water, i.e. surface water, groundwater or reservoir water. |
| Page 22, Table 8 | Is there a further category 'Unknown/Uncertain'? |
| Page 23, Table 9 | Water volume and environmental consequences need to align (if possible) with risk consequences considered by Water NSW and DSC.  Note that Water NSW considers 'recovery time' as a criterion. |
| Page 20, Table 5 | Turbidity and manganese should be included in Table 5 (turbidity has been included on page 23, Table 9). The inclusion of these parameters (plus hardness) was also requested by Water NSW (Broadleaf, 2015b). |
| Page 23, Table 9 | Manganese should be included in Table 9. The inclusion of manganese (plus hardness) was also requested by Water NSW (Broadleaf, 2015b). |
| Page 23, Table 9 | The water quality changes in Table 9 specify high or low parameters (dissolved oxygen, pH and iron), with no reference to the natural or baseline values. For example, a section of stream may have a naturally 'low' pH and 'high' iron where there is baseflow discharge. |
| Page 23, Table 9 | The reduction in water quality does not consider distance or location, except for a change in turbidity (at Cataract Reservoir, River and/or Creek). Is a reduction in water quality at the full supply level of the reservoir considered the same as a similar reduction in water quality on a first, second or third stream order? Also, is a major reduction in water quality still considered high if it is isolated to a 100 m section of a stream? |

| | |
|---|---|
| Page 23, Table 9 | There is no time or recovery factor specified with the consequences. For example, is a major reduction in water quality still considered high if the water quality recovers within a relatively short period of time? The notion of 'recovery time' has been included in Water NSW's risk management framework (Water NSW, 2015). |
| General, e.g. event trees and page 23, Table 9 | Reductions in groundwater levels/pressures are not defined as consequences (endpoints). This is due to the primary environmental value/focus is on the quantity and quality of reservoir water and on upland swamps. However further discussion around this would be useful. |
| P26, last para | See comment for page 10. |
| General comment | The risk assessment should be carried out in such a way that the following primary endpoints of interest are borne in mind as the consequences are assessed.<br>▪ Quantity of water available for drinking water purposes in Cataract Reservoir.<br>▪ Quality of water available for drinking water purposes in Cataract Reservoir.<br>▪ Ecosystem effects of water quantity and quality on water dependent species in the catchment area, with a particular emphasis on upland swamps. |
| General comment | The impacts of subsidence from the proposed series of longwalls and the resulting consequences will not all occur at the same time and each longwall will affect a relatively small part of the overall catchment of the reservoir. The consequences for both water quantity and water quality are also dependent on the levels of flow from time to time. In times of base flow, the localised consequence of stream bed cracking can appear to be severe, but in times of increased flow, the consequence is diminished. The consequence for the water quantity and quality in the reservoir is further reduced by dilution as water flows into the reservoir from those creeks that are not impacted by subsidence effects. The length of time over which each localised consequence exists also needs to be considered in assessing the overall level of consequence. |

*Responses to IRAP Review*

| Paragraph | Comment |
|---|---|
| C | A simple list of references will not adequately address our concern. We expect sufficient text to clearly show the 'pedigree' and source(s) of any technical information that is relied on. |
| F2 | We presume that there will be further review of the event trees as part of the initial risk assessment workshop. |
| F8 | We presume this process will take account of the risk assessment process and consequence ranking schemes used by Water NSW and the DSC. |
| F10 | Note that Water NSW considers recovery time as part of the environmental assessment. |
| R | Reference to 'workshops' (plural). |
| S | The definition of integrated risk assessment should also be included in the risk assessment methodology discussion document so that all relevant parties understand the content of the methodology. |

### *References*


Broadleaf (2015a); "Water NSW comments: responses to comments on the risk assessment dated 24 July 2015, Wollongong Coal, Russell Vale UEP". Version 1.

Broadleaf (2015b); "Discussion paper: UEP – integrated risk assessment approach, Wollongong Coal, Russell Vale Underground Expansion project". Version 7a.

Broadleaf (2015c); "IRAP review: responses to IRAP recommendations on the risk assessment dated 15 July 2015". Version 4.

Broadleaf (2015d); "Water NSW comments: Responses to comments on the risk Assessment dated 24 July 2015 Wollongong Coal, Russell Vale UEP". Version 1.

Independent Risk Assessment Review Panel (2015); "Russell Vale Colliery Independent Risk Assessment Review Panel Review of the proposed risk assessment methodology meeting minutes". Dated 15 July 2015.

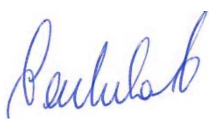
Water NSW (2015); "Water NSW risk management framework". Reference CD2011/3, dated February 2015.

# Draft Risk Assessment

# RUSSELL VALE COLLIERY UEP
# IRAP REVIEW OF THE
# INTEGRATED RISK ASSESSMENT

Date: 10 September 2015


IRAP Review Members: Ismet Canbulat – UNSW
Arthur Waddington – MSEC
Steve Perrens – Advisian
Andrea Madden – WSP | Parsons Brinckerhoff
David Robertson – Cumberland Ecology


Ismet Canbulat
On Behalf of the Independent Risk Assessment Panel

## 1. SUMMARY

Wollongong Coal Limited (WCL) has conducted a detailed risk assessment for the Russell Vale Colliery Underground Expansion Project (UEP). The risk assessment methodology was developed by DF Cooper of Broadleaf and WCL. The Independent Risk Assessment Panel (IRAP) has provided comprehensive comments on the risk assessment methodology in its previous report, entitled "Russell Vale Colliery, Independent Risk Assessment Panel, Review of the Proposed Risk Assessment Methodology", dated 15 July 2015.

The final risk assessment was facilitated by DF Cooper of Broadleaf and the results were conveyed in a draft report entitled "Final report: Integrated risk assessment for the UEP Wollongong Coal, Russell Vale Underground Expansion Project", dated 14 August 2015.

A risk register has also been provided by Broadleaf in a separate report, entitled "Risk register: Integrated risk assessment for the UEP, Wollongong Coal, Russell Vale Underground Expansion Project", dated 14 August 2015 (Version 1).

This current report presents the recommendations of IRAP on the above mentioned risk assessment and the risk register based on the relevant technical reports provided to IRAP up to the time of writing this report. Further general comments on the technical reports and recommendations are also offered.

It is the IRAP's opinion that the Integrated Risk Assessment (IRA) is based upon an approach that is detailed and is at an appropriate level to evaluate the risks to the swamps, streams, groundwater and Cataract Reservoir. However, IRAP has identified issues that need to be addressed in the risk assessment, the supporting technical studies or during the extraction plan process. It is considered that these issues are not "showstoppers" and can be managed by editing the risk assessment report and/or during the mining process.

It is considered that Section 6 of the risk assessment report requires some concluding narrative that brings together all the different assessed risks to each element of the environment (each swamp, the creek/river itself (flow and water quality), groundwater, flow and water quality reaching the reservoir – or loss from the reservoir). The concluding narrative should clearly state the consequences of various risks and should include the overall water balance graphic prepared by Ken Mills, SCT.

The Risk Register should clearly state the specific consequences and the proposed management/mitigation measures for each risk.

It is emphasised that the scope of the risk assessment and the IRAP's review is to address the impacts of underground mining on the quantity and quality of groundwater and surface water, and on environmental values associated with swamps. Wider environmental impacts of longwall mining are not considered in this review.

## 2. COMMENTS ON INTEGRATED RISK ASSESSMENT REPORT

- Previously it was stated that a quantitative analysis of the water losses would be conducted. If this analysis cannot be carried out due to lack of data it needs to be clearly stated (with the reasons) in the risk assessment report, so that the reasons for excluding the quantitative analysis is understood by all stakeholders.

- Table 1 (participants) to identify Andrew Dawkins from GeoTerra as having a surface water role.

- Table 5 (endpoint indicators) states the primary focus of the assessment is on changes to the overall water quality in Cataract Reservoir rather than localised effects in streams and swamps. However, Table 9 (consequences) specifies turbidity changes in Cataract River and Cataract Creek.

- Table 9 (consequences); the very high consequence for the environment states the requirement for major remediation. Additionally, the impact may not be able to be remediated.

- Table 9 (consequences); the loss of water stored in the reservoir should be included. For example, for the very high consequence for water volume, consider "Very large reduction in water volumes flowing into Cataract Reservoir 'and very large loss of water flowing out of the reservoir'…".

- Some risk ranking is not consistent with the impact – e.g. CS1153 and CS1154 relate to cracking of the bed of a swamp. However, the consequences (Table 9 of the report) are listed as "Negligible environmental impact requiring minor remediation". It is considered that cracking under a swamp would require more than "minor remediation". Re-wording of Table 9 is required.

- An overall/cumulative risk rating for each swamp is recommended.

- Additional risks to consider include:

    - Drawdown of the regional Hawkesbury Sandstone aquifer resulting in reduced baseflow discharge to streams, particularly Cataract Creek, and thus reduced quantity of water flowing into Cataract Reservoir. There is uncertainty whether this risk is covered by AH 111, BH 111 and CH 111.

    - The potential for horizontal shear zone hydraulic connection from the reservoir to the fractured zone above the mine, resulting in a loss of water from the reservoir.

- There is a broad statement on recovery times in Note 2, following Table 9 (consequences). It is recommended that recovery (e.g. short term, long term) be identified in the consequences table.

- Inclusion of "into the reservoir" prior to the comma in the first sentence in Section 6.2, and inclusion of "in the reservoir" prior to the comma in the first sentence in Section 6.3.

- Page 28, first bullet point, indicates that there are only two risks with high consequences and it would be useful to state what they are. Otherwise the reader can only determine what they are by reference to the Risk Tables 15 and 17 and the Event Tree in Figure 5 for Longwalls 6 and 7.

- It is noted that 200 mm is taken as a general indicator of significant subsidence to a swamp and most of the swamps will be subjected to maximum levels of tilt and strain that will potentially cause some level of damage. There is no justification for this assumption in the report. Also, the risk analysis does not appear to consider prior subsidence from mining in the Bulli and Balgownie Seams. Further explanation regarding the adopted subsidence criteria would be helpful as the risk register indicates much lower risk levels based upon the impacts being applied only to parts of the swamps. Clarity is required on the subsidence parameters that have been assumed in assessing each swamp.

- Does 'NR' in the final column of the risk register mean "none required"?

- For the risks assessed as 'medium' or 'high' the same surface locations are subject to a number of slightly different but related impacts. It is considered that this is a weakness of the 'event tree' approach in that it does not provide an integrated assessment of the various risks to a particular location (e.g. CCUS4 which gets listed 5 times in relation to slightly different potential effects). This issue should be remedied by the provision of a concluding narrative as set out in summary section.

- In overall terms, and in simple language, what is the overall risk of significant damage to CCUS4? Although this swamp is rated as a high risk of bedrock cracking, it is rated as being at low risk of consequential ecological damage, but this is not readily apparent in the risk register.

- In the text of the risk assessment, some succinct text that ties the findings of the risk assessment together as a summary for each important entity (swamp, stream, reservoir, etc) is missing. For example, in the risk register, some of the swamps are assessed in multiple ways, but the lines for the risk assessment are separated. For example, for the swamp CCUS4, the below information is available:

| Assessed Risk | Likelihood | Consequence | Identifier | Location | Nature of Impact | Existing Controls | Potential Impact | Management/ Mitigation |
|---|---|---|---|---|---|---|---|---|
| High | (A) Almost certain | (4) Serious impact | BS1113 | CCUS4 | Cracking of bedrock beneath swamp | Nil | Drying of swamp | Offset |
| High | (A) Almost certain | (4) Serious impact | BS1213 | CCUS4 | Cracking of controlling rock bars | Nil | Decreased water retention | Offset |
| Medium | (C) Possible | (2) Low - minor reversible impact | BS1114 | CCUS4 | Cracking of bedrock beneath swamp | Nil | Further drying of swamp. Greater fire vulnerability | Swamp edge already dry |
| Medium | (C) Possible | (2) Low - minor reversible impact | BS1214 | CCUS4 | Cracking of controlling rock bars | Nil | Drying of swamp - Increased susceptibility to fire | Offset |
| Medium | (C) Possible | (2) Low - minor reversible impact | BT121 | CCUS4 | Reduction and redistribution of flow through swamp | Nil | Increased flow on western side and decreased on eastern side (vegetation reliant on water) | Offset |
| Medium | (A) Almost certain | (1) V Low - negligible effect on flow to reservoir | BS1115 | CCUS4 | Cracking of bedrock beneath swamp | Nil | Reduced flow to creek (max flow 0.1 ML/day). Drying of swamp | Offset |

## 3. COMMENTS ON THE RISK REGISTER

- For the additional controls, the risk register frequently uses, for example 'As per response to AH211', but careful consideration indicates that AH 211 is not really relevant. Also, where the previous text is relevant, it would be helpful to have the relevant text repeated, rather than having to refer back to earlier sheets in the risk register.

- Where have the predicted subsidence parameters been provided for swamps CCUS24 and CRUS6 and where are the swamps located? Clearly state in the risk register.

- The controls regarding the prevention of inflow from the reservoir into the mine workings, as Longwalls 7 and 9 are mined, are dependent on the assumption that the record tracings are accurate. The NSW Department of Industry, Resources & Energy indicated that it is not confident that the plans of the Bulli Pillar Workings are accurate. This may be considered to be a residual risk in the risk assessment. It is recommended that if the panels are accessible, visual observations can be carried out.

- It is understood that the risk of inflows has been removed from consideration due to it being outside the scope of the study. It is however of note that if the pillar dimensions in the Bulli Seam are inaccurate there may be a mechanism for pillar failure and subsidence to occur.

- AS221 regarding possible failure of Russell Vale Seals has been removed as being outside scope, this requires further consideration by SCT.

- BS11311 indicates that swamp CRUS1 has been undermined by Longwall 6 with no observable impacts and that no further impacts are anticipated. Given the fact that Longwall 6 has been only partially extracted at this stage, is it possible that subsidence at the swamp has not been fully developed and that further impact may occur as mining continues?

- Suggested additions to groundwater risks are provided as underlined text in the following table. Comments are provided as underlined text in brackets.

| **LW1 to LW3** | | | **Current controls and/or notes** |
|---|---|---|---|
| AH 11<br>Increased groundwater flows into fractured strata and/or mine voids | AH 111<br>Reduced quantity of water flowing into Cataract Reservoir | - | First and second order streams above LW1-LW3. |
| AH 21<br>Redirection of surface flow due to stream bed cracking | AH 212<br>Surface flows do not re-emerge but divert into the groundwater system and/or the mine | AH 2121<br>Reduced quantity of water flowing into Cataract Reservoir | Maximum decrease of flow to Cataract Creek and Cataract River of 2.35 ML/day. |
| AS 21<br>Depressurisation leads to increased seepage from Cataract Reservoir into the regional groundwater system<br>(Depressurisation of the Bulgo Sandstone groundwater is assumed.) | AS 211<br>Reduced quantity of water in Cataract Reservoir | - | Regional groundwater is below the RL of the base of the reservoir and therefore does not contribute to reservoir storage.<br>(In this context, regional groundwater is assumed to be in the Bulgo Sandstone, as groundwater in the Hawkesbury Sandstone is above the RL of the reservoir. This was confirmed in an email sent by A Wu (text by A Dawkins) (3 September 2015). There is some differing information about the geological unit below/near the reservoir (refer to Appendix 1, A.5). Clarification is required.) |
| **LW6 and LW7** | | | **Current controls and/or notes** |
| BH 11 | BH 111 | - | Mine design with 0.7 depth of cover offset |

| | | | |
|---|---|---|---|
| Increased groundwater flows into fractured strata and/or mine voids | Reduced quantity of water flowing into Cataract Reservoir | | from full supply level of Cataract Reservoir. |
| BS 21<br>Depressurisation of regional groundwater system<br>(Depressurisation of the Bulgo Sandstone groundwater is assumed.) | BS 211<br>Reduced quantity of water in Cataract Reservoir | - | Regional groundwater currently does not contribute to the reservoir as it is below the reservoir level.<br>(In this context, regional groundwater is assumed to be in the Bulgo Sandstone. See above comment.) |
| **LW9 to LW11** | | | **Current controls and/or notes** |
| CH 11<br>Increased groundwater flows into fractured strata and/or mine voids | CH 111<br>Reduced quantity of water flowing into Cataract Reservoir | - | |
| CS 21<br>Depressurisation of regional groundwater system<br>(Depressurisation of the Bulgo Sandstone groundwater is assumed.) | CS 211<br>Reduced quantity of water in Cataract Reservoir | - | Regional groundwater currently does not contribute to the reservoir as it is below the reservoir level.<br>(In this context, regional groundwater is assumed to be in the Bulgo Sandstone. See above comment,) |

## 4. COMMENTS ON PROPOSED CONTROLS

- Controls for groundwater predominantly refer to Section 3, Condition 8 of the draft Development Consent conditions. It is expected that the controls will be provided in detail at a later stage, and that the IRAP will be provided with an opportunity to comment.
- Some text in the risk register under ‘Current Controls’ is not really a control – e.g., AS1124 which states, “There are existing power lines and bike tracks in the swamp with associated clearing and erosion of trails”. Check and correct all current controls.
- Precision and clarity are required for the proposed controls for “medium” and “high” risks.
- It is recommended that during mining exploratory holes may be be drilled to determine the accuracy of the old mine plans as well as to estimate the boundary of the previous workings (this point is repeated in controls). Based on the results necessary controls can be implemented (e.g., change of mine plan).

# Appendix 1: Comments on the Associated Technical Studies

## A.1. COMMENTS ON SUBSIDENCE ASSESSMENT

- A comprehensive historical assessment of Corrimal Fault and D8 Dyke has been conducted. This brings high level confidence to the fact it is highly unlikely that the fault extends under the reservoir. However, a map of Corrimal Fault with respect to the planned workings would be beneficial to show that the fault will intersect one final time in LW7 ~300m away from the reservoir.

- It is considered that the subsidence assessment is sound and acceptable. However, the predictions are based on Longwall 4 and parts of Longwall 5. A back analysis of subsidence predictions for each panel after completion of the panels is recommended. This will enable WCL to assess the validity of the initial predictions and if necessary it will allow additional controls to be implemented. Having said that, a recent report on the back analysis of LW5 reveals that the predictions are within acceptable levels of initial predictions.

- Based on the subsidence predictions, it is considered that the potential consequences and risks to the environment arising out of the subsidence impacts to water quality and quantity in the reservoir are low.

- SCT letter report No.WRCV4440B provides calculations of subsidence based upon pillar sizes of 22m by 33m, mining height of 2.2m and roadway widths of 6m. The mine plan indicates that many of the pillars beneath and beyond the end of Longwall 7 are much smaller in plan dimensions, with some as narrow as 12m. A more accurate assessment might show an increased subsidence, but given the nature of the subsidence that is likely to occur, it is possible that the consequence would not significantly change.

- Insofar as the risk of adverse impacts on water quality and quantity are concerned the subsidence predictions are not critical as the proposed workings are no longer under the reservoir. The critical point is the stability of the approximately 300m wide barrier pillar left between the proposed longwall panels and the reservoir.

- Overall, the proportion of coal that has been extracted from the remaining bord and pillar area would appear to be approximately 37.5%. If the pillars are as shown in the record tracings, and as indicated in Figure 8 of the Geological Report, then the conclusions reached by SCT regarding the potential mode of failure of the pillars, as Longwall 7 is mined in the Wongawilli Seam, would appear to be reasonable. In that situation, it is unlikely that the barrier between the mine and the Cataract Reservoir would be compromised.

- Since the Gretley Colliery disaster in 1996, when the mine plans of an adjacent flooded colliery were found to be inaccurate, the Division of Resources and Energy has added a disclaimer to the abandoned mine plans and record tracings that it provides, noting that it gives no warranty as to the accuracy of them. Because of the disastrous consequences that would result from a significant flow of water from the reservoir into the mine workings, a well-considered and detailed methodology for management of this risk will need to be put in place during mining.

- Another concern relates to the practicality of sealing the mine in the event of significant water make from the reservoir, since the access adit below the escarpment is at a much lower level than the reservoir and the collapsed and fractured zones above the three seams are likely to have hydraulic connectivity. There is no answer to this, other than to ensure that an adequate barrier is left in place and even then further modelling may be required. Adaptive management would not be appropriate to deal with this issue.

- Section 4.9 of the report, Paragraph 1, indicates that four high resolution closure marks had been set up across Cataract Creek to measure the valley closure movements that had been predicted to occur as Longwall 5 was mined. Since this was not done until the extraction of Longwall 4 had been completed, the measured movements did not include any closure that might have resulted from the mining of Longwall 4. Furthermore, valley closure lines CC1, CC2, CC3 and CC4 are too short to capture the total valley closures and only allow measurement of local closure movements across the bottom of the valley. This will not allow comparison of predicted and measured closures with other published research into such movements in the Southern Coalfield. It is an accepted practice to record closure movements on each side of the valley for a distance equal to the depth of cover. Therefore, for future valley closure monitoring it is recommended that the survey lines are extended in length.

- Section 4.9 of the report, Paragraph 3, indicates that the closure increased steadily with longwall face position reaching a maximum of 49 mm when Longwall 5 finished. In context, it is not clear where this closure was actually measured, nor whether it was an incremental or total measurement. The confusion arises because the closures shown in Figure 12 of the report indicate that the maximum values relate to CC1 and CC4, both of which are indicated to have had maximum closures of approximately 45 mm, after ‘adjustment for step changes’. The report should clearly state where the closures were actually measured and where they were incremental or total measurement.

- A number of government agencies expressed concern regarding the levels of uncertainty associated with subsidence prediction. It is considered that this probably stems from some of the earlier predictions that were made, which later proved to be inaccurate, but it will be helpful if the risk assessment has at least considered the possibility that the subsidence effects could be greater than predicted by SCT in its latest report.

- Given that where the three seams have been mined there is the possibility of connectivity from the surface to the mine workings, is there a potential risk that the Bulli Pillar Workings could become flooded beyond the end of Longwall 7 and thus potentially affect the stability of the pillars over time? This risk should be considered.

## A.2. COMMENTS ON SURFACE WATER HYDROLOGY REPORTING

- The updated surface water assessment ‘Surface Water Modelling: Response to Planning Assessment Commission’ (WRM, 19 August 2015) takes account of six months (20/10/2104 – 23/4/2015) of additional flow monitoring data collected at an additional two sites on Cataract Creek and five sites on tributary creeks.

- A somewhat confusing aspect of the report is that the numbering for the monitoring locations does not align with the tributary numbering used for the modelling. (e.g., tributary monitoring location CT2 relates to Tributary 3). Correct this.

- The flow records indicate that there are different hydrologic processes occurring within adjacent catchments which appear to have similar landscape features:

  - The limited data from Tributary 2 (27.5 ha catchment containing swamp CCUS6 and undermined by both Longwalls 4 and 5) shows rapid runoff after rainfall which recedes rapidly. This suggests that this catchment is dominated by surface runoff and that Swamp CCUS6 has little effect on prolonging the flow following rainfall. This behaviour for Swamp CCUS6 is confirmed by the hydrograph (Graph 10 in ‘Preferred Project Report – Biodiversity’, Biosis, 14 June 2104).

  - In contrast, the adjoining catchment – Tributary 3 (25 ha catchment containing part of CCUS3 and undermined by longwalls 4, 5 and 6) shows a rapid response to rainfall and then a slow recession. The hydrograph for Swamp CCUS3 shows similar behaviour to CCUS6 (Graph 10 in 'Preferred Project Report – Biodiversity', Biosis, 14 June 2104). However, the 'Surface Water Modelling' report notes that '…..there is a strong, persistent baseflow response, which may be indicative of groundwater discharge'. This persistence of baseflow in Tributary 3 occurs despite being undermined by Longwalls 4, 5 and 6.

- In the case of Swamp CCUS4 located within Tributary 3, the gauge at the outlet from the swamp and the catchment outlet exhibit similar response with flow reducing to negligible levels within a week to 10 days after rainfall.

- The hydrologic model has been re-calibrated to attempt to capture the responses shown by the most recent flow monitoring in Cataract Creek and the tributaries.

- For the "worst case" assessment of potential loss of flow in the creeks, the modelling assumes 'high runoff' characteristics to the west of Mt Ousley Road and 'low runoff' characteristics to the east. The "worst case" analysis assumes that all catchments affected by mining (189 ha) do not contribute to flow to the reservoir. The results of this modelling are summarised in the table below:

| **Catchment** | **Area (ha)** | **Total Flow (ML/day)** | | **Baseflow (ML/day)** | |
|---|---|---|---|---|---|
| | | **Average** | **Median** | **Average** | **Median** |
| Cataract Creek (existing) | 518 | 13 | 4.9 | 4.1 | 2.9 |
| Cataract Creek (affected catchments) | 189 | 6.4 | 2.8 | 2 | 1.6 |
| Cataract Creek (remaining) | 329 | 6.6 | 2.1 | 2.1 | 1.3 |
| Bellambi Creek (existing) | 932 | 21.7 | 6.2 | 6.87 | 4.29 |
| Bellambi Creek (affected catchments) | 17 | 0.4 | 0.1 | 0.13 | 0.08 |
| Bellambi Creek (remaining) | 915 | 21.3 | 6.1 | 6.7 | 4.21 |

- The tributary flow monitoring appears to show that the swamps do not provide a long term baseflow contribution (as sometimes asserted). Can this be confirmed by the hydrologists and included in the supporting technical documentation?

- The assessed 'worst case' modelling suggests that not only would there be a reduction in flow to the reservoir, but the baseflow in the creek would be zero for large periods of time (see Figures 8.5 and 8.6 in the Surface Water Modelling report (Appendix F to the Residual Matters Report, June 2014). This impact is not included in the risk assessment.

- Assessed 'worst case' loss of flow have been considered as an 'upper bound' in the risk assessment for each group of longwalls (Identifiers AH2121, BH2121, and CH2121 all assessed as medium risk). However, the likelihood and consequence rating for AH2121 is different to BH2121 and CH 2121, but the reason is not apparent. Also, the assessment does not aggregate the overall effect of all three impacts together.

- Has the baseflow contribution from Tributary 3 (assumed to be from groundwater) been taken into account in the groundwater modelling and in the risk assessment?

## A.3. COMMENTS ON HYDROLOGIC BEHAVIOUR OF UPLAND SWAMPS

- There are currently 23 piezometers in various swamps. However, 15 of these have only been installed in the last 12 months and have limited data that warrants analysis.

- The table below summarises the indicative water table recession rates for the longer term piezometers (based only on measurements from graphs in Preferred Project Report – Biodiversity, Biosis, June 2014):

| Swamp | Piezometer | Recession rate (mm/day) |
|---|---|---|
| BCUS4 | PB4C | 15 - 20 |
| CRUS1 | PCr1A | 15 |
| CCUS2 | PCc2 | 40 |
| CCUS3 | PCc3 | 100+ |
| CCUS4 | PCc4D | 20 - 25 |
| CCUS5 | PCc5A | 15 - 25 |
| CCUS5 | PCc5B | 15 - 20 |
| CCUS6 | PCc6 | 65 |

  A detailed data analysis, similar to the above table, would be beneficial for understanding of the relationship between hydrological characteristics of swamps and vegetation.

- The swamps appear to form into two groups:

  - Recession rate 15-25 mm/day – BCUS4, CRUS1, CCUS4, CCUS5;
  - Recession rate 40 + mm/day – CCUS2, CCUS3 CCUS6.

  What does this approximate analysis say about the hydrologic processes? Rates of less than 25 mm/day probably reflect evapotranspiration plus some outflow (eg CCUS4). Higher recession rates suggest either there is a more direct outflow pathway or the water holding characteristics of these swamps are very different to the first group.

- From the clearest mapping (Figure 10 of the Preferred Project Report – Biodiversity, Biosis, June 2014) it appears that the following swamps have not been assessed:

  - CCUS3 located over Longwall 5 – already mined;
  - CCUS6 located over Longwall 4 – already mined;
  - CCUS 7 located north of Cataract Creek – not due to be undermined;
  - CCUS8 located north of Cataract Creek – over the main headings
  - CCUS9 located north of Cataract Creek – over the main headings
  - All BCUS swamps except 4 and 11 – not due to be undermined.

- CCUS4 is rated as having 6 risk aspects, the most serious of which are cracking beneath the swamp and cracking of the controlling rock bar (leading to a 'High' risk rating). How should the other four 'medium risks be considered in respect to the overall risk to the swamp?

- BCUS4 gets a 'medium' risk rating on 4 aspects while CCUS1 and CCUS2 get a 'medium' rating for cracking beneath the swamp.

## A.4. COMMENTS ON THE ECOLOGY

- A summary on the level of dependence of vegetation communities/swamps on groundwater would be beneficial, either in the risk assessment supporting technical information report or in the notes column of the risk register.

- The design of the mine layout has removed some of the high risk ecological habitats (i.e. wetter swamps) from the areas of direct impact, which is an appropriate step.

- Much of the swamp vegetation within the area of potential impacts comprises of hardy vegetation that is not absolutely groundwater dependent - rainwater and surface runoff would play a significant role in sustaining those swamps and, dominant plants are relatively hardy, with potential to survive fluctuating water availability. Such vegetation is not as likely to be vulnerable to changes as would be the case if the swamp was largely or entirely groundwater dependent.

- The recourse to the offset policy provides a backup such that if swamps are monitored and found to be significantly impacted, offsetting can be prescribed.

- With regard to the swamps to be mined under, it is believed that monitoring has been designed to pick up key ecological responses/impacts should there be cracking and draining of the swamps. It is considered that the proposed monitoring strategy is sound and acceptable.

- It is also important to note that much of the "swamp" vegetation in the swamps that will be mined under is actually comprised of relatively hardy vegetation that grows in ephemeral swampy conditions and which is not likely to be quite as sensitive to subsidence impacts as other obligate swamp vegetation.

- The recourse to the swamp offset policy is also a good measure that provides confidence in the monitoring and proposed responses should any ecological damage occur.

- The monitoring results for the current phase of the project should be reviewed and, if relevant, adaptive changes/improvements made to any subsequent phases of monitoring. This needs to be included in the final risk assessment document.

## A.5. COMMENTS ON GROUNDWATER

- The expanded groundwater monitoring network (from late 2014) has improved the understanding of the groundwater systems and allows for better detection of changes to the groundwater systems with continued mining.

- It is understood that following mining, the groundwater levels in Layer 1 (upper Hawkesbury Sandstone plus Newport/Garie Formation, Bald Hill Claystone and Upper Bulgo Sandstone) continue to fall following mining, with drawdown over longwalls 1-3 resulting in permanent dewatering.

- Depressurisation and regional groundwater (AS 211, BS 211 and CS 211) is assumed to be in the Bulgo Sandstone, as groundwater in the Hawkesbury Sandstone is above the RL of the reservoir (refer to Section 3). This was confirmed in an email sent by A Wu (text by A Dawkins) (3 September 2015). Further explanation was provided; ‘in close proximity to the reservoir (such as RV23) the regional gw [groundwater] is within the upper Bulgo Sandstone/Bald Hill Claystone/lower Newport Formation’. There is some differing information which needs clarifying:

    - A cross section near RV23 (Figure 35 in the preferred project report) shows Hawkesbury Sandstone near the reservoir.

    - RV19 is located in close to the reservoir (upstream), with groundwater within the Hawkesbury Sandstone.

- The GeoTerra / GES report (2015) only categorises the deeper Hawkesbury Sandstone aquifer as the ‘regional’ aquifer, which can cause confusion with AS 211, BS 211 and CS 211.

- Recommend to update the conceptual groundwater model (Figure 25) to better represent the conceptual groundwater systems in the vicinity of the Russell Vale Colliery UEP. For example, this figure shows a thick sequence of Hawkesbury Sandstone beneath the reservoir (see point above).

- Recommend to update the piezometer location figure (Figure 10) as the clarity is low and it is difficult to locate each piezometer that is discussed in the report. RV16 is not shown in the figure. In Figure 2, RV20 is shown twice and RV 22 is missing.

NSW GOVERNMENT | Planning & Environment

**Planning Services**
**Resource Assessments**
Contact: Sara Wilson
Phone: 0414 997 714
Email: sara.wilson@planning.nsw.gov.au

Mr David Clarkson
Group Environment Manager
Wollongong Coal Limited
PO Box 281
FAIRY MEADOW NSW 2519

Dear Mr Clarkson

**Russell Vale Colliery**
**Underground Expansion Project (MP 09_0013)**
**Integrated Risk Assessment**

The Department has completed a review of the process and draft documentation completed for the Integrated Risk Assessment for the Russell Vale Colliery Underground Expansion Project (UEP), which was implemented to satisfy Recommendation 1 of the Planning Assessment Commission's *Review Report* (2 April 2015) for the project.

Specifically, Recommendation 1 requires that Wollongong Coal Pty Ltd (WCL) establish:

> *"a risk assessment panel, constituted by an independent Chair, Water NSW, the Dams Safety Committee, the Division of Resources and Energy and the proponent to oversee an integrated risk assessment, particularly focusing on links between subsidence and water (both groundwater and surface water) impacts of the proposal. This risk assessment, including associated work rerunning the groundwater modelling as recommended by Dr Mackie; and addressing the issues raised by the relevant agencies and experts (as highlighted by this report), needs to be completed before the application can be determined.*

The scope of the risk assessment was developed by WCL in consultation with key agencies, and is stipulated in the Terms of Reference (TOR) for the Independent Risk Assessment Panel (IRAP), dated 19 June 2015. In summary, the TOR require WCL to:

- constitute an IRAP to conduct an ongoing assessment of the risks to Cataract Reservoir, groundwater, surface water and upland swamps during the extraction of longwalls associated with the UEP;
- develop a risk assessment methodology;
- utilise the latest available data to identify and assess the risks related to the extraction of the UEP longwalls;
- engage experts to assist and/or review the Risk Assessment Report and any other specialist studies;
- consult with regulatory authorities and Water NSW during the process; and
- implement advice from the IRAP during the Extraction Plan and post-approval stages of the UEP.

The Department is satisfied that WCL is implementing the IRAP process in accordance with the TOR.

On 15 June 2015, the Department approved the members of the IRAP, which include an independent Chair and experts in subsidence, ecology, surface water and groundwater. Risk assessment workshops were held during July and August 2015, where a risk assessment methodology was agreed and the risk assessment was conducted. During this process, the IRAP made a number of recommendations for the provision of additional technical information.

A draft *Risk Assessment Report* and a draft *Risk Register* were subsequently prepared by Broadleaf Capital International Pty Ltd and distributed to agencies on 14 August 2015. The technical information requested by the IRAP was included in a draft document titled *Independent Risk Assessment Panel – Risk Assessment Supporting Technical Information,* which was prepared by Hansen Bailey and submitted to the Department on 19 August 2015. This document included the following additional specialist studies:

- *Review of Barrier to Protect Stored Waters of Cataract Reservoir,* SCT Operations Pty Ltd (SCT), 12 August 2015 (Appendix B).
- *Assessment of Corrimal Fault and Dyke 8 at Russell Vale East as Risks to the Stored Waters of Cataract Reservoir,* SCT, 19 August 2015 (Appendix D).
- *Russell Vale Colliery Underground Expansion Project, Russell Vale East, Revised Groundwater Assessment,* Geoterra Pty Ltd and GES Pty Ltd, 18 August 2015 (Appendix E).
- *Russell Vale Colliery Underground Expansion Project – Surface Water Modelling: Response to Planning Assessment Commission,* WRM Water & Environment Pty Ltd (WRM), 19 August 2015 (Appendix F).

The Department is satisfied that SCT has provided a comprehensive discussion of the background to the selection of the protective barrier between the proposed mining and Cataract Reservoir and its suitability in the context of historical experience. The Department is also satisfied that all existing available information on the Corrimal Fault and Dyke D8 has been thoroughly analysed. It is noted that the Dam Safety Committee (DSC) has indicted that it is also satisfied with the information included in the SCT reports.

The Department is satisfied that the *Revised Groundwater Assessment* and model utilises the latest available data, including data collected from an expanded piezometer network and recent monitoring following extraction of Longwall 6 (340m), to provide an updated understanding of the local groundwater system and predicted mine inflow dynamics. The Department considers that the revised assessment addresses the groundwater related issues raised in the Commission's *Review Report* (refer to Appendix A of the assessment).

The Department accepts that the revised *Surface Water Modelling* undertaken by WRM utlises recent flow monitoring data from an expanded surface water monitoring network to refine the previous estimates of steamflow and baseflow losses associated with the UEP. However, the Department maintains its previous position that this type of modeling provides coarse estimates rather than firm predictions.

Overall, the Department is satisfied that the additional technical information provides greater confidence in the previous predictions made in relation to the impacts of the UEP on underground and surface waters, and the risks to the stored waters in Cataract Reservoir.

The Department distributed the draft *Risk Assessment Report,* the draft *Risk Register* and the *Supporting Technical Information* to agencies for comment. The comments received from the Office of Environment and Heritage and Water NSW are attached to this letter. Comments from the Department of Primary Industries (Division of Resources and Energy) will be forwarded to you as soon as they are received by the Department. The Dam Safety

Committee and Department of Primary Industries (Water) have advised that these agencies will not be making further comments.

Wollongong Coal is requested to address the issues raised in agency comments during the finalisation of the Risk Assessment Report.

If you have any questions in relation to this matter, please contact Ms Sara Wilson on phone 0414997714.

Yours sincerely

Howard Reed

Howard Reed 7.9.15
**Director**
**Resource Assessments**

| | |
|---|---|
| **From:** | Malcolm Hughes |
| **To:** | Margaret Kirton |
| **Cc:** | Fiona Smith; Peter Dupen |
| **Subject:** | RE: Russell Vale UEP - Integrated Risk Assessment meeting |
| **Date:** | Monday, 7 September 2015 10:11:01 AM |
| **Attachments:** | image002.png |

Hi Margaret

Thank you for the opportunity to provide comments on the draft Integrated Risk Assessment and associated supporting documents as described below:

- Broadleaf Capital International Pty Ltd. - UEP Draft Integrated Risk Assessment Report and draft Risk Register dated 15 August 2015
- Hansen Bailey – UEP Independent Risk Assessment Panel – Risk Assessment supporting documents dated 19 August 2015:
- SCT, 2015a – Review of Barrier to Protect Stored Waters of Cataract Reservoir
- SCT, 2015b - Response to Galvin & Associates Pty Ltd Report dated 3 March 2015
- SCT, 2015c – Assessment of Corrimal Fault and Dyke D8 at Russell Vale East as Risks to the stored waters of Cataract Reservoir
- Geoterra/GES, August 2015 – UEP Russell Vale East Revised Groundwater Assessment
- WRM, August 2015, August 2015 – UEP Surface water modelling – Response to PAC

WaterNSW requests the following issues be further considered before the report is finalised:

- Table 9 in the Broadleaf Capital International Pty Ltd - UEP Draft Integrated Risk Assessment Report and draft Risk Register dated 15 August 2015 identifies consequences. The table identifies consequences for water volume and focusses on water flows into Cataract Reservoir but does not address water flowing out of the reservoir into the groundwater system or mining voids. This needs to be added to the table.
- WaterNSW is aware that during previous Bulli Seam mining north of the Russell Vale mine area in the mid-2000's at the former Bellambi mine, a large intrusive was intercepted (see attached figure and summary). This intrusive body was found to consist of an emplacement of a hard Igneous Dyke/Sill wrapped by a halo of soft Sill/Cinder. Mining of Longwalls 509 & 510 was modified to terminate about 110 m prior to the intercepting the dyke. Inspection of LW508 (just south of 509 west block) indicated "minor drips and wetness where the longwall intersected the dyke, which could suggest a high probability of loss of stored water from the Cataract reservoir into the mine workings had LWs 509 and 510 been extracted at full length". The dyke had not been detected by surface mapping. The risk assessment should respond to this information.
- With regards to valley closure on Cataract Creek, the Risk Register (AH211, BH211, BS131, CH211) proposes a control of adaptive management by ceasing extraction of the active longwall should trigger values for valley closure in Cataract Creek be reached. Some further information on the proposed adaptive approach (including indicators, triggers and responses) is requested so that WaterNSW can be satisfied that the Department's proposed performance measure for this creek would be met.
- The WRM, August 2015, August 2015 – UEP Surface water modelling – Response to PAC report notes that some subcatchments of Cataract Creek are likely to have already been impacted (flow reductions and iron staining) by previous mining subsidence. They

provide a “worst-case” prediction that if all surface waters were to be lost from impacted catchments, a maximum average total of 7.5 ML/day (2.74 GL/year) would be lost from creeks and tributaries flowing Cataract Reservoir. The Geoterra/GES, August 2015 – UEP Russell Vale East Revised Groundwater Assessment contradicts this prediction (although only on the basis of groundwater modelling so is less authoritative), and instead predicts that a total of 15 ML/year would be lost due to baseflow, surface flow and leakage from base of storage losses. WaterNSW requests clarification on the predicted maximum water loss.

WaterNSW has some additional comments for the Department’s consideration:

- The draft Risk Register Item BS23 – Hydraulic Connectivity associated with the Corrimal Fault notes section states that: As per DSC requirements dated 26 March 2015, “The presence or absence of the Corrimal Fault will be proved by the development of MG 7 first workings. If the Fault is intercepted then the DSC will not recommend the approval of the western end of LW 7 and will request that the longwall be setback from the Fault, leaving a hydraulic barrier of coal against the Fault for protection against ingress. If the Corrimal Fault is absent from LW 7 MG, the DSC has no concerns with the extraction of Long all 7 regarding the Fault”. WaterNSW understands the company has stated its commitment to add this requirement to the UEP’s Statement of Commitments. If this is not done it should be recommended to the PAC as a condition of approval in the development consent should they decide to approve the project.
- During a meeting WaterNSW had with Wollongong Coal on the 31 August, the company advised that they have recently submitted an updated draft Mine Closure and Contingency Plan to the Dams Safety Committee. WaterNSW requested a copy as we have a key interest in this plan and we want to be satisfied it is adequate. The company has yet to provide a copy to WaterNSW – although it is expected today. The Department should not consider recommending approval unless it is satisfied that the proposed Mine Closure and Contingency Plan contain feasible closure and contingency measures.

WaterNSW emphasises the following - The proposal includes mining under significant upland swamps which if approved would cause environmental consequences greater than negligible. WaterNSW considers this is an unacceptable level of environmental consequence. We note that it is proposed to require offsets to mitigate this level of environmental consequence. We discussed offsets during the meeting WaterNSW had with Wollongong Coal on the 31 August and it was emphasised by WaterNSW that any offsets should be located within the local catchment where the swamps are located.

Regards
Malcolm

**Malcolm Hughes**
Senior Manager Planning & Environment
WaterNSW

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**T:** 02 47242452 **M:** 0427 466 934

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**From:** Margaret Kirton [mailto:Margaret.Kirton@planning.nsw.gov.au]
**Sent:** Thursday, 3 September 2015 1:42 PM
**To:** Malcolm Hughes
**Subject:** Russell Vale UEP - Integrated Risk Assessment meeting

Hi Malcolm,

I have been trying to call you to let you know that tomorrow's meeting between the agencies and the IRA Panel has been cancelled, but I haven't been able to get through.

If you have any final comments to make on the draft IRA, it would be appreciated if they could be received by cob Friday, 4 September.

Please give me a call if you have any questions.

Regards Margaret

***Margaret Kirton***
***Senior Planner***
***Resource Assessments***
***Department of Planning & Environment***
***GPO Box 39 | Sydney NSW 2001***
***T 9228 6289***
***E Margaret.Kirton@planning.nsw.gov.au***

## Figure 1 Location of Subsidence Survey Lines

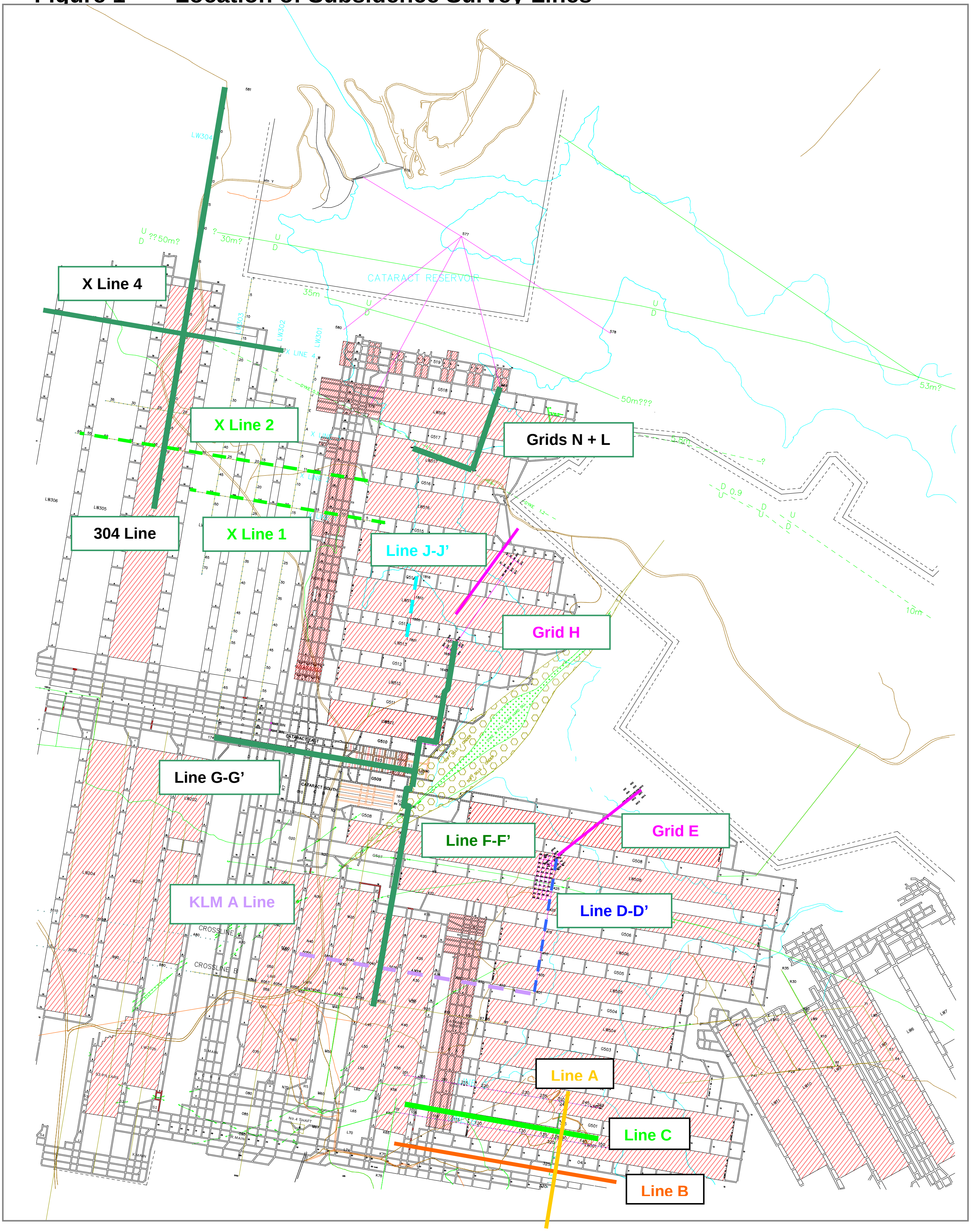


Figure 1 shows the location of Cataract Dam and Storage, subsidence survey lines, 500 & 200 series longwalls and the emplacement of a hard Igneous Dyke/Sill wrapped by a halo of soft Sill/Cinder in the Bellambi mine south of Cataract Dam and north of Russel Vale.

Mining commenced in 509/510 west block on 27 August 2005. The first phase of extraction involves splitting the pillars, while pillar extraction commenced in mid-October. 509 west and 510 west are short blocks terminating about 110m prior to the large igneous dyke. Inspection of LW508 (just south of 509 west block) indicated minor drips and wetness where the longwall intersected the dyke, which could suggest a high probability of loss of stored water from the Cataract reservoir into the mine working had LWs 509 and 510 been extracted to full length. Note that the dyke was not detected by surface mapping technique.

| | |
|---|---|
| **From:** | James Dawson |
| **To:** | Margaret Kirton |
| **Cc:** | Lachlan Wilmott; Martin Krogh; Gabrielle Pietrini |
| **Subject:** | OEH preliminary comments on Russell Vale UEP risk assessment report |
| **Date:** | Wednesday, 2 September 2015 10:43:19 AM |
| **Attachments:** | image001.png |

Dear Margaret,

OEH has briefly reviewed the Russellvale UEP Intergrated Risk Assessment Report and supporting documents. Please note that we have previously provided detailed comments on the impacts of the development particularly on upland swamps and groundwater.

The UEP Integrated Risk Assessment Report does not adequately address OEH's previous concerns and OEH believes that many of our earlier comments are still relevant. OEH is particularly concerned that the UEP ignores the advice and recommendations of the Australian Governments Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mines (IESC 2014, 2015), who made quite specific recommendations about risk to coastal upland swamps, surface water, groundwater and threatened species in relation to the Russell Vale Expansion proposal.

OEH questions the independence of the UEP risk assessment, as it appears to have been written by the same consultants who produced the EIS/EA and the
RTS.

Major continuing concerns include:

**Application of the Risk Assessment to upland swamps**

- The Integrated Risk Assessment Report includes a framework for risk assessment which considers likelihood, consequence and ability for remediation to occur. OEH believes that applying this assessment in light of the subsidence predictions, fracturing thresholds and the inability to remediate swamps would result in higher risks than are currently identified. OEH has previously disagreed with the risk assessment applied to upland swamps and in response undertaken our own risk assessment to individual swamps which identified most of the swamps being at High Risk (see OEH Comments 14 July 2014).

- The IESC does not consider that concerns regarding the loss of water from swamps (and streams) to mines or lower aquifers due to deep connective cracking has been explicitly assessed by the proponent. The IESC considers that the loss of any water from swamps due to cracking, regardless of whether it is lost through deep connective cracking to the mine or deeper aquifers, or through shallow cracking and re-emergence down gradient within Cataract Catchment, presents a significant risk to their long term viability.

- The IESC is not satisfied that the proponent has provided supporting evidence that redirected surface flow will re-emerge down gradient within Cataract Creek or directly into Cataract Reservoir.

- The likelihood that cracking and tilting will occur to the base of at least 14 swamps within the project area is considered high.

- The initial risk assessment within the biodiversity assessment used established criteria, which indicated that 14 swamps are likely to experience negative environmental consequences. The final risk assessment potentially underestimates the risks to swamps from cracking by equally weighting risks to perched water and flow accumulation, resulting in the proponent's final ranking of risks as low, where there remains a high likelihood of cracking and tilting. The risks assigned to compressive tilts and strains within the final risk assessment should be considered high where they exceed established criteria.

- The subsidence assessment does not provide a reasonable estimation of the risk of impacts to overlying swamps as it does not take into account potential increased subsidence implications of multiple goaf strata settling after longwall extraction, and possibly underestimates the risks of cracking beneath swamps by using less stringent strain criteria than elsewhere in the Residual Matters Report.

- The hydrological and soil conditions within the swamps provide habitats for an array of threatened flora and fauna communities. Where these threatened species occur, the loss or severe decline of the swamps within the project area would be expected to negatively impact these species

- Changes to the slope (through subsidence induced tilt) above the established subsidence criteria are predicted to occur in 14 headwater swamps within the project area. Tilts are predicted to range between 19 and 32 mm/m at various points within these swamps. Tilt is predicted to be most severe where multiple underlying goaves are directly adjacent to multiple underlying chain pillars (for example, between proposed longwalls one to three and between longwall five and proposed longwalls six and seven). In these locations, changes to surface flow regimes are expected to be more severe, and therefore these localities represent a higher risk to headwater swamps.

**Subsidence assessment and potential for connective fracturing**

- The proponent has not provided adequate justification for the use of 0.7 times depth of cover for the setback.

- The IESC does not have increased confidence from the proponent's response that the proposed project would not have a significant impact on the stored waters of Cataract Reservoir through connective cracking.

- The potential for impacts outside the 35º angle of draw and for connectivity along shear planes, the lack of measurements of height and lateral extent of fracturing and depressurisation above mined Longwalls 4 and 5, and the uncertainty associated with the extent of Corrimal Fault highlighted by the NSW Dam Safety Committee (2014) and the Sydney Catchment Authority (2014), contribute to a continued level of uncertainty regarding the potential connectivity between the reservoir and the proposed project.

- SCT (2015; Ken Mills) has stated "*based on SCT's experience of monitoring groundwater depressurisation directly above extracted longwall panels at multiple sites, the* [Tammetta] *approach appears to give a very reasonable estimate of the height of depressurisation. This outcome is not surprising given the Tammetta approach is derived from a broad database of hydrogeological experience in single seam mining situations. At Russell Vale East, the Tammetta approach is not so applicable because of the multi-seam interactions that may be occurring. A key point however, is that the Tammetta approach is likely to provide a lower limit on the height of depressurisation given that the presence of multi-seam mining is expected to increase the height of depressurisation compared to an equivalent single seam situation*"

  Tammetta (Coffey 2013 GEOTLCOV24840AA-AB) has already assessed the potential for depressurisation (surface to seam connective fracturing) above the earlier Russell Vale East proposal (the mine layout hasn't really changed all that much compared to what is currently proposed and predicted subsidence is still very similar) indicating that the height of depressurisation was predicted to extend to the surface over many areas of the proposed mine plan. Tammetta (Coffey 2013 GEOTLCOV24840AA-AB) concluded that "*Figure 9 shows the protrusion of the interpreted potential drainage thickness above ground surface for Wonga East. Outlines of significant swamps are also shown. Complete drainage is calculated to occur over parts of LW3 to LW8.*"

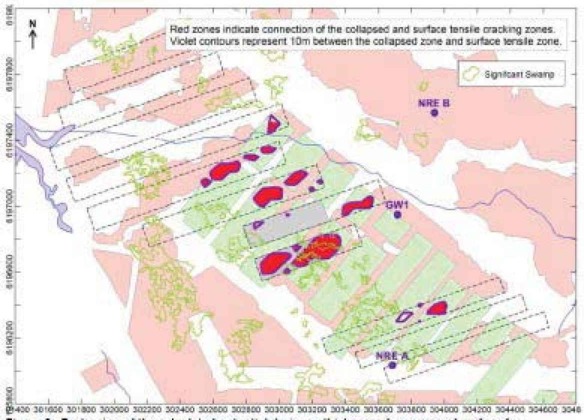

Figure 9. Protrusion of the calculated potential drainage thickness above ground surface for Wonga East.

  "*A serious risk to Cataract Creek is present in the area where Cataract Creek, Balgownie LW11, a Bulli pillar extraction block, and Wongawilli panels LW7 and LW8 coincide (see Figures 9 and 1a). The interpretation indicates that the collapsed zone and surface tensile fracturing zones will connect in this area, and lead to creek drainage into the mined void. The calculated baseflow of Cataract Creek is 11.7 ML/day (see above), which is 6% of the average water volume generated by Lake Cataract between 2006 and 2012 (from the SCA water balance reports web page).*"

- If Tammetta's assessment of depressurisation is likely to underestimate the degree of depressurisation due to the presence of **multi-seam mining which is expected to increase the height of depressurisation compared to an equivalent single seam situation** (SCT 2015), then the UEP risk assessment is clearly out of step with statements and predictions from their own subsidence engineer, Coffey 2013 and the IESC.

**Giant Dragonfly**

- The Giant Dragonfly is a swamp dependant endangered species that is known from only a limited number of swamps on the Woronora Plateau. Two of the three swamps the species is known to inhabit within the UEP mining domain are planned to be undermined however impacts to this species has not been included in the risk assessment.
- The IESC (2014) carried out a sensitivity analysis of the likely impacts to individual species resulting from a range of likely impact factors resulting from mine subsidence in upland swamps. They concluded "*because inundation controls peat*

*stability and fire (the other two strongest influences), it is the most important aspect of the swamp to maintain*". Furthermore, "*The giant dragonfly appears to be the worst affected at high-impact scenarios but is also substantially affected with low-impact scenarios*".

OEH is happy to discuss these and issues at the meeting on Friday.

Regards,

James


**James Dawson**
Senior Team Leader, Ecosystems and Threatened Species
Illawarra Region
South Branch, Regional Operations Group
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## Dianne Munro

**From:** Heather Middleton <heather.middleton@damsafety.nsw.gov.au>
**Date:** 10 September 2015 3:00:27 pm AEST
**To:** David Clarkson <dclarkson@wcl.net.au>
**Subject: Comments for DPE**

DSC staff have had the opportunity to review the documents presented at the recent MSC meeting and are satisfied with the approaches WCL have taken to address issues with respect to the development of effective contingency and closure plans.

DSC staff are confident that WCL have demonstrated that in the unlikely event of a connection to the Mine developing, that water from the outflow could be contained for an extended period (up to 10 years) in the workings that currently exist underground and would therefore have ample time to install effective seals where required.

DSC would have no difficulty in approving extraction of longwall 7 if the Corrimal Fault is absent, or can be demonstrated to be terminating at longwall 7. Even if the Corrimal Fault is demonstrably present in LW7, DSC has no concerns with extraction of the Eastern 2/3 of LW7, but may insist on a leaving a hydraulic barrier of solid coal against the fault for protection against ingress.

DSC staff are satisfied with the Integrated Risk Assessment that has been undertaken on behalf of WCL and feel that the process undertaken was as rigorous and far reaching as is possible given the nature of the risks being assessed.

kind regards

**Heather Middleton | Acting Manager of Mining Impacts**
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## Margaret Kirton

| | |
|---|---|
| **From:** | Chris Hammersley <chris.hammersley@industry.nsw.gov.au> |
| **Sent:** | Wednesday, 9 September 2015 1:01 PM |
| **To:** | Margaret Kirton |
| **Cc:** | Greg Kininmonth |
| **Subject:** | FW: Russell Vale UEP Risk Assessment |

Good Afternoon Margaret
Please find below ESU comments in respect of the Integrated Risk Assessment of the UEP – Russell Vale Colliery

**Final Report : Integrated risk assessment for the UEP (draft, version 4, 14 August 2015)**

Table 2. DRE is not mentioned in the stakeholder group, however in the Introduction section under "Scope of the risk assessment" - water/subsidence Point 1 identifies the establishment of a risk assessment panel
"by an independent chair, Water NSW, the Dams Safety Committee, the Division of Resources and Energy and the proponent to oversee an integrated risk assessment",

Table 3 Context Summary – under External Factor - "the region includes important ecological resources" and then states under Implications - "these are primarily upland swamps, which could be impacted". DRE would like to see this section provide more detail as to what "ecological resources" the upland swamps contain.

Section 7 Risk treatment – refers to an action plan to address major risks and areas of residual uncertainty. Many of these are noted in the "Risk Register" (Broadleaf 2015). However what action plans are not included in the "Risk Register" and where are these located?

- **Risk Register – Integrated Risk Assessment for the UEP (draft, Version 1, 14 August 2015**

The statement throughout the "Risk Register Table under the "Notes" column states the following: "Empirical observations suggest there is no effect on swamps that are not directly over the longwalls, with previous mining resulting in softening of underlying strata resulting in subsidence being confined to the longwalls (rather than a typical subsidence bowl)". It is ESU's understanding that previous mining was mostly board and pillar extraction with some mini-longwall and some longwall extraction.

In the "Additional Controls and Treatments" column – there is a common reference to "NR" (not required). Why is (N/A) Not applicable not used?

In row "BH 213" refers to "BH2 Valley Closure on Cataract Creek" but in notes refers to "mining has previously occurred beneath this swamp twice"?

In row "BS 1124" – grammatical error in Notes section "A small area (0.51 ha) of CCUS1 ois"

How can we be certain for example in row "CS1153 – in "Notes" Mining beneath swamp BCUS4, likely to result in tilts and strains of sufficient magnitude to result in fracturing, will be restricted to a small upper section of this upland swamp" that there is no disconnectivity and discontinuity of water moving from the upper level to a lower level?

Can the risk assessment include a plan with proposed LW's and creeks and swamps identified on it.

Regards

Chris Hammersley | Inspector – Environment (Southern)
NSW Dept of Industry | Division of Resources & Energy | Environmental Sustainability Unit
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# Final Risk Assessment

To: Rhys Brett
Business Development Manager
Wollongong Coal
Email: rbrett@wcl.net.au
P: 02 4223 849
CC: Dianne Munro and David Clarkson

From: Independent Risk Assessment Panel

Date: 28 September 2015

REVIEW OF THE RISK ASSESSMENT CONDUCTED FOR THE RUSSELL VALE COLLIERY UNDERGROUND EXPANSION PROJECT

Dear Rhys,

The Independent Risk Assessment Panel (IRAP), which comprises Ismet Canbulat, Arthur Waddington, Andrea Madden, Steve Perrens and David Robertson, has conducted a review of the integrated risk assessment conducted by Wollongong Coal Limited (WCL) for the proposed Russell Vale Colliery Underground Expansion Project (UEP).

In line with the Terms of Reference provided by WCL, IRAP's review included the risks to Cataract Reservoir, groundwater, surface water and Upland Swamps during the extraction of Longwalls 1, 2, 3, 6, 7, 9, 10 and 11. As part of the review, the technical studies conducted by WCL provided the background information for the expected subsidence and associated potential impacts related to the extraction of the above mentioned longwall panels in the Russell Vale East area.

The review by IRAP consisted of two stages. In the first stage the risk assessment methodology that was developed by DF Cooper of Broadleaf and WCL was reviewed. IRAP provided comprehensive comments on the risk assessment methodology in a report, entitled "Russell Vale Colliery, Independent Risk Assessment Panel, Review of the Proposed Risk Assessment Methodology", dated 15 July 2015. WCL adapted the methodology in line with IRAP's recommendations and the adapted risk assessment methodology was approved by IRAP in a letter entitled "Review of the Risk Assessment Methodology Proposed for the Russell Vale Colliery Underground Expansion Project, dated 31 July 2015.

In the second stage, the risk assessment that was conducted by WCL was reviewed. The risk assessment was facilitated by DF Cooper of Broadleaf and the results were conveyed in a draft report entitled "Final report: Integrated risk assessment for the UEP Wollongong Coal, Russell Vale Underground Expansion Project", dated 14 August 2015. A risk register was also provided by Broadleaf in a separate report, entitled "Risk register: Integrated risk assessment for the UEP, Wollongong Coal, Russell Vale Underground Expansion Project", dated 14 August 2015 (Version 1). Detailed comments on the risk assessment and the associated documentation was provided by IRAP to WCL in a report, entitled "Russell Vale Colliery UEP IRAP Review of the Integrated Risk Assessment", dated 10 September 2015. IRAP comments have been addressed in the final risk assessment and the associated documents.

It is the IRAP's opinion that the risk assessment has been conducted by appropriately qualified experts in the fields of mine subsidence engineering, groundwater, surface water and ecology. It is understood that the WCL experts worked on the project together for a considerable period of time, which provided them the experience and the knowledge required to conduct the "integrated" risk assessment, which aims to ensure that the risks associated with underground mining on the quantity and quality of groundwater and surface water as well as upland swamps have been assessed and appropriate controls are identified.

Following an extensive review of the risk assessment and the relevant documentation, it is the opinion of IRAP that the risk assessment is 'integrated' and has been based upon an approach that is sufficiently detailed and at an appropriate level to evaluate the risks to the swamps, streams, groundwater and the waters of Cataract Reservoir.

Yours Sincerely

Ismet Canbulat
On Behalf of the Independent Risk Assessment Panel

## *APPENDIX D*

## Review of Barrier to Protect Stored Waters of Cataract Reservoir

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12 August 2015

David Clarkson
Group Environment Manager
Wollongong Coal
PO Box 924
Dapto NSW 2530

Dear Dave

**REVIEW OF BARRIER TO PROTECT STORED WATERS OF CATARACT RESERVOIR**

Wollongong Coal is proposing to mine coal in the catchment of Cataract Reservoir in the Southern Coalfield of New South Wales using longwall mining methods. The stored waters of Cataract Reservoir are recognised to be a significant asset that is required to be protected from mining impacts. In the mining layout proposed for the Russell Vale East area (referred to as the PPR), a protective barrier to the full supply level (FSL) of Cataract Reservoir was used to preclude longwall mining in close proximity to the reservoir. The size of this barrier is based on 0.7 times depth (35° angle of draw) or about 200 m horizontal distance at this site. This document outlines the background to the selection of this barrier size and assesses its suitability in the context of historical experience.

The Dams Safety Committee (DSC) is the body entrusted to protect the stored waters of Cataract Reservoir and has powers under the Mining Act 1992 to regulate mining within Notification Areas around these stored waters. The DSC is not prescriptive in regards to barrier size and prefers a risk based assessment process. The mine design process requires an initial barrier size to be adopted prior to conducting such a risk assessment or more detailed studies.

Barrier sizes implied or accepted in historic legislation and current practice range in size from zero to 1.2 times overburden depth. A 0.7 times depth barrier was used for the initial PPR design because it is consistent with historical norms that existed prior to the Reynolds Inquiry and is about 50 m more than the offset recommended by Reynolds (1977) based on the findings of a Commission of Inquiry into coal mining under or in the vicinity of the stored waters of the Nepean, Avon, Cordeaux, Cataract, and Woronora Reservoirs in New South Wales, Australia. Subsequent investigations including groundwater monitoring and modelling, indicate that this 0.7 times barrier is conservative to fully protect the stored waters of Cataract Reservoir and, on this basis, the 0.7 times depth barrier has not been changed.

## 1. CURRENT DSC CONTROL MECHANISM

In New South Wales, the integrity of major water supply infrastructure is safeguarded by the *Dams Safety Act (1978)* and the DSC responsible for administering the Act. Section 89 of the *Mining Act 1992* requires the Minister to notify the DSC of any proposal to mine with a Notification Area. The DSC may object to the granting of a mining lease within a Notification Area. The Notification Area includes the structures (dam wall and spillway), the stored water, and an area around these where mining has any significant potential to affect the dam or the security of its stored water.

Current policy of the DSC as outlined in DSC4B (2010) indicates that:

> *Approvals to mine in Notification Areas are issued subject to conditions recommended by the DSC which may limit the extent and type of mining, specify a particular layout, or may stipulate a monitoring program or other project be undertaken. Each mining application is assessed on its merits and there are no predetermined limits on the extent or type of mining. However, it is unlikely that an applicant will be able to demonstrate that following mining would be within tolerable limits for a major water supply dam (particularly a concrete dam).*

- *Uncontrolled extraction (e.g. full sized longwalls) within 1.7 times depth of cover of the dam structure.*
- *Any mining within 1.2 times depth of cover of the dam structure.*
- *Mining under the stored waters with less than 60 m depth of cover.*
- *Secondary extraction (e.g. longwalls or pillar extraction) under the stored waters with less than 120 m depth of cover.*
- *Uncontrolled extraction under the stored waters.*

The absolute minimum barrier to uncontrolled longwall mining implied in these guidance notes is indicated in the last dot point to be zero metres, but, in practice, the DSC seek confidence that the stored waters are protected through individual assessment on a case by case basis anywhere within about 1.2 times overburden depth. The DSC has previously approved controlled extraction directly under the stored waters of Cataract Reservoir at South Bulli Colliery (now Russell Vale Colliery) with appropriate limits on panel width and the size of intermediate chain pillars.

For larger longwall panels in a location where there has been previous mining in other seams such as the Russell Vale East area, extractive mining directly below the reservoir, controlled or otherwise, is unlikely to provide the same level of protection to the stored waters as is possible for single seam mining and a suitably sized barrier is recognised to be a more effective protection strategy.

In order to develop a suitably sized barrier, it is helpful to understand the history of interactions between mining and stored waters and the frameworks used to control mining activity. The minimum barrier size adopted at Russell Vale East is based on 0.7 times depth because such a barrier is considered sufficient to provide full protection to the stored waters of Cataract Reservoir at this site (notwithstanding that geological structures require their own assessment). A barrier of this size is also consistent with the benchmark barrier size indicated in the DSC guidance notes implied by the requirement for a line indicating 0.7 depth to be included on mining plan applications.

A review of historical prescriptive guidelines indicates that this size barrier is likely to be conservative and ensure that the stored waters of Cataract Reservoir are fully protected.

## 2. Historical Interactions Between Mining and Regulators of Stored Waters

Reynolds (1977) provides a summary of the interactions between mining interests and the various government bodies responsible for the water supply catchment up until that time. This section draws from that summary. The development of the Reynolds Guidelines, the formation of the DSC, and the creation of the role of the Principal Subsidence Engineer within the Department of Mineral Resources followed as a more flexible means to administer mining operations in catchment areas and to continue to develop understanding of mining interactions with stored waters.

A debate between the NSW Metropolitan Water, Sewerage and Drainage Board (the Board) and Department of Mines (the Department) regarding the appropriate level of protection to be afforded the metropolitan catchment areas from the impacts of underground coal mining was first raised circa 1880 at the proclamation of the Sydney water supply catchment area.

Due to deficiencies in the legislation of the day, the Board did not have effective authority or control over the catchment and was not able to redefine its boundaries. The Board was also not able to prevent dealings with the title to land or limit the type of land use. However through inter-departmental cooperation, authority and control over the surface of the catchment was able to be exercised. Subsequent changes in legislation gave the Board the power to prevent pollution of the water supply caused by surface activities but its control of mining under the catchment was restricted to comments regarding the granting of mining rights to be issued by the Minister in accordance with the Mining Act.

Around 1903, concerns were raised relating to the possible effects of undermining the structures and storages with the construction of Cataract Dam. At the time, the Board contended that no mining should be allowed under the stored waters and within a ¼ mile (about 400 m) of their limits. The Department disagreed, allowing for coal to be mined under the catchment provided that complete protection for the dam structures was maintained. However special provisions were inserted by the Department into lease conditions limiting minimum pillar sizes and adits and shafts locations within the catchment areas. Lease conditions aimed at providing protection for the stored waters continued to evolve to allow bord and pillar mining under the stored waters (and marginal zones) while prohibiting secondary pillar extraction. Marginal zones around the stored waters were determined by horizontal measurements (in units of chains – approximately 20m) in excess of a minimum 10° angle of draw.

In 1950 proposed changes to lease conditions based on international experiences were recommended including allowing a greater percentage of extraction to occur based on a minimum overburden thickness. The Board protested against the proposals, seeking a larger marginal zone and special protection measures in the case of geological faults. It seems that the Board accepted that some mining could be tolerated under the stored waters and acknowledged that its policy in regard to no mining under stored waters was difficult to defend due to a general lack of knowledge of the issue within the Board.

In 1959 the Board took an aggressive step in asking the Department to exempt the whole catchment area from the leasing provisions of the Mining Act. The Department refused.

In 1960 the Board objected to a number of mining applications, advising against mining under stored waters or water supply structures or within a rationally determined marginal zone (that was acceptable to the Board).

Over the next few years a series of conferences were held between the Board and the Department in an attempt to reach agreement. A series of compromises appears to have been made during and between these conferences. These included increasing the size of the marginal zone around the boundary of the stored waters and provision for geological features. In 1961 an agreement was reached that the marginal zone around the Full Supply Level (FSL) would be a 35° angle of draw equivalent to 0.7 times depth. During 1962 further discussions centred on the size of the barriers to be left below the various dam structures.

By 1963 the Board was still insisting that no mining should be allow beneath the stored waters and retaining structures except for controlled access roads and that additional buffers be provided against geological features, however the size of the marginal zone was ratified between the parties as a 35° angle of draw. Additional international research into this matter was also conducted at this time. The Department would not agree to fully implement the Board's requirements and as such the deadlock remained for another nine years until, in 1973, a Commission of Inquiry was formed to investigate the effects of mining on the stored waters of the five dams located below the Woronora Plateau (Reynolds 1977). This inquiry has become known as the Reynold's Inquiry.

The Reynold's Inquiry was far reaching in its scope of investigations including overseas study tours and the advancement of mining subsidence monitoring data collection and analysis standards generally. Likewise the findings and recommendations are comprehensive and appear to be scientifically robust as they continue to be consistent with current understandings of mining subsidence interactions with surface and groundwater systems. They also addressed inconsistencies in the legislation standards of the day that had potentially contributed to disagreement between officers of the Board and the Department.

Justice Reynolds concluded that mining should be allowed beneath the stored waters with proper safeguards in place and detailed the nature of mining geometries that would provide these safeguards. Reynolds recommended a marginal zone around the FSL of the stored waters based on a barrier equal to 0.5 times depth (26.5° angle of draw). Reynolds also recommended that the field of subsidence engineering be further developed and made comment on possible pathways for the implementation of the Inquiry's recommendations.

An outcome of the Reynolds Inquiry was the creation of the *Dams Safety Act 1978* and Dams Safety Committee (DSC) to administer that Act. Since then, the DSC has used the Reynolds Inquiry recommendations as a guide without being bound by them.

At the inception of the DSC, extra buffer zones additional to the Reynolds Inquiry recommendations of 0.5 times depth were used as the basis for defining where mining activity adjacent to stored waters may need to be controlled although extractive mining was still permitted within this zone. This zone was called a restricted zone and was equal in size to 0.7 times depth (35° angle of draw) plus an additional 0.5 times depth giving a total distance from the reservoir FSL of 1.2 times depth. The DSC was not typically interested in mining activities outside of the 1.2 times depth barrier. Outside of the 0.7 times depth barrier, there was typically no restriction on mining but the DSC was able to limit mining if necessary. Within the 0.7 times depth barrier, mining activity was controlled.

Many examples of uncontrolled secondary extraction exist in the Southern Coalfield where a barrier of 0.7 times depth has successfully provided protection barrier for the storage reservoirs. There are also a number of examples of much smaller barriers (10° angle of draw or 0.17 times depth) being used effectively as the boundary between unrestricted and limited mining at moderate depths of cover. However, an inflow event that occurred at Blue Panel in Wongawilli Colliery and another at Kemira Colliery (Mt Kembla Colliery) highlighted the need for minimum depth limits and an awareness of the potential influence of geological structures.

With the passage of time, increased experience, and other advances in understanding as well as changes to the way mining leases are administered (e.g. consolidation of mining leases and modification to the way notification areas around prescribed dams function), the DSC has moved away from prescriptive guidelines toward a risk assessment based approach exercised on a case by case basis. This approach allows for recognition of far field subsidence effects, valley closure effects, previous mining, and special geological structures to be properly considered and assessed for each site. Nevertheless, the application of the historical barriers that were successfully used when barriers were prescribed provides a strong basis to have confidence that such barriers are effective.

## 3. APPLICATION OF 0.7 TIMES DEPTH BARRIER AT RUSSELL VALE EAST

In mine planning for the PPR layout in the Russell Vale East mining area, a minimum barrier of 0.7 times depth was applied to the FSL around the Cataract Reservoir as the boundary between first workings and secondary extraction by the longwall method. This barrier size provides a minimum horizontal barrier of 200 m between the nearest longwall goaf and the FSL of Cataract Reservoir. There is also a vertical barrier of about 300 m between the stored waters and the mining horizon along most of this barrier.

In some locations, there has been previous pillar extraction mining in the Bulli Seam within the 0.7 times depth barrier. This previous mining comprises three types: first workings development headings, pillar workings where areas of pillars have been formed, and pillar extraction areas where pillars have been mined. None of these areas of previous mining are considered to compromise the effectiveness of the barrier.

First workings developments at 300 m below the surface are not considered to provide any credible risk to the stored waters.

Areas of standing pillars are shown on mine plans of the Bulli Seam in the barrier between the western end of Longwall 7 in the Wongawilli Seam and the FSL. An assessment of these pillars in SCT Report WCRV4440B indicates that they are large enough that proposed longwall mining will not cause an increase in hydraulic conductivity of the overburden strata in this area.

Areas of pillar extraction within the barrier are limited in lateral extent so vertical disturbance to the overburden strata does not extend to the surface. There have been no recognised interactions with the stored waters from this previous mining. Proposed mining in the Wongawilli Seam is not considered to have potential to significantly modify the height of any existing disturbance to the overburden strata associated with previous mining.

The hydraulic conductivity of undisturbed rock in the overburden strata at Russell Vale Colliery is of the order of $1x10^{-9}$ m/s. At this hydraulic conductivity, it is not credible to have high rates of uncontrolled inflow even for a barrier based on 0.17 times overburden depth to the Bulli Seam. SCT are not aware of uncontrolled inflows from the surface at any underground coal mines in Australia at overburden depths greater than about 170 m and there are many examples where much lower overburden depths have been effective at maintaining a barrier between the surface and underground.

These inflows occurred where extractive mining was undertaken directly below the water source and not where there is a horizontal stand off to the water source. At Russell Vale East the overburden depth at the edge of the reservoir is of the order of 300 m. With lateral offsets of greater than 50 m to all previous Bulli Seam mining, and offsets of greater than 200 m to all Wongawilli Seam mining, there is no credible pathway for high rates of uncontrolled inflow through intact strata.

Geological structures are recognised to have potential to compromise the effectiveness of the barrier between the reservoir and mining horizon if they are continuous and have elevated hydraulic conductivity, either naturally or as a result of mining. An assessment of the potential for two significant geological structures, the Corrimal Fault and Dyke D8, to compromise the barrier in the Russell Vale East mining area is presented in SCT Report WCRV4466A. The results of this assessment indicate that these structures do not compromise the effectiveness of the proposed barrier between the stored waters of Cataract Reservoir and the mining horizon.

The 0.7 times depth barrier between the reservoir and the FSL of Cataract Reservoir is considered to be suitable to provide full protection to the stored waters in the reservoir.

If you have any queries, or require further clarification of any of these issues, please don't hesitate to contact me.

Regards

Ken Mills
Principal Geotechnical Engineer

## 4. References

SCT Report WCRV4440 "Response to Galvin and Associates Pty Ltd Report dated 3 March 2015" Letter Report addressed to David Clarkson dated 8 August 2015.

SCT Report WCRV4466A "Assessment of Corrimal Fault and Dyke D8 at Russell Vale East as Risks to the Stored Waters of Cataract Reservoir" SCT Report addressed to David Clarkson dated 9 August 2015.

DSC4B 2010 "Mining Near Prescribed Dams Mining Applications" Guideline prepared by Dams Safety Committee dated June 2010.

Reynolds R.G. 1977 "Coal Mining Under Stored Waters" Report on an Inquiry into Coal Mining Under Stored Waters of the Nepean, Avon, Cordeaux, Cataract, and Woronora Reservoirs, New South Wales, Australia.

## *APPENDIX E*

## Response to Galvin and Associates Pty Ltd Report Dated 3 March 2015

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12 August 2015

David Clarkson
Group Environment Manager
Wollongong Coal
PO Box 924
Dapto NSW 2530

Dear Dave

**RESPONSE TO GALVIN AND ASSOCIATES PTY LTD REPORT DATED 3 MARCH 2015**

As requested, please find herein our review of and response to the report prepared by Galvin and Associates Pty Ltd (GAPL) "Review of Subsidence Aspects Associated with Russell Vale Colliery Underground Expansion Project" dated 3 March 2015.

## 1. CONTEXT OF PROFESSOR GALVIN'S COMMENTS

Professor Galvin qualified his comments in the GAPL report by saying that he was "not in a position to undertake the level of inquiry required to provide comprehensive advice in the given timeframe" and that he had not "had opportunity to undertake a full field inspection and to review all relevant documentation in detail". The concerns raised by Professor Galvin need to be viewed in this context because it is considered likely that had Professor Galvin been in a position to review all the documentation and discuss the basis of the mine layout design, he would likely have formed a view similar to that expressed in the technical reports presented to Wollongong Coal. He would also be likely to have confidence that there are no unacceptable risks to the stored waters of Cataract Reservoir.

Without being able to conduct a full review, the options available to Professor Galvin were limited to advocating a risk based approach, an approach that is entirely appropriate under those circumstances but unfortunately pre-supposes that the risks have not already been considered in a multi-disciplinary context, which they have been. The mine design for Russell Vale East has been developed on the basis of this multi-disciplinary interaction.

Professor Galvin makes the observation that the threat that mine subsidence may present to the Sydney's water catchment "may or may not have merit – I am not yet in position to offer an opinion". It is anticipated that with the opportunity to further review the detailed studies that have been conducted, Professor Galvin will be more comfortable that the design developed by the multi-disciplinary team that has been working on the Underground Expansion Project (UEP) for several years does not present a credible threat to the quantity and quality of the stored waters of Cataract Reservoir and the consequences for the ecological integrity of the catchment are minor and tolerable in the overall context of the site.

## 2. Multi-Disciplinary Team and Project History

SCT Operations Pty Ltd (SCT), Biosis Pty Ltd (Biosis), and Geoterra Pty Ltd (Geoterra) have provided a multi-disciplinary team to assess the subsidence effects, the impacts, and the consequences. This team has worked with Wollongong Coal (and its predecessor Gujarat NRE) since early 2013 to design a mine layout that aims to reduce the consequences of mining in relation to the integrity of the stored waters of Cataract Reservoir, the quality of the drinking water, and the ecological integrity of the catchment.

The subsidence assessment for the mine layout design originally proposed by Gujarat NRE prior to the commencement of Longwall 4 was prepared by Seedsman Geotechnics Pty Ltd. The design was based on an assumption that the bridging characteristics of the overburden strata would be similar to those observed above single seam mining operations further west. The concept was that surface subsidence would be limited to only a few hundred millimetres so that impacts and consequences would be negligible for swamps, creeks, and other features irrespective of the arrangement of the longwall panels relative to surface features. An adaptive management strategy was proposed to confirm this prior to mining under any significant features. Longwall 4 was mined in an area remote from the reservoir where subsidence impacts and consequences would be negligible should they be greater than anticipated.

When the subsidence effects measured above Longwall 4 were observed to be greater than predicted because of the significantly reduced spanning capacity of the overburden strata associated with previous mining, the mine layout was significantly modified. The footprint was modified to remain remote from the reservoir, remote from Cataract Creek, and as far as possible to avoid mining under upland swamps identified as significant and Dyke D8. This design referred to as the PPR design was developed to manage the consequences of subsidence impacts to levels that were consistent with current practice and on this basis considered likely to be tolerable to the Government and the community.

The PPR layout was designed specifically to minimise environmental impacts, particularly to upland swamps, and to maximise protection to the stored waters of Cataract Reservoir at the higher subsidence levels associated with the multi-seam environment. The redesigned PPR layout is still prefaced on the concept of adaptive management should monitoring, for instance closure levels across Cataract Creek or groundwater monitoring studies, indicate that changes to the mine plan should be made.

Within the practical constraints for mining in this area, CCUS4 is the only swamp recognised as significant that could not be avoided. A program of detailed monitoring of this swamp is in place to provide data on the significance of mining impacts to swamps. Mining below CCUS4 and the monitoring program are considered tolerable given that the swamp has previously been mined under in two seams and there is a shortage of high quality monitoring data for upland swamps of the types found at Russell Vale East.

Professor Galvin notes on Page 2 of his report that the material he reviewed "has a high focus on the likelihood that mine subsidence effects will fall within a given range. There is a lack of detailed consideration as to the consequences should these outcomes be more adverse than predicted." The subsidence assessment report that Professor Galvin reviewed was primarily a subsidence effects report. The mining impacts and consequences are primarily in the groundwater and environmental domains although the impacts and consequences for some built infrastructure and natural features such as cliff formations are addressed in the subsidence assessment report. Issues related to groundwater and environmental impacts and consequences are addressed separately in specialist reports prepared by Geoterra and Biosis. It is unclear whether these were available to Professor Galvin to review.

Wollongong Coal has allowed there to be a high degree of interaction between specialists on this project from the outset. The interactions between subsidence effects, impacts, and consequences have been explained, considered, and queried on numerous occasions in the field, during face to face meetings, in teleconferences, and in numerous telephone conversations and emails. The various specialist studies have been conducted with a high level of multi-disciplinary interaction (in the author's experience much more than usual in similar projects).

## 3. MONITORING

Monitoring provides the basis for understanding. The significant monitoring effort in the Russell Vale East area has advanced the understanding of this site and continues to do so. It should be recognised that given the protracted nature of the approvals process some of this understanding has developed since the submission of the PPR documents reviewed by Professor Galvin and has therefore not necessarily been available to him for review.

Subsidence monitoring above Longwalls 4 and 5 was upgraded, including the introduction of three dimensional surveying, to provide the type of measurements of subsidence effects suitable to give confidence in the prediction of subsidence effects above other panels and assessment of the impacts and consequences of mining by SCT, Biosis, GeoTerra, and other specialists. Previous monitoring in the Balgownie Seam was reviewed and reanalysed in the context of the better understanding of mining subsidence processes that is now available. This understanding was presented in the PPR subsidence assessment report.

An understanding of groundwater interactions has continued with additional piezometer installations, ongoing monitoring and other related investigations. SCT have gained, and continue to develop, understanding of the interaction between subsidence and groundwater through multiple borehole investigations into existing goafs at numerous sites (half of which are located in the Southern Coalfield), numerical modelling, and correlation with understanding of subsidence mechanics (Gale 1998, Mills and O'Grady 1998, Mills 2001, Gale 2004, Gale 2008, Gale and Shepherd 2011, Mills 2012, Mills 2014, Walsh et al 2014). Most of these investigations have been conducted on a commercial-in-confidence basis and the opportunity to present the data in the public domain in these circumstances is sometimes limited. However, the monitoring and associated studies have provided an improved understanding of the key drivers of subsidence processes and their impact on groundwater systems.

At Russell Vale East, groundwater and caving investigations have been undertaken to investigate the effects and impacts of previous mining where one, two, and three seams had extracted, including through a Balgownie Seam chain pillar to investigate the effects of the high compression loads developed in this area.

A comprehensive program of monitoring water inflow rates to the Russell Vale Colliery has been set up to study the inflow rates to each panel, to each goaf, and to each seam. This program has provided insight into the nature and magnitude of water balance inputs that has been used to identify the likely sources of inflow and their magnitude.

Detailed monitoring of the subsidence effects, impacts, and long term consequences for CCUS4 is in place.

The results of the ongoing monitoring continue to be reviewed and there is capacity within the mining system to adapt the mine design should this prove necessary, but at this point in time the monitoring that has been undertaken supports the assumptions that have been made. The current design is considered to be robust and to provide a level of protection to surface features and particularly the stored waters of Cataract Reservoir that is consistent with and generally exceeding contemporary standards.

## 4. OPPORTUNITIES

The studies associated with this project have identified the very significant potential that exists within the coal mines along the Illawarra Escarpment, and most particularly at Russell Vale Colliery, to use any water that is captured in the mines for the long term benefit of the community. There is a tendency to think of water that is captured in the mine as being lost from surface storage whereas in fact water captured in the mine is actually entering a different type of storage but one that is also available to be used for community benefit. Water that is captured in the mines comes primarily from the catchment rather than the reservoir and is likely to have originated from rainfall that would otherwise have been lost to surface evaporation or transpiration.

By setting up to utilise water inflow to the coal mines along the Illawarra Escarpment through a suitable treatment plant, the storage potential of these mines is available to use for the long term benefit of the community. The advantages of such storages are multiple:

- Significant water storage is available without having to flood a valley or build a dam.
- There is no evaporation loss.
- The mines will eventually fill up with water and outflows would need to be managed by having a treatment system in place.
- Mining operations are available to fund treatment facilities during their operation that are then available to be passed on to the community.

The opportunity exists at Russell Vale Colliery because of the dip of the strata to the west to a low point near No 4 Shaft. This geometry provides capacity to store water within abandoned sections of the mine while having ready access to a low point suitable to extract water. While considering the risks to the catchment, it is appropriate that opportunities of potential long term benefit to the community are also recognised and considered.

## 5. RISKS

Professor Galvin suggests that "there is potential for the consequences of leakage into the Russell Vale Coal Mine workings to be much higher than in the case of other collieries that mine in the vicinity of stored waters". He also indicates that "it is not inconceivable that any major leak could be unstoppable and escalate over time".

These statements need to be challenged because apart from Appin and West Cliff Collieries which are shaft entry mines, all the other collieries that mine or have mined below the Woronora Plateau have portals that are below the level of the stored water. The issue is a significant one, but Russell Vale Colliery is far from unique and does not represent a higher consequence event as the statement suggests.

Furthermore, it is not credible that the PPR longwall layout presents a risk of a major leak that could escalate over time. The proposed longwalls are offset from the full supply level (FSL) of Cataract Reservoir by a minimum distance equal to 0.7 times the depth or about 200 m horizontally from the FSL. The background to this offset is discussed in SCT Report WCRV4466.

The Dams Safety Committee (DSC) is the body entrusted to protect the stored waters of Cataract Reservoir and has powers under the Mining Act 1992 to regulate mining within Notification Areas. The DSC is not prescriptive in regards to barrier size. For mine planning purposes it is difficult to develop a mine plan without adopting a minimum barrier size. A 0.7

times depth barrier was used for the PPR because it is consistent with historical norms that existed prior to the formation of the DSC and is about 50 m more than the offset recommended by Reynolds (1977) based on the findings of a Commission of Inquiry into coal mining under or in the vicinity of the stored waters of the Nepean, Avon, Cordeaux, Cataract, and Woronora Reservoirs in New South Wales, Australia.  Subsequent investigations including groundwater monitoring and modelling, has not indicated that the 0.7 times barrier should be increased.

## 5.1 Protection Barrier to Stored Waters

In the 6th paragraph of Page 3, Professor Galvin notes the high reliance on 0.7 times depth as a sufficient offset and regards this concept as requiring more critical review.  The sufficiency of the offset is assumed to be in regard to any potential for high inflow events.  It is accepted that no offset is sufficient to totally prevent some level of inflow associated with the pore pressure drawdown that is associated with underground mining but this level is so small as to be insignificant for all practical purposes.

SCT consider that a minimum barrier of 0.7 times depth (200 m at an overburden depth of 285 m at Russell Vale East) to longwall extraction is more than sufficient to protect the stored waters of Cataract Reservoir located some 300 m above the mining horizon from any potential for high inflow events.

There are some already extracted Bulli Seam goaf areas within this 200 m wide barrier, but none of these are wide enough to cause fracturing up through the overburden strata to a level where there is any potential to compromise the effectiveness of the barrier.  Proposed mining in the Wongawilli Seam does not have potential to significantly change the height of fracturing above these goaf areas.

There are also some areas of standing pillars in the Bulli Seam within the 200 m wide barrier.  These have been assessed on the basis of subsidence monitoring experience above similar geometries as unlikely to be destabilised by mining.  Pillar stability at the western end of Longwall 7 is addressed in Section 5.5 of this report.

## 5.2 Geological Structures

Geological structures are recognised by the DSC and Wollongong Coal as having potential to compromise the effectiveness of any barrier between the stored waters and the mining horizon. The two structures in the area of Russell Vale Colliery that were identified as having potential to compromise the effectiveness of the barrier were the Corrimal Fault and the D8 dyke. A detailed assessment of both structures is presented in SCT Report WCRV4466A as a separate document to allow the detail to be presented without overwhelming the focus of this response.  However, the main findings are presented below.

The principal findings of this detailed assessment are consistent with the original interpretations used for mine design and there is considered to be no credible potential for significant inflow through either of these structures.

Both structures have been exposed in areas of coal extraction over distances in excess of 3.4 km in the Bulli Seam and again in the Balgownie Seam. Dyke D8 is exposed for nearly 2 km and the Corrimal Fault has been intersected at several intersections in all three seams including being mined through recently in Longwall 6 of the Wongawilli Seam. In none of these intersections was there any evidence of additional inflows to the mine through either structure. The workings that intersect these structures remain open and there continues to be no evidence of inflows above background levels from the areas where these structures are intersected.

### 5.2.1 Corrimal Fault

The Corrimal Fault is evident in all three seams that have been mined in the Russell Vale East area. These intersections in three seams provide a high degree of confidence in the geometry of the fault structure in three dimensions. Near the escarpment, about 3 km to the east of Longwall 6, there is a significant offset across the fault. There is also evidence in the surface topography and lineation of drainage lines about 1.5 km east of Longwall 6 that may be coincident with the Corrimal Fault.

Survey measurements in the Bulli Seam indicate the maximum throw (offset) of the fault is 29m near the escarpment and reduces to about 15 m at a distance of 1.3 km east of Longwall 6 based on floor contours. Measurements of the fault offset where it is exposed in the longwall face of Longwall 6 indicated that the throw at this location show a local high of 2.9 m and more generally about 1-1.5 m with the throw reducing in both directions but mainly to the west. Mine plans indicate that the throw in the Bulli Seam at this location and further to the west is not sufficient to have affected the layout of the workings and an intersection in the Balgownie Seam indicated a reduced throw compared to that observed in Longwall 6 directly below.

These observations indicate that the Corrimal Fault has pinched out in the Bulli Seam by about Longwall 6 and is also pinching out in the lower seams but slightly further to the west. This type of tapering behaviour is common with geological fault structures (Shepherd 2003). Although there is some potential for the fault to still be present in the Wongawilli Seam where it crosses Longwall 7, the throw is expected to be less than about 1 m at this horizon and it is apparent from mine plans that the fault has pinched out completely in the Bulli Seam about 30 m above.

A projection of the Corrimal Fault to the western side of the reservoir is in the area of truncated and irregular pillar workings in Corrimal Colliery and has been interpreted as possibly indicating a continuation of the fault under the reservoir. The projection needs to take a different alignment to the fault on the eastern side of the reservoir to be fully coincident but it is possible that such a change in direction could occur. The change from a regular to irregular geometry corresponds with a requirement introduced in 1931 to more accurately report on mine layouts coupled with two campaigns of mining that span this change in requirement and a change in general mining direction in the second campaign. The truncated workings are considered to be associated with a change to a more profitable mining area during the second campaign. The workings although irregular are not shown on mine plans as being truncated against any geological structure and the seam levels in the Bulli Seam workings on either side of the projected zone are not consistent with any significant offset.

The truncated nature of the pillar workings is considered more likely to be a result of mining operational issues and a change in reporting standards rather than being associated with a continuation of the Corrimal Fault.

At the location where the fault intersects Longwall 7, the nearest point on the reservoir is still some 540 m further to the west and the overburden depth at the edge of the reservoir on the projected alignment is approximately 305 m. The alignment projection is intersected by previous workings in the Bulli Seam at about 140 m from the reservoir with no evidence of inflows having occurred during mining or since.

Surveyed floor levels in the Bulli Seam indicate that the fault has completely pinched out where it passes under the reservoir. If the fault were hydraulically conductive, and SCT is not aware of any experience of geological faults in the coastal areas of the Southern Coalfield being highly conductive, the 3 km plus of intersection with workings in two seams would have indicated some increased (and presumably ongoing) inflow. No such inflows have been observed.

Mining of Longwall 7 is not expected to cause any movements within the overburden strata that would cause the ground on the projected alignment of the fault to move differentially across the fault (if it were to exist). There is no recognised mechanism whereby the existing hydraulic conductivity of the Corrimal Fault could be increased between Longwall 7 and the reservoir.

On the basis of these observations, mining Longwalls 6 (which has already occurred) and mining Longwall 7 (a panel that is 25 m narrower than Longwall 6) are not considered to present any credible risk to the stored waters through inflows along the alignment of the Corrimal Fault.

### 5.2.2 Dyke D8

Dyke D8 extends some 3 km across the Russell Vale East mining area including below Cataract Creek (just upstream of the FSL) and below Cataract Reservoir. It was intersected in multiple pillar extraction areas of the Bulli Seam, the nearest of which is 90 m from the FSL of Cataract Reservoir. The nearest point Dyke D8 will be intersected by first workings (development roadways) will be 900 m from the FSL and the nearest point the dyke will be intersected by full extraction is by Longwall 7 in the Wongawilli Seam some 1700 m from the FSL, although the dyke passes within 50 m of the FSL where it crosses Cataract Creek about 260 m from the goaf edge of Longwall 7 at an overburden depth to the Wongawilli Seam of approximately 285 m.

There is no record in any of the intersections of the D8 Dyke, including the most recent ones in Longwalls 4 and 5 of any increased inflow through the dyke. There has been no observed increase in inflows from goafs that have intersected the dyke, including the goaf that is only 90 m from the FSL along the dyke alignment.

There is considered to be no potential for tensile movements or shear movements to occur as a result of subsidence from proposed mining of Longwall 6-7 and 9-11.

### 5.2.3 Inflow Potential on Geological Structure

Since there has been limited history of inflows from geological intersections in the Southern Coalfield, it is difficult to provide a definitive estimate of inflow magnitude. The maximum recorded inflow on a geological structure was observed in Blue 2 Panel at Wongawilli Colliery at a nominal depth of 110 m below surface. An inflow rate of about 2.4 Ml/day occurred in a location where a significant dyke / sill system that extended below the reservoir was intersected by pillar extraction workings mined to within about 100 m of the FSL of Avon Reservoir (Doyle and Poole 1986). This inflow rate decreased over time to be less than 0.8 Ml/day within 3 years.

Even if Dyke D8 were to be found to be hydraulically conductive (which 3 km of intersections suggest is not the case), the maximum credible inflow rate for Dyke D8 (surface to seam 285 m, remote from the reservoir 1.7 km along the line of the dyke, and remote from tributary streams 260 m to Cataract Creek) is considered to be much less than 0.2 Ml/day and much less than the limit of tolerability for inflows adopted by the DSC of 0.5Ml/day (DSC 2014).

On the basis of these observations, there is considered to be no potential risk from the proposed mining of increased inflows along Dyke D8.

## 5.3 Assessment of Inflow Potential

Experience of mining in the Southern Coalfield indicates that a horizontal offset of 0.7 times depth between longwall extraction and the FSL is sufficient to protect the stored waters of the Sydney's water supply reservoirs except at shallow depth or where there may be significant geological structures. The two geological structures of significance in the vicinity of Russell Vale East, the Corrimal Fault and Dyke D8, are well defined through previous intersections in three seams, have not been observed to be hydraulically conductive, are aligned such that the distance along the alignment of the structure is large by comparison with overburden depth, and proposed mining is not expected to cause differential subsidence movements sufficient to cause any significant change in the hydraulic conductivity of either structure.

There is certainly no credible scenario where direct connection to the Cataract Reservoir would lead to water uncontrollably exiting the portal. There are credible scenarios where inflows might increase incrementally with the extent of mining and might be greater during high rainfall events. Once this water and other water captured in the mine is treated to an acceptable water quality standard, there are significant opportunities for ongoing benefit to the Illawarra and Sydney communities.

On the basis of these observations, there is considered to be no credible risk from the proposed mining to the stored waters of Cataract Reservoir or to public safety.

## 5.4 Cumulative Subsidence Estimates

In the fifth paragraph of Page 3 of the GAPL report, Professor Galvin notes that cumulative strains and tilts are not presented. There are a number of challenges for presenting cumulative strains and tilts at any site and for the Russell Vale Project in particular. The main challenges to presenting or even measuring cumulative strains and tilts in a multi-seam environment are that the directions of maximum tilts and strains are no longer able to be easily identified, particularly when the panels in each seam are not aligned.

For the UEP, the challenge is increased by the absence of any actual subsidence monitoring data for the Bulli Seam. Nevertheless, estimates of maximum cumulative strains and tilts are presented in Appendix 1 of both SCT Reports NRE14123 and WCRV4263 at the completion of mining in the Bulli Seam, the Balgownie Seam, and the Wongawilli Seam at the location of each of the identified swamps.

## 5.5 Pillar Stability at Inbye of Longwall 7

Professor Galvin notes that the pillars at the inbye end of Longwall 7 have not been specifically assessed for stability (in the documents provided). This point is accepted. The pillar stability assessments conducted were of a general nature based on pillar width to height ratios and experience of subsidence monitoring at the site adjacent to similar geometries and were not specifically included in the subsidence assessment report.

It is noted that, while there has been no experience to date of any instability in the overlying Bulli Seam of pillars located outside the Balgownie or Wongawilli Seam longwall panels being destabilised by longwall mining, this does not preclude the possibility given the right circumstances.

Figure 1 shows that the mine records in this area are complete and a meaningful pillar stability assessment is considered possible. The overburden depth ranges 295-325 m.

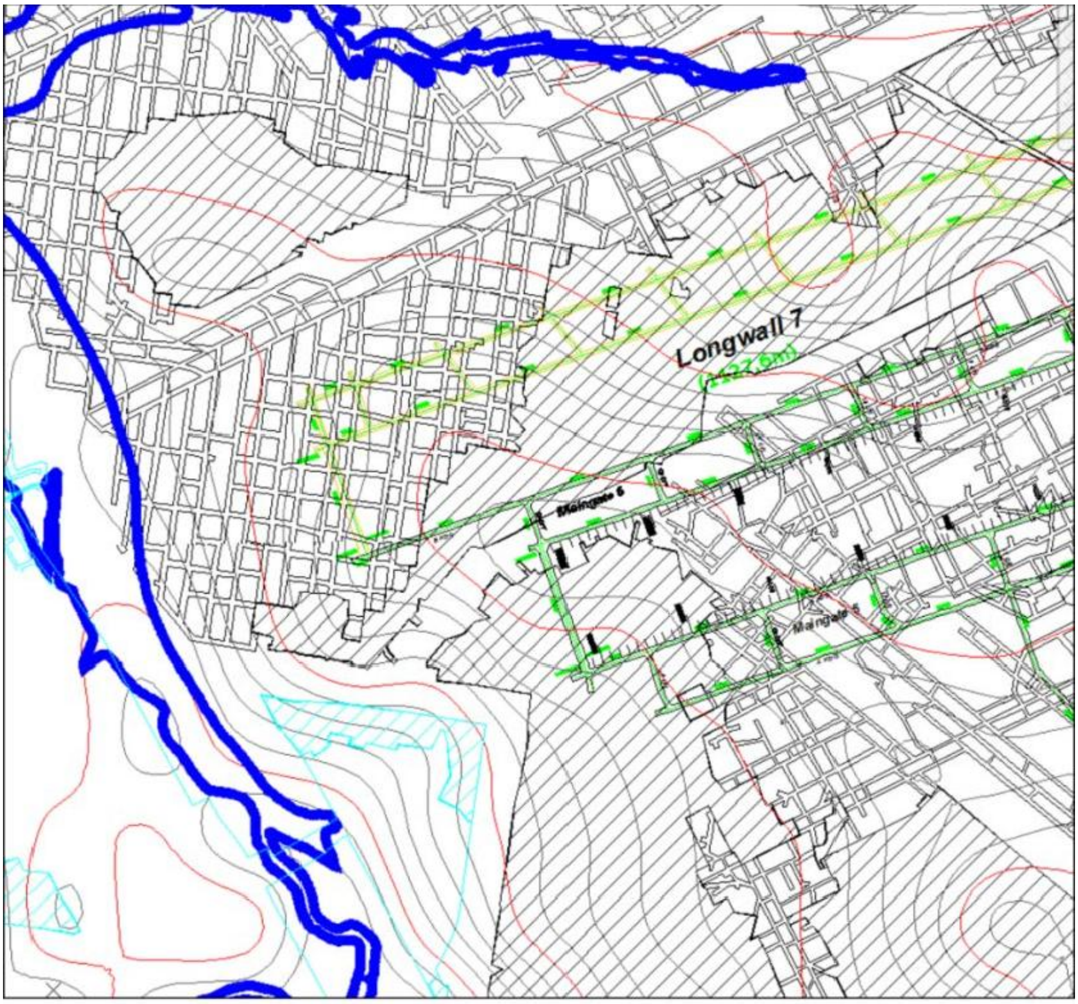


**Figure 1: Pillar Geometry in Bulli Seam at inbye end of Longwall 7.**

The pillar height in this area is not known specifically but is assumed to be 2.2 m which is the average seam height in this area. The pillars range in width from about 12 m to about 30 m wide and, for stability, have been assessed as though they are square in plan even though most have one side that is 1.5-2.0 times the length of the other. The Bieniawski pillar design formula ($Q_p = 6\ (0.64+0.36\ W/H$ where $Q_p$ is the nominal pillar strength, W is the pillar width and H is the pillar height) has been used for pillar stability assessment based on experience of monitoring pillar behaviour in the Bulli Seam reported in Mills and Gale (1994).

An initial assessment of this area indicates that the pillars have a nominal width to height ratio of 5 to 14 and generally greater than 10, and that even if they were to become overloaded, they would be likely to build strength as they deform so that surface impacts would be low and the consequences insignificant. The following assessment discusses these issues in more detail.

### 5.5.1 Stability Assessment

A stability assessment indicates that at an overburden depth of 325 m, the Bulli Seam pillars have load capacities in excess of their nominal strength at ratios ranging from about 1.2 to greater than 2.0 based on tributary area loading. These ratios would be reduced further by any abutment loading from Longwall 7. It is noted that for large width to height pillars in Bulli Seam conditions such as those at the inbye end of Longwall 7, strength is a function of frictional resistance able to be developed within the geological setting and is not a function of the cohesive strength of the coal (Mills and Gale 1994).

Frictional strength is not characterised by statistical variability, unlike the cohesive strength that governs the behaviour of small pillars and leads to the concept of a probability of failure as a means to assess stability. Large pillars are not subject to collapse and continue to gain strength even when they are overloaded. The ratio of pillar load to nominal strength for large pillars is indicative of pillar condition underground rather than a point at which there is any significant change in behaviour. A ratio of 1.0 for large width to height ratio pillars is typically indicative of roadway conditions underground that are not suitable for efficient mining.

The magnitude of the abutment loading can be estimated, but for the purposes of this assessment, the pillars are assumed to become heavily loaded enough to close the adjacent roadways as this scenario is the most conservative.

### 5.5.2 Maximum Subsidence Associated with Heavily Loaded Pillars

Maximum subsidence can be estimated by considering the equilibrium that would be established once the roadways fill up with coal. It is assumed the coal displaced into the roadway would bulk to twice its original volume and there would be no change in volume in the coal in the pillar. Average sized pillars with a nominal geometry of 22 m by 33 m, a roadway widths of 6 m, and a pillar height of 2.2 m have been used in the calculations.

The total volume of an average pillar plus roadway is 2400 $m^3$. The volume of the coal pillar is 1600 $m^3$. The extraction ratio of 67% is consistent with this type of mining. Assuming the 800 $m^3$ of void space is reduced by 50% when it is filled with bulked up coal, the total volume required to be filled to bring the system to equilibrium is 2000 $m^3$. The corresponding pillar height to accommodate this volume is 1.76 m and the resulting closure at seam level is 0.44 m.

Some further compression subsidence is expected above the pillars as a result of the increased vertical stresses in the vicinity of the longwall abutment, so total subsidence of up to about 0.6 m is considered possible before the pillars come into equilibrium, assuming there is no weight redistributed to other larger pillars. Any such redistribution would tend to reduce the magnitude of subsidence that may be expected.

### 5.5.3 Consequences of Overloaded Pillars

It should be recognised that subsidence that might occur over a panel of large width to height standing pillars is likely to be compression subsidence such as occurs above a chain pillar and not the type of subsidence that typically occurs above a longwall panel or a panel of small pillars that may have collapsed or been mined. Above a longwall panel, subsidence movements are of a generally stretching nature in a vertical direction causing a reduction in vertical stress and an increase in hydraulic conductivity.

At the western end of Longwall 7, the subsidence would be associated with compression subsidence and the hydraulic conductivity would be decreased as a result. This behaviour was observed in RV16, a test hole drilled through the Balgownie chain pillar and was observed in the piezometer response in RV17 at the start of Longwall 6.

In RV16, an extracted goaf in the Bulli Seam was found to be able to support a water head of about 300 m without any visual evidence of loss of flow from the borehole into the goaf. This reduction in hydraulic conductivity has been attributed to the vertical compression stresses generated in the goaf by the underlying Balgownie Seam chain pillars.

Piezometer RV17 showed a rise in pressure when Longwall 6 commenced. This behaviour is commonly observed at other sites and represents the pore pressure generated when the strata is compressed under abutment load.

The consequence of an increase in vertical compression is that the hydraulic conductivity above the start of Longwall 7 is likely to be reduced by any pillar compression subsidence that may occur. A drop in the surface level would have no practical consequence so even if the standing pillars at the start of Longwall 7 were to become overloaded, the subsidence associated with this process would not be expected to cause any increase in hydraulic conductivity between the reservoir and the mining horizon in the Bulli Seam.

## 5.6 Tammetta Approach

In Paragraph 1 on Page 4, Professor Galvin discusses the uncertainty around the use of the Tammetta approach to calculating the height of depressurisation (Tammetta 2012). The contentiousness that is referred to by Professor Galvin relates mainly to the Tammetta approach being seen as too conservative and estimating a height of depressurisation that is greater than it is. However, based on SCT's experience of monitoring groundwater depressurisation directly above extracted longwall panels at multiple sites, the approach appears to give a very reasonable estimate of the height of depressurisation. This outcome is not surprising given the Tammetta approach is derived from a broad database of hydrogeological experience in single seam mining situations.

At Russell Vale East, the Tammetta approach is not so applicable because of the multi-seam interactions that may be occurring. A key point however, is that the Tammetta approach is likely to provide a lower limit on the height of depressurisation given that the presence of multi-seam mining is expected to increase the height of depressurisation compared to an equivalent single seam situation.

## 6. General Comment

The three areas of concern expressed by the SCA and reflected in Professor Galvin's comments relate to water quantity, water quality, and ecological integrity (particularly of the upland "swamps"). The challenge for assessment is that the impact and consequences for any of these three are not likely to be strongly related to any variation in actual versus predicted subsidence effects.

The consequences for water quantity, water quality and ecological integrity are unlikely to be significantly changed if actual subsidence varies from predictions. Even if there were to be 50% more subsidence, strain, or tilt, the consequences for water quality and ecological integrity are likely to be at a similar level as for predicted subsidence and are unlikely to be more and certainly not 50% more.

The inflow process is quantifiable through measurement and understanding of historical experience. Inflow magnitude is not a function of subsidence effects over the longwall panels or whether they are accurately predicted or not. For instance, any increase from predicted of subsidence, tilt, or strain measured over any of the longwall panels remote from the reservoir is unlikely to significantly change the inflow that occurs through the barrier between the reservoir and mine.

Having stepped back from the FSL of the reservoir by a distance of 0.7 times depth (about 200 m), there is no credible way that inflows of any consequence can come into the mine from the stored waters. Furthermore even if there was some credible way, the amount of water would be of the same order of magnitude as the water that is currently coming into the mine. The maximum credible inflow from the reservoir is much less than the 0.5 ML/day that the DSC recognises as being tolerable loss and the maximum credible inflow is able to be managed through normal pumping operations (DSC 2014).

The PPR design at Russell Vale East is much more conservative than the Blue Panel design referred to above.

The set back from the FSL is a minimum of 0.7 times depth (200 m) from the reservoir at a depth in excess of 270 m and there are no geological structures except for the Corrimal Fault and Dyke D8. The Corrimal Fault is not water bearing (multiple intersections have demonstrated this), does not exist below the reservoir, and the pathway along the alignment of the fault extension (where the fault doesn't exist) is about 540 m. Dyke D8 is also not water bearing at multiple intersections and is several kilometres to any new goaf intersection.

There are some pillar extraction areas in the Bulli Seam that are closer to the reservoir than 200 m but these areas are not large enough to cause fracturing high enough into the overburden to be an issue for inflow.

Putting aside credible maximum inflows for a moment and considering what might be the consequence if the incredible were to happen (i.e. never before heard of in any mining scenario that SCT is aware of or the Reynolds Inquiry could find for a similar circumstance) and inflow from the reservoir reached a notional 10 Ml/day. There is abundant down dip storage available to store water to allow several months to several years, depending on the inflow rate and the levels considered, to arrange for a pumping and treatment option to manage inflows. The reservoir operates at below the level of any inflow points most of the time, so the inflow potential would not be continuous. Sediment flowing into the fracture network would reduce the inflow over time.

There is therefore no potential for uncontrolled outflow from the portals to cause a public safety hazard.

As discussed, the option to manage inflow from the surface through storage in the mine and subsequent treatment has potential to benefit the community in the long term through the addition of extra storage that is free from evaporation

Assessment of impacts and consequences for water quality and ecological integrity are the domain of specialists in these areas, Geoterra and Biosis. These issues are discussed in their reports.

## 7. Conclusions

In summary, it would appear that Professor Galvin has had limited opportunity or time available to become fully briefed on all the documentation, issues, and work that has been completed. While his comments are considered appropriate given this lack of briefing, it is considered likely that he would form a similar view to the views formed by the specialists involved in this project if he had the opportunity to be fully briefed on the site details and the specific monitoring data that is available.

If you have any queries, or require further clarification of any of these issues, please don't hesitate to contact me.

Regards

Ken Mills
<u>Principal Geotechnical Engineer</u>

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*APPENDIX F*

**Assessment of Corrimal Fault and Dyke D8 at Russell Vale East as Risks to the Stored Waters of Cataract Reservoir**

Strata Control Technology

R E P O R T   T O :

**WOLLONGONG COAL**

Assessment of Corrimal Fault and Dyke D8 at Russell Vale East as Risks to the Stored Waters of Cataract Reservoir

**WCRV4466A**

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| **REPORT TO** | David Clarkson<br>Group Environment Manager<br>Wollongong Coal<br>PO Box 924<br>Dapto NSW 2530 |
| **SUBJECT** | Assessment of Corrimal Fault and Dyke D8 at Russell Vale East as Risks to the Stored Waters of Cataract Reservoir |
| **REPORT NO** | WCRV4466A |
| **PREPARED BY** | Ken Mills<br>Stephen Wilson |
| **DATE** | 19 August 2015 |

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## SUMMARY


Wollongong Coal Limited (WCL) operates Russell Vale Colliery in the Southern Coalfield of New South Wales. WCL is proposing to mine longwall panels in the Wongawilli Seam beneath the catchment of Cataract Reservoir from an area where there are geological features known as the Corrimal Fault and Dyke D8. WCL commissioned SCT Operations Pty Ltd (SCT) to assess the potential for the Corrimal Fault and Dyke D8 to provide flow pathways between the stored waters of Cataract Reservoir and the mining horizons. This report presents the results of that assessment based on all available information including mining records in three seams dating back to the 1880's.

The assessment indicates that there is no credible risk of inflow through either the Corrimal Fault or Dyke D8 as a result of the proposed mining.

The Corrimal Fault tapers to become insignificant with less than 1m of throw at seam level some 540m from the edge of the reservoir at an overburden depth of greater than 300m. The fault has not been found to be hydraulically conductive or water bearing at any of numerous intersections in all the three seams including the most recent intersection where the fault was mined through in Longwall 6. Furthermore, proposed mining does not have potential to enhance connection between the seam and the reservoir along the projected alignment of the fault.

Previous mining in the Bulli Seam provides a strong basis to determine the location and throw or offset across the Corrimal Fault. This mining indicates that there is no disruption to mining layouts and no significant offset in the coal seam along the alignment of the Corrimal Fault beyond the area of the proposed Longwall 7. The Corrimal Fault has a maximum recorded throw of about 29m near the escarpment several kilometres to the east of the proposed mining of Longwall 7 but, as is typical of faults in the Southern Coalfield, the throw tapers out along the alignment of fault. The fault either does not extend under the reservoir at all or has such a small throw as to be insignificant for all practical purposes.

Apparent truncation of historic workings in Corrimal Colliery on the northern side of Cataract Creek across an arm of the reservoir has been investigated as an indication of a possible extension of the fault below the reservoir. The changed nature of the workings depicted on mine plans is considered to be primarily a result of a change in reporting standards for mine workings that were introduced in 1931, coincidentally between two campaigns of mining in this area, one from the south prior to 1931 shown as an idealised layout and the second from the west with all the detail of individual roadways. The layout of the second campaign is consistent with difficult mining conditions in this area potentially associated with the confluence of several dykes. The seam floor contours do not show a step change in elevation that would be associated with a significant fault.

The area of apparently truncated workings is not closely aligned with a projection of the Corrimal Fault and there are approximately 40

intersections over about 1km along this alignment including an area of pillar extraction where there has been no indication of faulting either in mine plans or in the alignment of mine workings. Although it not possible to be completely definitive, on balance, the apparently truncated workings on the northern side of the Cataract Creek arm of the reservoir are not considered to indicate that the Corrimal Fault continues under the reservoir and if it does, the throw across the fault is of such a low magnitude as to be insignificant for all practical purposes.

Dyke D8 passes below the reservoir and is intersected by the mine workings. There has been no history of inflow through this dyke at numerous intersections in all three seams. The lateral offset of the proposed longwall goafs from the reservoir along the alignment of the dyke is sufficiently large at 1.7km for there to be no credible risk to the stored waters of Cataract Reservoir.

The additional research undertaken as part of this assessment has increased the understanding of the characteristics of the Corrimal Fault and Dyke D8 but this increased understanding has not changed the original interpretation that proposed mining does not present a credible pathway for inflow from Cataract Reservoir through either the Corrimal Fault or Dyke D8.

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# 1. INTRODUCTION

Wollongong Coal Limited (WCL) operates Russell Vale Colliery (formerly NRE No1 Colliery and previously South Bulli Colliery) in the Southern Coalfield of New South Wales. WCL is proposing to mine longwall panels in the Wongawilli Seam beneath the catchment of Cataract Reservoir from an area where there are geological features known as the Corrimal Fault and Dyke D8. WCL commissioned SCT Operations Pty Ltd (SCT) to assess the potential for the Corrimal Fault and Dyke D8 to provide flow pathways between the stored waters of Cataract Reservoir and the mining horizons. This report presents the results of that assessment based on all available information including mining records in three seams dating back to the 1880's.

SCT has conducted a detailed study of the available historical mine plan information pertaining to the Corrimal Fault and Dyke D8. The extent and significance of these features has been assessed in the context of proposed Wongawilli Seam mining beneath the catchment of Cataract Reservoir. The review focuses primarily on the detail around the Corrimal Fault and where it tapers out. The location and extent of Dyke D8 is well known and there is clear evidence that Dyke D8 extends from the mining horizon through to the surface and extends below the reservoir.

This report is structured to provide a site description, a review of historical mining information available in the area, a review of recorded experience of mining close to the Corrimal Fault and Dyke D8, further information relating to the lateral extent of the Corrimal Fault, a discussion of results, and conclusions.

# 2. SITE DESCRIPTION

Figure 1 shows the location of the Corrimal Fault, Dyke D8, and the positions of the proposed longwall panels at Russell Vale East relative to the stored waters of Cataract Reservoir. All three of the economic coal seams in this area have been mined; the Bulli Seam from the 1880's to the 1950's, the Balgownie Seam predominately from 1960's through to 1982, and, most recently, the Wongawilli Seam from 2008 to the present. Access to all three seams has been maintained. Previous mining provides direct measurement of the seam elevations, the presence of geological structures, the nature of these structures, and other information such as their potential to be water bearing or hydraulically conductive. This data provides a strong basis to assess the location and nature of the Corrimal Fault and Dyke D8 and the risks they present to the stored waters of Cataract Reservoir.

The immediate surface above Russell Vale East mining area is largely native bushland that is both freehold (owned by WCL and RMS) and crown land owned by the Water NSW (formerly Sydney Catchment Authority). To the east of the escarpment, the Illawarra Escarpment State Conservation Area (administered by the National Parks and Wildlife service) has been formed following donation of this freehold land by South 32 Pty Ltd (formerly Illawarra Coal Holdings – BHP Billiton).

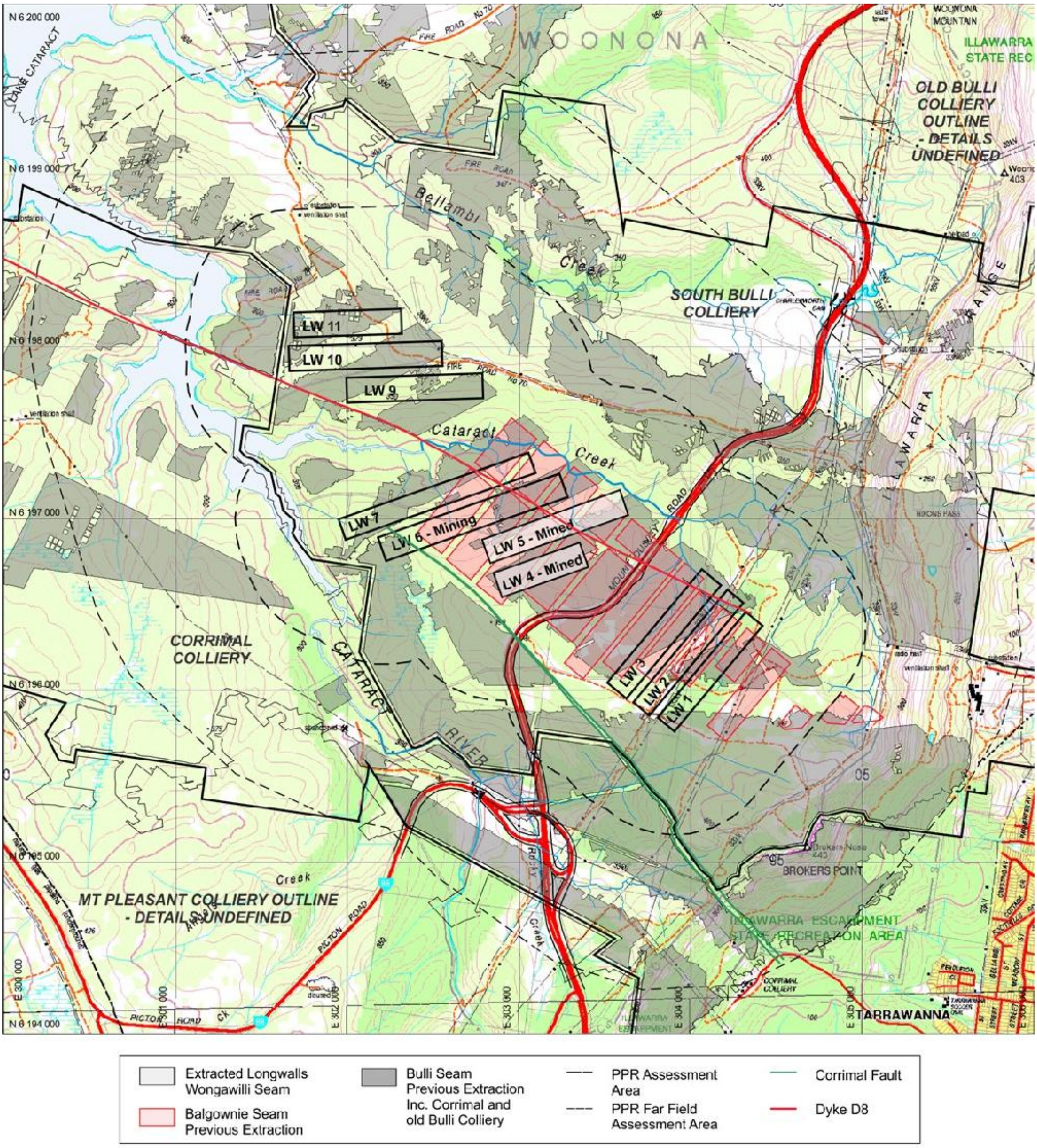


**Figure 1: Site plan showing the locations of previous mining, the stored waters of Cataract Reservoir, and major geological structures including the Corrimal Fault and Dyke D8.**

The majority of the Russell Vale East mining area is contained in the Special Area for the Sydney Drinking Water Catchment in the catchment of Cataract Creek.

The general dip of the strata is toward the west and northwest. A broad syncline known as the South Bulli Syncline is located in the Russell Vale East area and extends west for about 12km from the escarpment.

The overburden depth to the Bulli Seam ranges from outcrop on the Illawarra Escarpment to about 360m in the Russell Vale East area. Within the Russell Vale East area, overburden depth ranges from about 230m to 360m. The Balgownie Seam is located approximately 10m below the Bulli Seam, and the Wongawilli Seam is located a further 25-30m below the Balgownie Seam.

There are two major geological features in the area, the Corrimal Fault and Dyke D8, as well as a number of smaller dykes that are not significant in the context of this assessment.

## 2.1 Corrimal Fault

Figure 2 shows the nature of the Corrimal Fault determined from surveyed measurements of seam floor contours in the Bulli Seam. The Corrimal Fault outcrops on the Illawarra Escarpment to the south of the Hawkesbury Sandstone cliff formation known as Broker's Nose. The throw on this fault is significant at the escarpment and is reported in Harper (1915) to be about 29m. The Corrimal Fault tapers away toward the west as is typical of many of the larger faults of this nature in the Southern Coalfield.

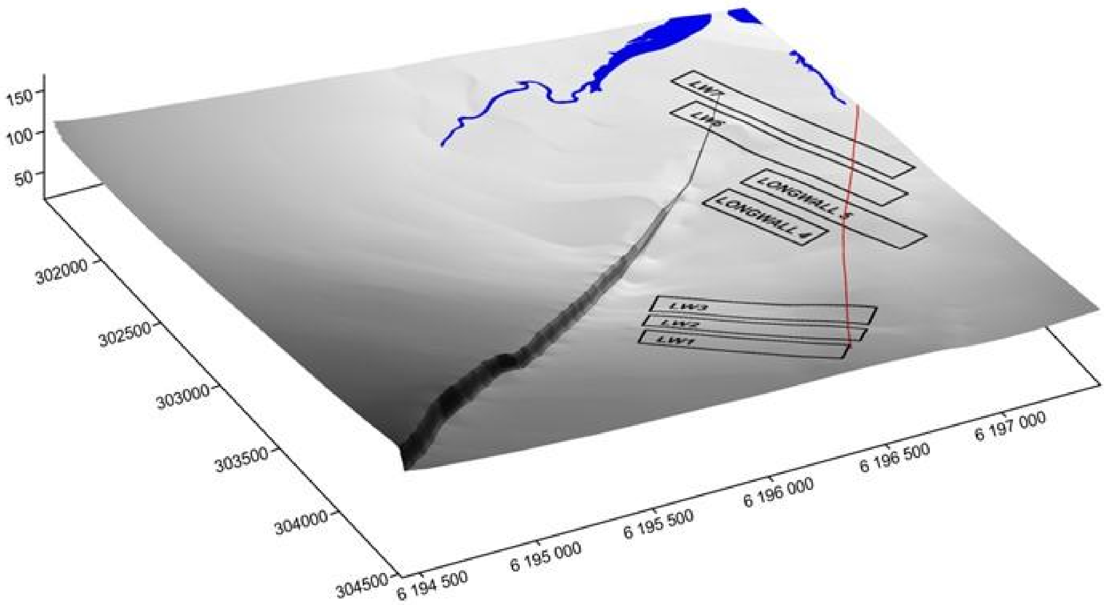


**Figure 2: Three dimensional model layer of the Corrimal Fault at Bulli Seam level. The Cataract Reservoir and extracted and proposed Wongawilli Seam longwall panels are superimposed for reference purposes.**

The configuration of early coal mining in the eastern parts of both Corrimal and South Bulli Collieries was heavily influenced by the position and size of the Corrimal Fault. The fault was adopted as the boundary between the two mines within about 1km of the Illawarra Escarpment. As the fault tapers away to the west, South Bulli Mine was able to drive multiple roadways through the fault and the boundary with Corrimal Colliery was no longer defined by the fault from then on. Further west again, the fault tapers away completely so that there is no evidence of it in the layout of the Bulli Seam mine workings at all. A possible alignment on the northern side of Cataract Creek is discussed in detail in Section 5.

Figure 3 shows the major geological structures in this area of the Southern Coalfield with the location of the Corrimal Fault highlighted (ACARP 1992). There are numerous similar features located along the Illawarra Escarpment that trend northwest and taper away to the west.

Sheppard (2003) presents a summary of the characteristics of geological fault structures in the Southern Coalfield of NSW that shows the throw and length of geological structures are broadly related. This summary is reproduced in Figure 4. The Corrimal Fault has a maximum throw of 29m and a length of 3-6km (accounting for the part east of the escarpment which has been eroded).

The surface topography west of the escarpment on the alignment of the Corrimal Fault is located in outcrop of the Hawkesbury Sandstone strata. The Hawkesbury Sandstone slopes to the west and has been incised by the watercourses that form the tributaries of the Cataract Reservoir. A surface lineament that may coincide with the Corrimal Fault is apparent in the alignment of two tributaries of Cataract River just west of the Illawarra Escarpment and to the south of the fault alignment and would be consistent with a hade on the fault to the north of about 45°. This possible alignment is located in an area where the Corrimal Fault has maximum throw observed underground.

## 2.2 Dyke D8

The geological feature referred to as Dyke D8 (WCL 2013) is known to, or inferred to exist at Bulli Seam level for approximately 7km in an ESE-WNW direction and extends approximately 3km within the Russell Vale East mining area. The location of the dyke is shown in Figure 1. The dyke traverses both the South Bulli Colliery and the Corrimal/Cordeaux Colliery mining leases a number of times.

Dyke D8 is a vertically oriented planar geological structure that extends from below all three seams through to the surface. Dyke D8 has been intersected in all three seams and is apparent in surface lineaments observed on the surface in Cataract Creek and numerous minor tributaries across the area.

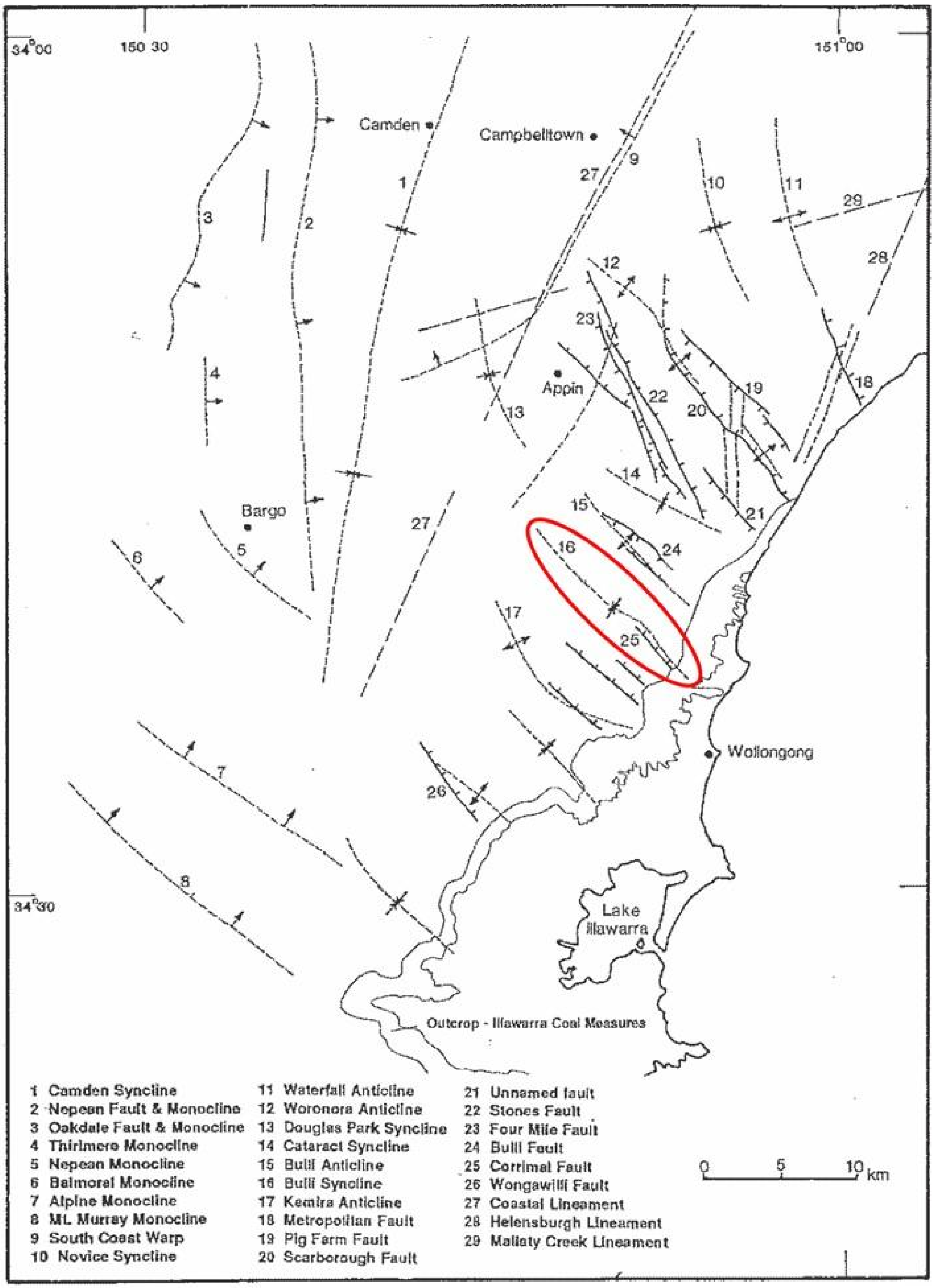


**Figure 3: Regional structural elements of the Southern Coalfield – the South Bulli Syncline and Corrimal Fault are labelled 16 and 25 respectively (after ACARP 1992).**

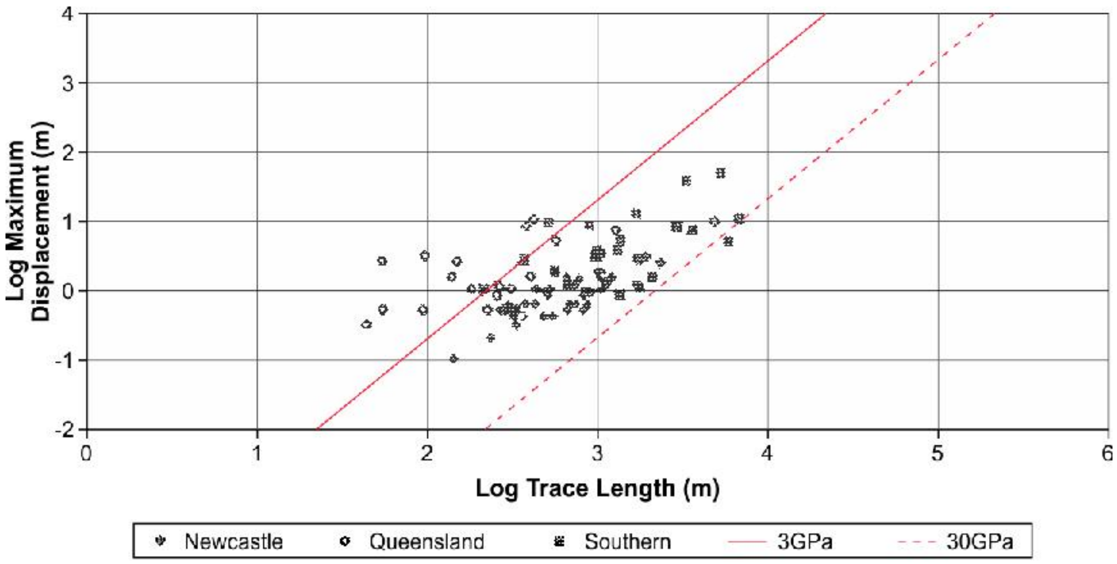


**Figure 4: Summary of characteristics of geological fault structures (after Sheppard 2003).**

Dykes are intrusive geologic features that are created when volcanic material is intruded into existing strata at high pressure at a time when the thickness of the overburden strata was much greater than it is today. The hydraulic pressure is sufficient to jack the rock apart in a direction perpendicular to the lowest of the three principal stresses acting in the rock at the time of dyke emplacement. This process forms large planar features that can extend laterally for many kilometres and vertically through the, now, full overburden section.

The dyke has been intersected in all three economic seams mined in this area. Figure 5 shows a photograph of its intersection on the longwall face in Longwall 5 in the Wongawilli Seam. The dyke has been intersected at an oblique angle in this photograph and appears wider than it is. Dykes also tend to increase in width in coal seams where the horizontal stresses are lower allowing the dyke to thicken up where it is injected into the coal strata.

There is no record in any of the previous intersections of the dyke being water bearing or hydraulically conductive to any significant extent.

## 3. HISTORICAL INFORMATION

A detailed study of available historical mine plan information relating to geological features known as the Corrimal Fault and Dyke D8 has been undertaken to ascertain the extent of these features and to assess their significance in the context of the effects, impacts and consequences from proposed longwall mining in the Wongawilli Seam. Of particular interest is the potential for uncontrolled inflow from the stored waters of Cataract Reservoir.

**Figure 5: Photograph of Dyke D8 exposed underground in the longwall face of Longwall 5.**

This section focuses on the detail around the Corrimal Fault where the location and throw are less obviously well defined. The location and extent of Dyke D8 is known and there is clear evidence that Dyke D8 extends from the mining horizon through to the surface and extends below the reservoir.

### 3.1 Overview

Bellambi Colliery commenced operations on the escarpment at the outcrop of seams in the late 1850's with the adjacent South Bulli Colliery to the south, starting during the 1860's. These two mines merged operations focussing on the southern leases as the Bulli Seam geology in the north was found to be intruded with igneous sills and proved to be uneconomic. The combined venture discontinued the Bellambi name in favour of the South Bulli title.

The early stages of mining development at Corrimal Colliery, adjacent and to the south of South Bulli, commenced during the early 1870's, but it wasn't until the late 1880's that the main off-site coal transport systems were in place and the mine could increase production.

The Corrimal Fault was first encountered in the workings of Corrimal Colliery around 1895. The displacement of the fault in the Bulli Seam was established at this time. The fault was intersected at the adjacent South Bulli Mine in the Bulli Seam workings circa 1902. Around this time it was recognised by the management of both coal mining companies that this feature was significant in this area and would pose a barrier to mining layouts.

A practical agreement was reached between the two coal companies to exchange lease areas and alter the mine boundaries to align with the fault zone for about 1km to the west of the Illawarra Escarpment. It is surmised that this would have been in order to minimise the operational difficulties associated with major geological features and maximise the resource recovery opportunities to both companies. Although the fault was initially uncovered in Corrimal Colliery, the major portion of the faulted ground was to be located within the South Bulli mining lease area due to the strike direction of this structure and the configuration of the lease holdings.

Although the exact lateral extent of the fault is not clearly noted in all the documents relating to this period, this omission is not an uncommon practice both in past record keeping and indeed record keeping of the present day.

During this study, the preference has been to examine the original data where possible as it is recognised that conversion of traditional manually drafted records into digitised electronic data brings with it the possibilities and opportunities for transpositional errors and inconsistencies. Examination of mining plan records cannot avoid some interpretation of the displayed information and therefore a thorough understanding of coal measures geology, the evolution of mining techniques and the surveying and drafting practices is considered important.

The sources of the information used in this assessment are reviewed in the following sections.

### 3.2 South Bulli Colliery

At South Bulli Colliery, the original mine plans and the original Record Tracings for the Bulli Seam workings have been examined. The mine plans consist of two sets of plans, duplicating the depictions of early Bulli Seam mining history at the site.

South Bulli Colliery also has substantial Balgownie Seam mining in proximity to the outcrop. The original mine plans for these workings were also examined. There is some duplication of information where the early Balgownie Seam workings are also shown on the Bulli Seam mine plans.

The recent NRE No1 / Russell Vale Colliery mining of the Wongawilli Seam underlies both the Bulli and Balgownie Seam workings in this multi-seam mining environment. The records for the Wongawilli Seam are available in digital format, to the current modern legislated standards.

### 3.3 Corrimal Colliery

A copy of the Record Tracings for Corrimal Colliery (also known as Brooker's/Broker's Nose Colliery and Corrimal-Balgownie Colliery) was obtained from the NSW Department of Mineral Resources. This copy has been examined over an extended period for a number of projects. Other sources of data for Corrimal Colliery included copies of some mine plans held by South 32 Pty Ltd (formerly BHP Billiton - Illawarra Coal) the last operator and current lease holder of this abandoned mine. The large majority of this information pertains to the Bulli Seam. Corrimal Colliery has very limited Balgownie Seam workings (referred to as Corrimal No 2 Mine on Record Tracing RT7).

### 3.4 South Bellambi Colliery

South Bellambi Colliery was a small operation that worked the Balgownie Seam between 1975 and 1979. A copy of the Record Tracing has been reviewed. The limited first workings of this mine are located to the northeast of the Corrimal Fault and are not considered to be relevant other than to confirm overburden and interburden thicknesses, the location of geological features, and the general rate and dip of the strata.

### 3.5 Additional Sources

Additional information has come from a series of yearly mining plans held in the University of Wollongong library archives. These plans of the Bulli Seam at South Bulli Colliery cover the years 1903, 1911, 1912, 1913, 1916 and 1917 showing the progress of the mining undertaken at the mine during those years.

Other data that has accumulated over the years at the Russell Vale Colliery mine site has also been included in the review, in particular a 1932 Wollongong District Plan showing the area of interest and titled 'Plan Showing Colliery Holdings on Cordeaux & Cataract Catchment Areas together with Incidental Geological Data'.

Historical geological reports including Harper (1915) and general coalfield geology reports (ACARP1992) have also been reviewed.

The historical archive collection 'Illawarra Coal – an Unofficial History of Coal Mining in the Illawarra' (www.illawarracoal.com) administered by Mr Brian Sheldon has been reviewed. Personal communications and information exchanges with Mr Sheldon have also been conducted.

Various reports compiled in support of the UEP – PPR mining approval applications have been reviewed, particularly a geological report of the Russell Vale East area – then referred to as Wonga East – (WCL 2013) and a geological report on the Corrimal Fault (WCL 2014) prepared by WCL geologists.

The review of all this information indicates that there is a large amount of data relating to the Corrimal Fault with most of this data contained on Bulli Seam mining plans.

### 3.6 History of Surveying for and Drafting of Mine Plans in NSW

An appreciation of the reasons mine plans were prepared and the standards for reporting are helpful in the interpretation of the Record Tracings and other information recorded on mine plans.

The information on early mine plans were recorded for two main reasons: first, to provide operational (production) needs of the mine and second to comply with NSW legislation. This legislation was aimed at both workplace health and safety and public safety.

Extensive historical research and re-education of the coal mining industry on the accuracy and reliability of mine plans was undertaken in 1998 to comply with the recommendations from the Gretley Disaster Inquiry (DMR1998). The following passage summarises the key points considered appropriate to this study.

- The first coal mining by European settlers in NSW is believed to have started in the late 1790's. In the Illawarra district, the first legal mining started in the 1840's.

- The first legislated requirement to accurately record mine workings on a plan was in 1902.

- The requirement to preserve mining plans was first introduced in 1931 when the plan of abandonment at the cessation of mining at a site was to be sent to the Mines Department for future reference.

- Plans were not required to be certified as accurate by a surveyor until 1931.

- The requirement for certificates of competency for mining surveyors was not introduced until 10 years later in 1941.

- Amendments to the 1912 NSW Coal Mines Regulation Act (CMRA) enforcing the Record Tracing concept (maintaining a second accurate copy of mine plan information) were gazetted in 1947.

- While the requirement to keep plans and copies in safe keeping was then in place, the actual standards for surveys and the drafting methods for depiction of the workings and associated information, was still missing. This meant that many adjacent mines had different coordinate systems and survey datums as well as different ways of showing the same type of mining method.

- Previous amendments to the 1912 CMRA had provided for 'the general rate and direction of dip of the strata', but the requirement to record detailed information for reduced levels of the seam floor and geological features in the workings were not introduced into legislation until during the 1950's with further amendments in the early 1970's.

- The first attempt to set uniform standards for survey and drafting practices was in 1968, but it wasn't until 1976 that the comprehensive Surveying and Drafting Instructions for Coal Mine Surveyors were published in the government gazette.

- These instructions brought into place standard practices for systems including coordinate grids, height datums, the area (with no overlap) and scales of plans as well as the requirement for a separate plan for each seam worked.

- Since that time, opportunities for further inconsistencies to develop have arisen through the advent of Computer Aided Drafting (CAD) and conversion to digital records, as well as the transformation from state to national (and international) coordinate systems for mapping.

This summary of the development of record keeping indicates that there are likely to be differences across the database of information in the type of information presented, the level of detail, the completeness, and the accuracy of that information. Prior to 1977 there is a standard, prior to 1948 a different standard with a significant change in 1931. From 1931, with the legal requirement to certify as accurate the quarterly (3 monthly) working places surveys, regular datelines appear on the plans for the first time. Prior to 1931, there are some workings dated but because it was not a legislated requirement, there is often inconsistency in the frequency of date notations. A change in the detail recorded in response to the 1931 legislative change is clearly apparent in the mine plans for both South Bulli and Corrimal Collieries.

It has also been recognised through experience, that different individuals (and mining companies) have different interpretations of legal requirements. The compliance with standards may have been enforced through infrequent auditing by the local mines inspectorate. Poor compliance often resulted in opportunities to collect data being lost due to mining progress making worked–out areas inaccessible. The nature of some mining methods precludes the possibility of retro-fitting newer legislated standards for recording information in previously mined areas.

Although there are limits to the information displayed on the mine plans, it has been possible to resolve some inconsistencies and omissions for South Bulli Colliery up until 1917 by using yearly mining plans held in the University of Wollongong library archives. There are no records of this type for the period from 1917 to 1931 and this period remains the period of most uncertainty. Other milestones are 1948 and 1977 when further changes in legislation occurred. The mining timeframes for the area of interest being assessed provide a basis to assess the level of confidence in the reliability of the available information. For instance, the Balgownie Seam mine plans for South Bulli Colliery are presented to the 1977 standard.

Throughout this study, the accuracy and reliability of the mine planning database has be researched and challenged to define the level of certainty and assign confidence to the predicted residual risk levels.

# 4. MINING EXPERIENCE IN CLOSE PROXIMITY TO CORRIMAL FAULT AND DYKE D8

In this section, the experience of mining in close proximity to and developing roadways through the Corrimal Fault and Dyke D8 is presented based on the Record Tracings and other mine plans detailed in Section 3.

## 4.1 Corrimal Fault Intersections

Figure 6 shows an overview of the intersections in the Bulli Seam for the Corrimal Fault in both Corrimal and South Bulli Collieries.

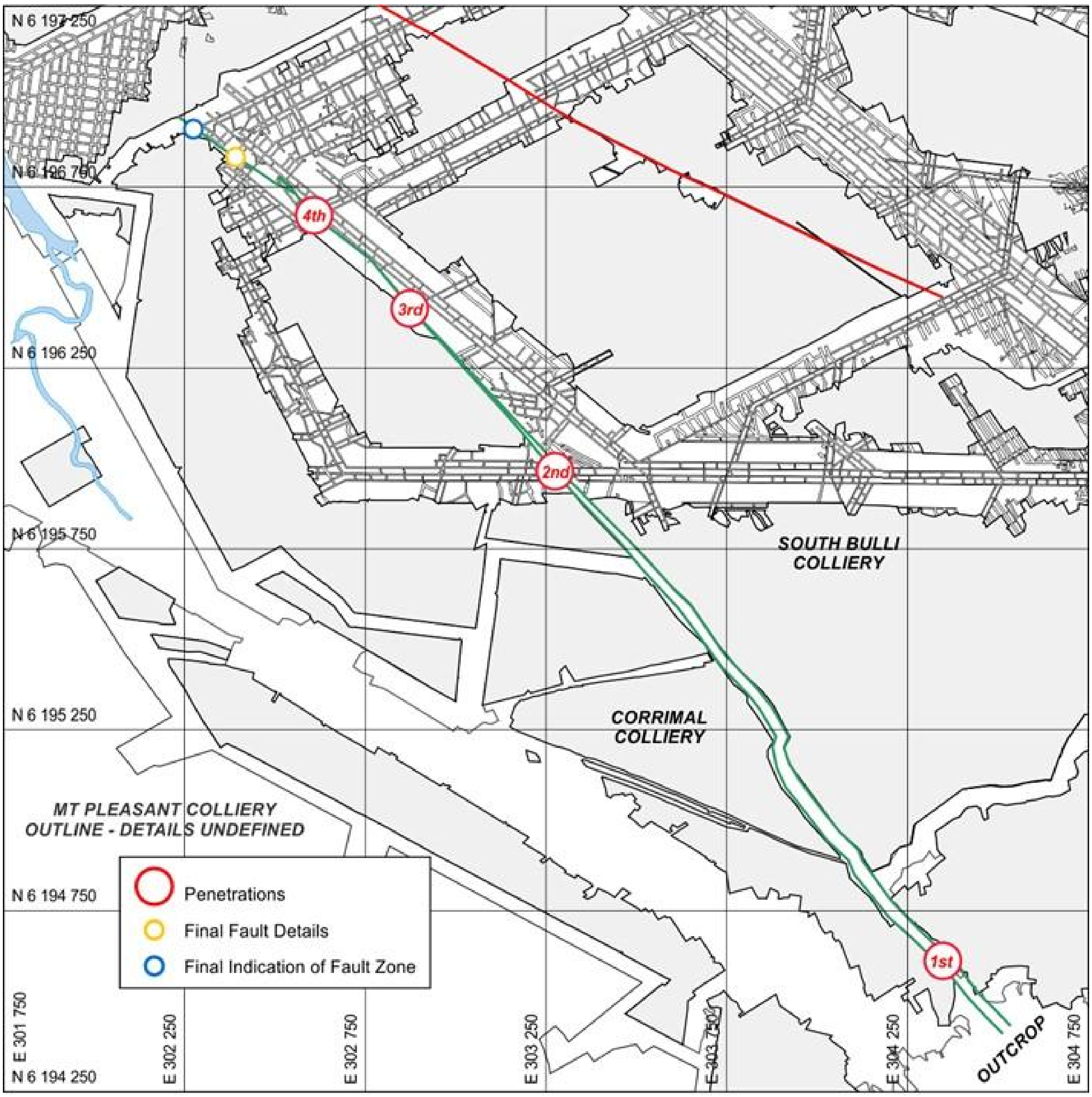


**Figure 6: Bulli Seam mining intersections/penetrations of the Corrimal Fault from seam outcrop in the southeast to the northwest.**

#### 4.1.1 Bulli Seam Intersections

The Corrimal Fault zone is marked on combined Bulli Seam plans for a length of 3.4km from seam outcrop within Corrimal Colliery to a pillar extraction area in South Bulli Colliery. The fault was first intersected in the Bulli Seam workings of Corrimal Colliery approximately 250m northwest of the seam outcrop in about 1895. At this intersection, the fault is shown on the various plans as a normal fault with a throw of 94 or 95 feet (29m). The fault is described in Harper (1915) as having a 94 foot throw and a hade angle of 45° to the northeast. Harper also mentions the steep grade of the seam adjacent to the fault. The intersection at this location is the only point in Corrimal Colliery where roadways (stone drifts) have been shown as driven through the fault in the Bulli Seam.

A water drainage tunnel was also driven in the lower seams to drain water locally ponded by the displacement associated with the Corrimal Fault. The north eastern section of Corrimal Colliery in the area of the earlier Broker's Nose Colliery had a history of water ingress, most likely associated with mining practices of pillar extraction at shallow depth on the eastern side of the escarpment. Early proposals for the Broker's Nose Mine in the Balgownie Seam included assessment of the potential for Balgownie Seam workings "to drain the upper seam" i.e. the Bulli Seam. Ultimately a 'water tunnel' was excavated at a location close to the lower side of the Corrimal Fault to constantly drain the up dip workings by gravity. This arrangement involved a staple shaft down to the Balgownie Seam and then a cross-measure drift outcropping in the Wongawilli Seam horizon. This water tunnel arrangement has been used elsewhere. South Bulli Colliery has a similar arrangement via a Balgownie Seam roadway and another example is known to have had existed at the Mt Kembla Colliery.

Significantly, the Corrimal Fault itself, despite a significant throw of 29m was not found to be hydraulically conductive sufficient to drain the water ponded on the downthrown side of the fault. A water tunnel was required to achieve the necessary drainage of this area.

The next roadways to be driven through the Corrimal Fault are located approximately 1.7km to the northwest within South Bulli Colliery. At this second penetration location, the fault zone is initially recorded on the 1911 yearly plan as having a throw or offset of 74 feet (22.5m). The later reduced level (RL) information indicates that a coal transport (haulage) drift has been constructed in one of the roadways. The main fault plane appears to be accompanied by two parallel prominent joints or minor faults. Harper (1915) makes reference to the Corrimal Fault in South Bulli Colliery in his description of Corrimal Colliery: "South Bulli Colliery workings proved what is apparently the same fault, with a displacement of a little over sixty feet". This reference appears to coincide with an area approximately 130m to the northwest of the second penetration site where detailed RL information on either side of the fault zone is shown for first time on the 1913 yearly plan.

Between the first and second penetrations of the fault zone, both mines have used the adjacent mines workings locations and reduced levels to estimate the varying throw of the fault zone. This fact is highlighted by the inclusion of sections of workings (with relevant data) of one mine, on the other mine's plans and vice versa. The position, throw and width of the fault zone appear to have been instrumental in the lease transfers calculations for the balanced compensation of area impacted by the fault zone. In fact the barren ground of the fault zone width has been used as the boundary barrier separating the two mines.

Beyond the second penetration, the presence of the fault appears to influence panel layouts of this advancing section of the mine, as the first workings of the main headings run almost parallel to the fault zone with the fault zone then contained within an abutment barrier pillar between the first workings main headings and secondary extraction areas.

The third penetration of the fault zone is approximately 600m further to the northwest. In this location, three roadways were formed through the fault zone. The throw of the zone is noted as 8 feet (2.4m) on the 1911 yearly workings plan. The later 1913 yearly plan shows the difference between the "Foot of Jump" to the "Top of Jump" to be around 10 feet (3m).

There are two more intersections of the fault in what is assumed to be stub roadways to investigate the existence and throw of the feature before a fourth penetration of the fault zone has been made approximately 380m beyond the third. On the 1913, 1916 and 1917 yearly plans, the throw of the fault zone at these locations is noted as being around 6 feet (1.8m).

Further to the northwest, the first workings penetrate the faulting eight more times, possibly indicating that the feature is no longer a hindrance to mining. It is estimated that this mining occurred around 1920. Interestingly, the faulting is shown in one part, to have split into three prominent faults or joints and locally affected the roadway bearings. A final throw dimension of 4 feet (1.2m) and throw direction (downthrown to the northeast) is shown on the Record Tracing for this area. This final measurement is about 140m before of the end of the indicated faulting.

Figure 7 shows the Record Tracing in the area where the last recordings of the Corrimal Fault are shown. The Record Tracings indicate that secondary extraction in this area was carried out spasmodically during the late 1930's and 1940's. The final indication of faulting (and/or jointing) is marked on the Bulli Seam records where the hand worked pillar extraction used the fault zone as a limit in these secondary workings. The fault zone is shown as two distinct lines but no other information. The last throw measurements are about 140m to the southeast of this last depiction of the fault zone.

This recording appears to be the final influence of the Corrimal Fault on the mining layout and/or method of working in South Bulli Colliery and coincides with a substantial barrier pillar in the Bulli Seam believed to have been left to contain water. Subsequent in-seam drilling for inrush prevention for both the Balgownie and Wongawilli Seam mining confirmed this water management arrangement.

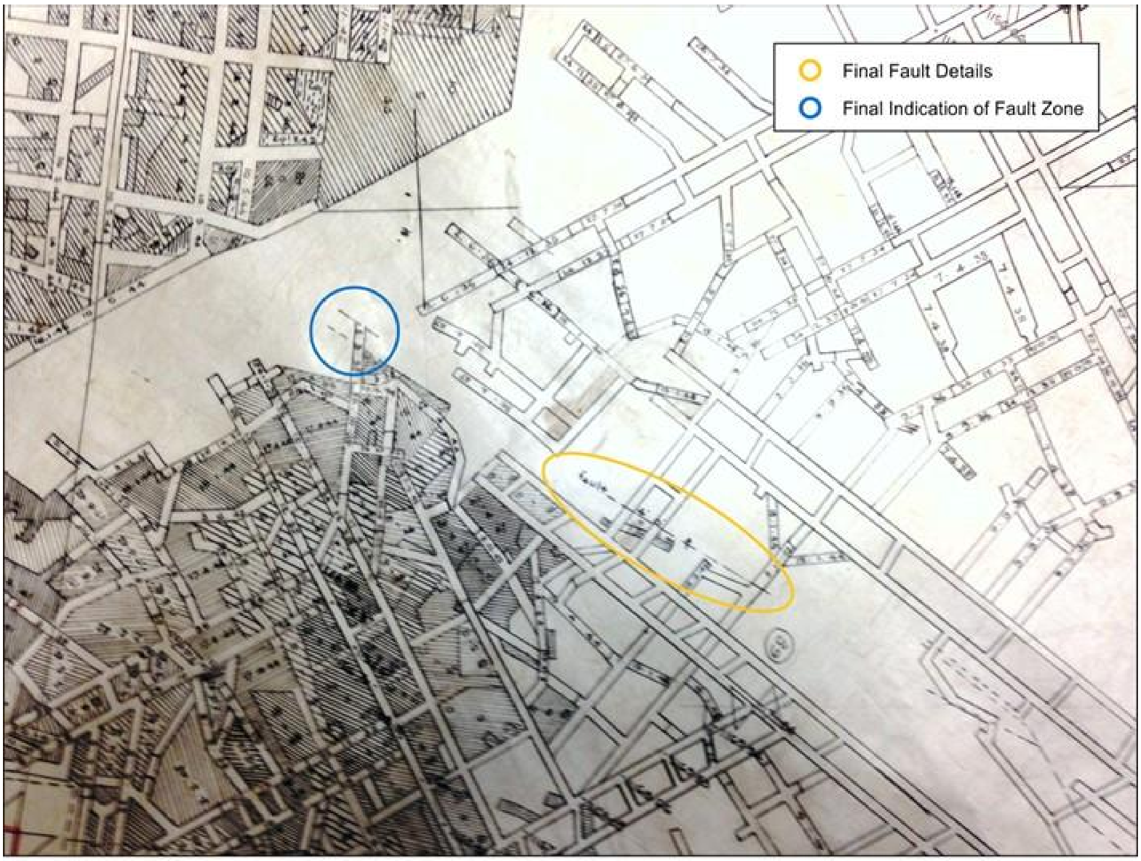


**Figure 7: Original Record Tracing of South Bulli Mine (scale 1"=2 chains) showing the final fault details and final marking of the fault zone to the northwest in the Bulli Seam.**

Figure 8 shows the Bulli Seam workings and the Corrimal Fault observations presented in Figure 7 plotted at the same scale and for the same area of the mine as for the details shown in Figures 9 and 10.

### 4.1.2 Balgownie Seam Intersection

In the Russell Vale East area, the Balgownie Seam is only about 1.2m thick and positioned some 5-10m below the Bulli Seam. During the late 1800's, the Balgownie Seam was developed by hand methods at the same time as the Bulli Seam was being developed to supplement the transport and ventilation systems of that era. Large scale mining of the seam commenced with continuous miner operations around 1968, before transitioning into the retreating longwall method of secondary extraction.

The mine plans for the Balgownie Seam are dominated by the longwall layout which operated from 1970 to 1982 when mining in this seam was discontinued for a period. Mining in the Balgownie Seam recommenced from 2001 to 2003 with additional first workings being developed along the northern extent of the earlier workings using a thin seam, cut and flit system.

Figure 9 shows the only Corrimal Fault intersection in the Balgownie Seam workings near the north western corner of the longwall area.


**Figure 8: Summary of Corrimal Fault observations in the Bulli Seam in the area of interest at common scale also used in Figures 9-10.**

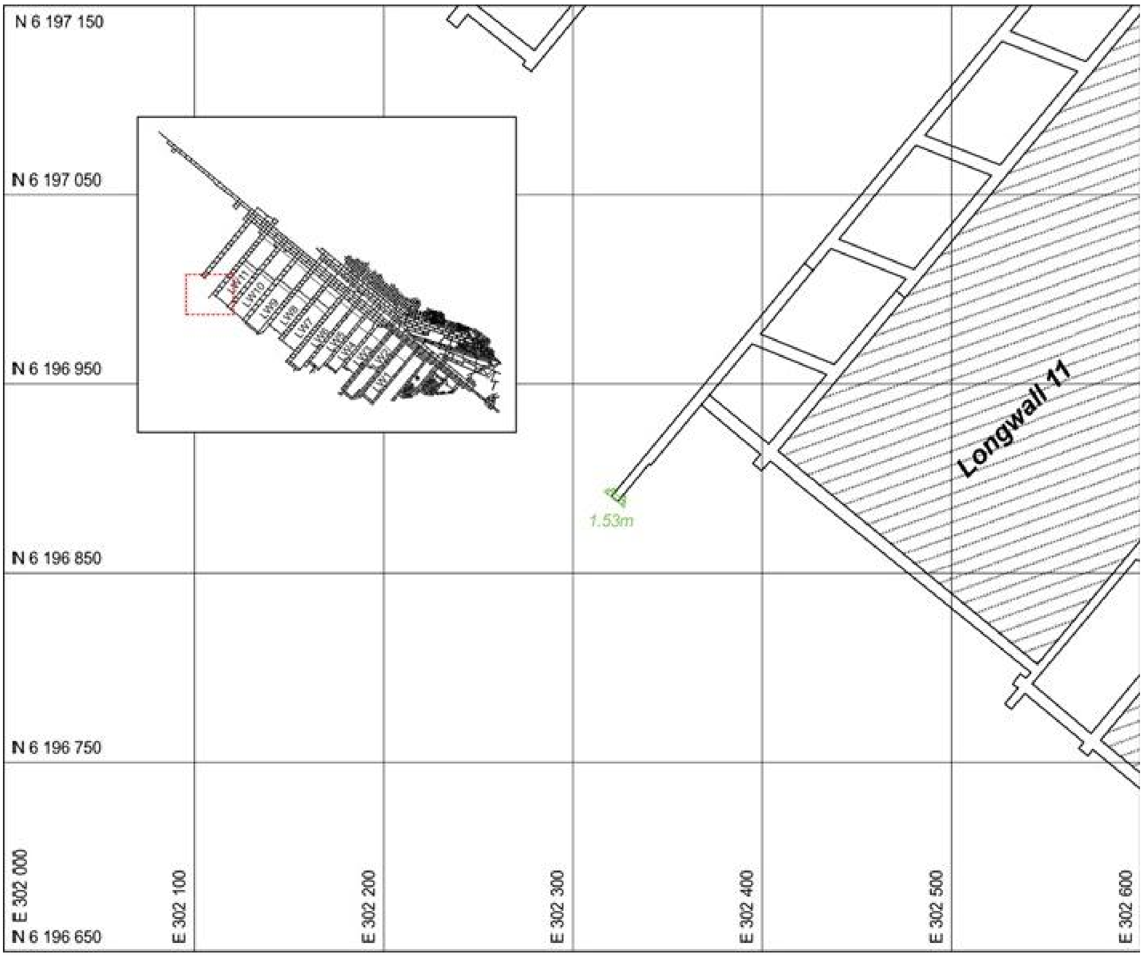


**Figure 9: Only Corrimal Fault intersection in the Balgownie Seam workings adjacent to the last longwall start line.**

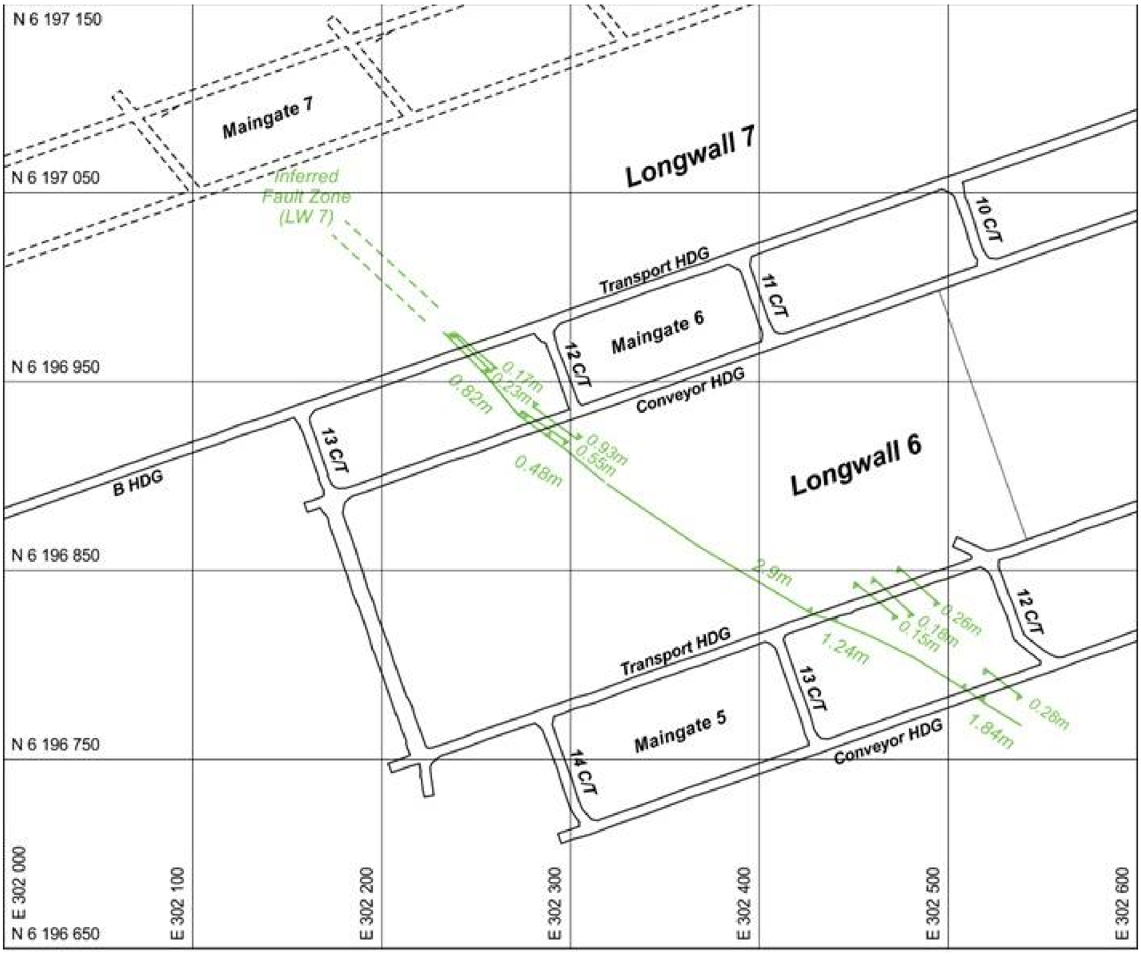


**Figure 10: Detail of intersections of the Corrimal Fault in the Wongawilli Seam - Longwall 6 goaf omitted for clarity.**

### 4.1.3 Wongawilli Seam Intersections

Wongawilli Seam intersections include penetrations in the four gate entries of Longwall 6 and the mine through of Longwall 6. Figure 10 shows the observations of Corrimal Fault intersections in the Wongawilli Seam workings mined to date.

The Corrimal Fault provided a limit to the thin seam mining in the Balgownie Seam. Balgownie Seam workings have only intersected the Corrimal Fault in one roadway at a location in south-western corner of the Balgownie Seam mining area, approximately 50m away from the final indication of faulting shown in the Bulli Seam. The notation on the throw of the faulting at this point is 1.53m (5 feet). There appears to be two normal faults shown with a horizontal offset of around 7m from the Bulli Seam position consistent with a hade on the fault of about 45°.

Russell Vale Colliery developed gateroads for Longwall 4 to within 40m of the Corrimal Fault during 2011. Similar to the Balgownie Seam practice, the mine planning for the Wongawilli Seam relied on the Bulli Seam details of the Corrimal Fault for decision making purposes. The first intersection of the Corrimal Fault in the Wongawilli Seam occurred in Maingate 5 inbye of Longwall 5 starting line (i.e. Longwall 6 tailgate). Two roadways penetrated the fault zone. The main fault was measured to have a throw of 1.8m in the south eastern conveyor roadway and 1.2m in the transport roadway 65m to the northwest. The throw in the gateroads was confirmed by the recent extraction of Longwall 6 through the fault zone in June 2015.

The next exposure of the Corrimal Fault in the Wongawilli Seam was in the conveyor roadway of Maingate 6 Panel. This position is within 15m of being directly below the final Bulli Seam faulting indication. Here, three faults of varying type have been mapped within a 10m roadway zone. The total throw measures 0.86m (3 feet).

There has been some deterioration of the immediate roof in this area thought to be from a combination of the roof strength deterioration and elevated stresses associated with the faulting as well as increased stress as a result of the overlying Bulli and Balgownie Seam workings.

The last intersection of the Corrimal Fault in the Wongawilli Seam is currently in the transport roadway of Maingate 6 Panel. This intersection is 50m from the Maingate 6 conveyor roadway and about 15m northwest of the inferred end of the faulting in the Bulli Seam. At this point, similar to the conveyor exposure, a 6m wide fault zone consisting of 3 faults of various types, is interpreted to have a total offset of 0.42m (1.4 feet).

Longwall 6 mined through the Corrimal Fault in June 2015. The fault was exposed on the longwall face and provided additional insights into the local variations to the position, size and type of the faulting zone within the longwall block. The fault planes exposed on the longwall face showed variations in throw across the face from less than 1m to up to 2.9m.

### 4.2 Dyke D8 Intersections

Figure 11 shows the Bulli Seam intersections of the Dyke D8 east of the Cataract Reservoir.

Dyke D8 was first encountered in the Bulli Seam workings of South Bulli Colliery around 1902 at close to its intersection with Dyke D7 approximately 1.7km west of the seam outcrop. From here, Dyke D8 is present in the Russell Vale East mining area for about 3km before crossing under Cataract Reservoir.

Within the Russell Vale East mining area, the Bulli Seam workings have penetrated Dyke D8 on at least 20 occasions with secondary pillar extraction workings immediately adjacent to the feature for over 2km of its length.

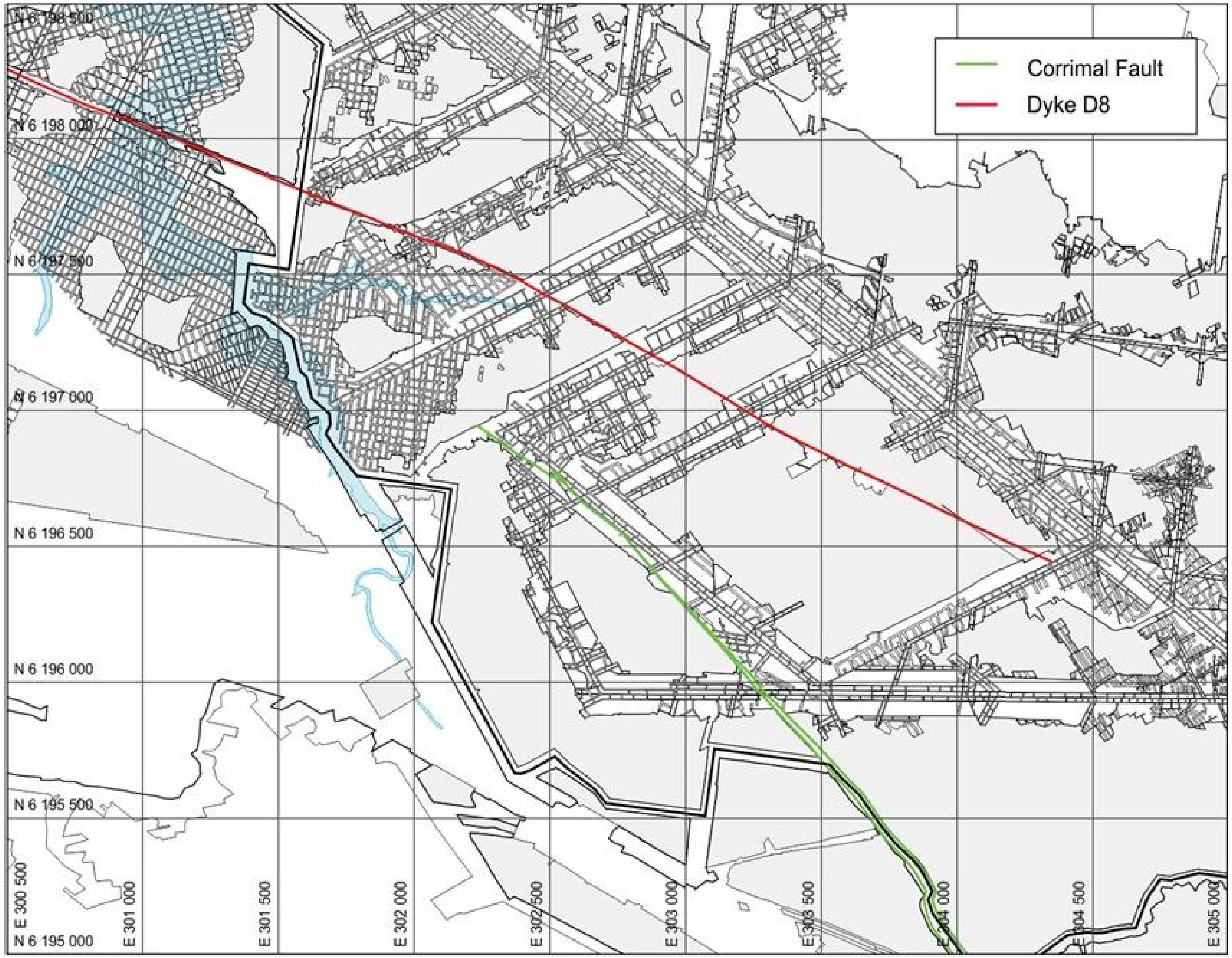


**Figure 11: Bulli Seam intersections of Dyke D8 east of the Cataract Reservoir together with the Corrimal Fault.**

The period of this mining extends from the early 1900's to the mid 1940's during which time the dyke is documented as being variable in thickness, composition and hardness, but generally displaying a range of widths in the coal seam varying from 1m to 4m. It is likely that the width of the dyke in the adjacent strata is much less because of the higher horizontal stresses in this adjacent strata.

In the neighbouring part of Corrimal Colliery, Dyke D8 was first intersected at the Bulli Seam horizon circa 1931. At this location the dyke is immediately beside and below the Full Supply Level (FSL) of the Cataract Reservoir and is shown to have a localised thickness of around 7m. The dyke composition is noted as "basalt" with the mine plans suggesting that the thickness and hardness of this intrusion was a major influence on the mining layout for the 20 year working duration of this section of the mine. There have only been a minimum number of penetrations (3) of the dyke along almost 1.5km of workings. Secondary pillar extraction was carried out up against the dyke for a distance of 350m in the early 1950's.

Within the smaller mining footprint of the Balgownie Seam workings at South Bulli Colliery, Dyke D8 was penetrated 20 times during the mining of the two heading longwall gateroad development panels from 1971 to 1981. Longwalls 5 and 6 extracted completely through the dyke whereas Longwalls 7 to 11 avoided this process by stopping the longwall face before the dyke, leaving a pillar of coal and restarting the longwall extraction on the other side. The decision to step around the dyke (and any cindering/silling) is believed to have been made in consideration of the dyke hardness and thickness with the resulting consequences including damage to the mining equipment and a reduction in the overall quality of the coal product produced. Stepping around dykes is a common mining practice. Examination and comparison of Dyke D8 details for both the Bulli and Balgownie Seam intersections show consistency in the position and thickness within the expectations of normal geological variability.

Recent mining in the Wongawilli Seam at Russell Vale Colliery has intersected Dyke D8 on eight occasions in the development panels for Longwalls 4 to 6. The Longwall 5 block was extracted through the dyke/sill configuration. The dyke position, thickness and hardness variations were consistent with the experience in the Balgownie and Bulli Seams although the horizon silling of the seam was more pronounced in the Wongawilli Seam. This characteristic is consistent with the thick banded nature of the Wongawilli Seam and the vicinity of the major local feature named as the Bulli Sill Complex (WCL 2013). With increasing distance to the west, the Dyke D8 trends further away from the Bulli Sill Complex.

## 5. LATERAL EXTENT OF CORRIMAL FAULT

Figure 12 shows the detail in all three seams from Figures 8, 9 and 10 superimposed onto the same diagram.

Details of the Corrimal Fault at the Bulli Seam horizon are well documented in the Record Tracings of the two mines that have intersected the fault.

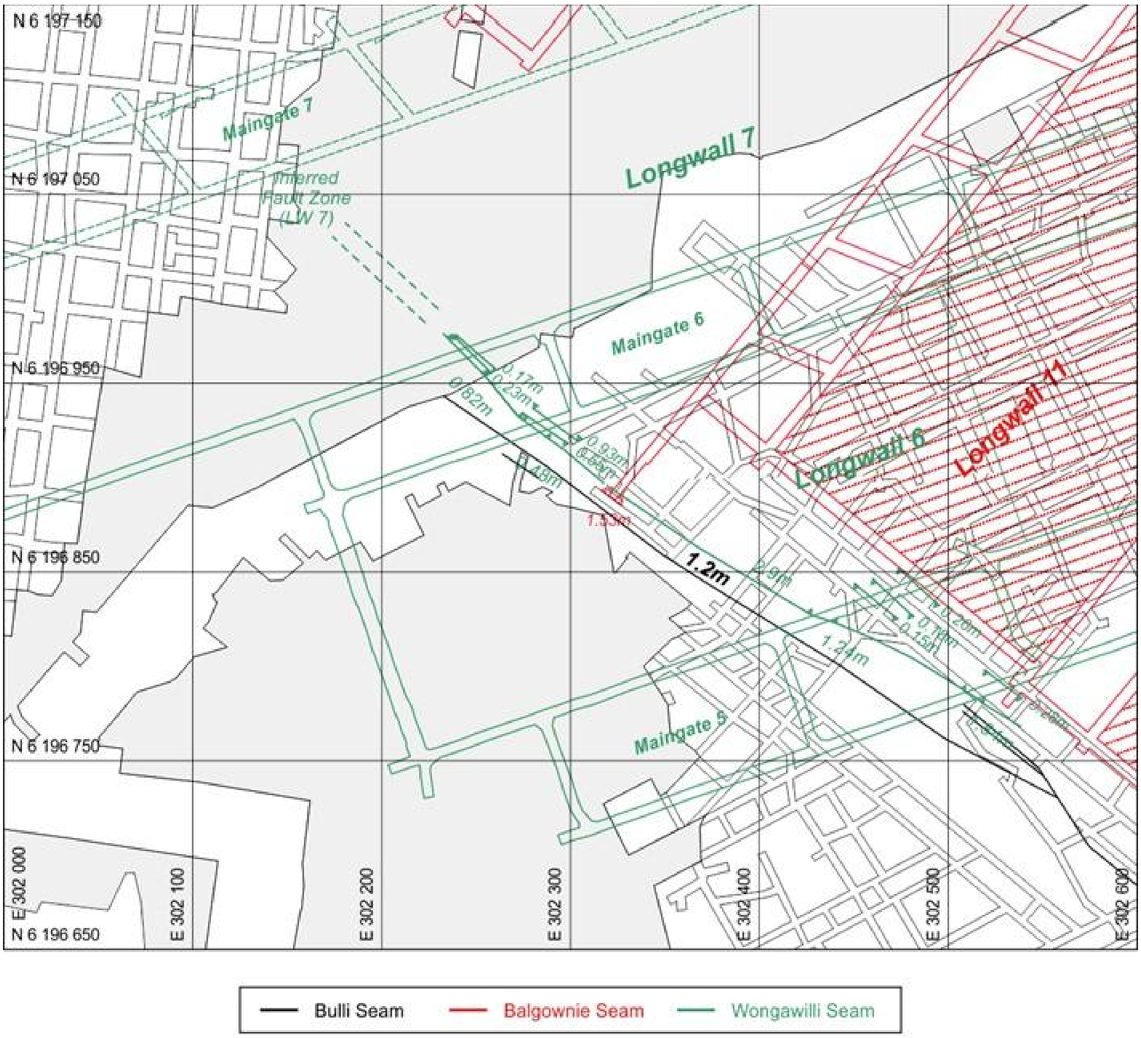


**Figure 12: Corrimal Fault intersections from all three seams superimposed onto the one plan - Longwall 6 goaf omitted for clarity.**

The position and extent of the faulting as depicted appears to be reliable from a practical mining sense.

The properties of the faulting in the Balgownie and Wongawilli Seams are less well defined because of the limited fault intersections in these seams. Where there is information, this information appears to coincide closely with the previous Bulli Seam interpretations and where the faulting has been inferred to be diminishing and terminating. There are minor variations apparent in the characteristics of the displacements but these appear to be localised and of limited extent. As discussed in Section 4, this information indicates that the Corrimal Fault is tapering away to the west.

Additional insights derived from the 1932 District Plan shown in Figure 13 confirm this view. This plan is coincidentally centred on the Corrimal Fault area and displays the interpretation of geology (dykes and faults) and structure (seam floor contours) of the Bulli Seam as it was understood at that time.

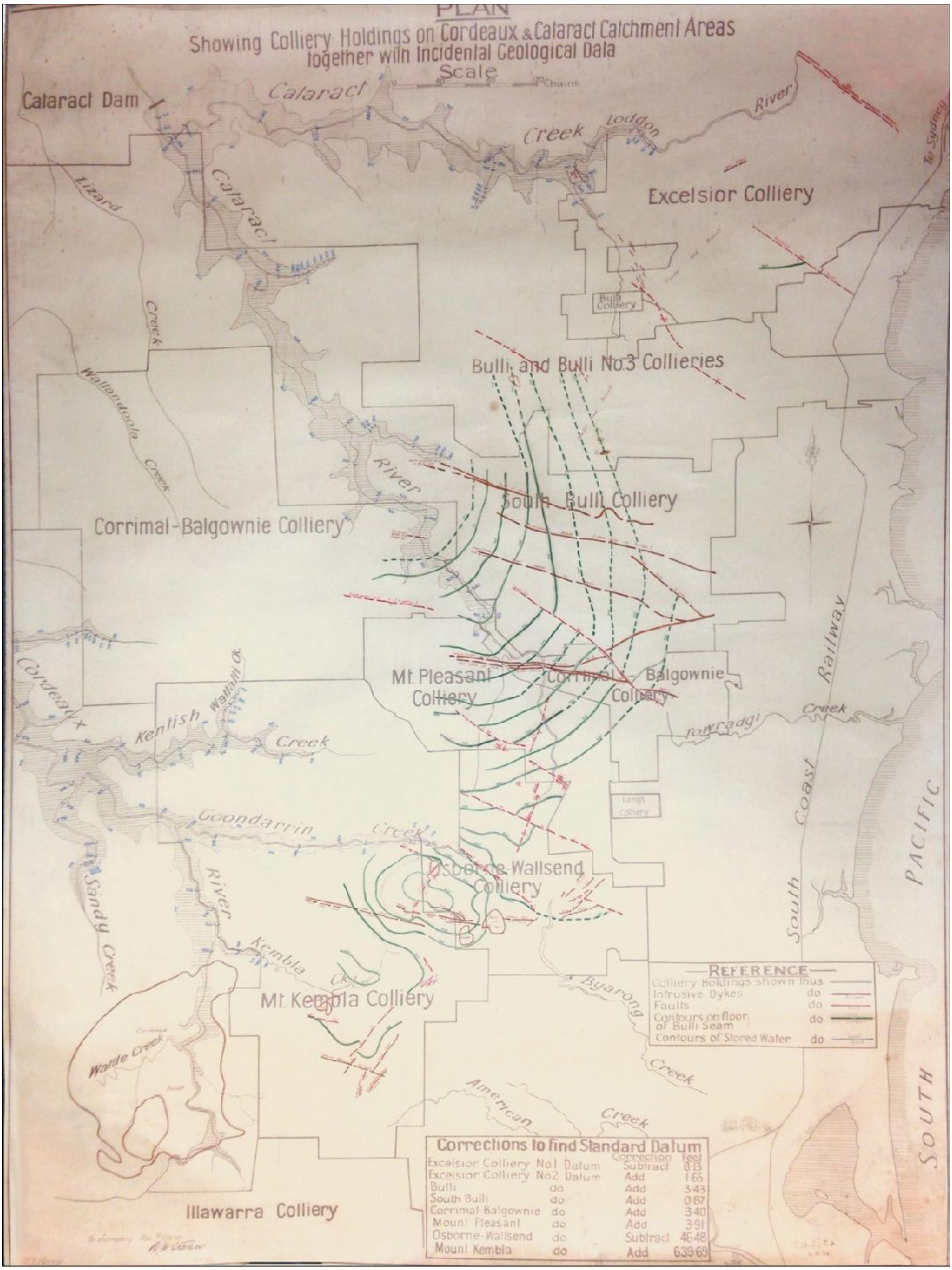


**Figure 13: An overview of the 1932 Wollongong District Plan.**

The plan also documents the differing datums used by each mine so allowing reduced level information to be adjusted to a common base that also includes details of the stored waters of Cataract Reservoir. This plan is considered to provide a valuable piece of information, especially in the context of the 1931 change in mine plan reporting standards.

## 5.1 Additional Bulli Seam Data and Investigations

An area of apparently truncated first workings in the Bulli Seam on the northern side of Cataract Creek in Corrimal Colliery, although not directly aligned with the projection of the Corrimal Fault, is close enough to warrant further investigation as a possible indicator of an extension of the Corrimal Fault below the Cataract Creek arm of the reservoir. This section presents the results of a detailed investigation into the workings in this area.

The outcome of this investigation indicates that the apparently truncated workings are primarily the result of a change in reporting standards that coincidentally occurred during the interval between two campaigns of mining in this area. The irregular shape of the pillars formed is consistent with some roof stability issues in this area, possibly a result of elevated stresses in the area beyond a fault termination, but more likely for other unrelated reasons. The apparently truncated workings are not considered to indicate a continuation of the Corrimal Fault. The alignment of the fault would need to have changed direction and the fault would need to have disappeared so as not to have any influence on South Bulli Colliery workings for more than a kilometre from its last recorded location.

Figure 14 shows the section of Bulli Seam coal unworked in Corrimal Colliery and the suggested projection of the extension of the Corrimal Fault from South Bulli Colliery. Close inspection of the Record Tracing for Corrimal Colliery in the vicinity of this portion of unworked coal reveals a number of facts available for interpretation. These facts include:

- An initial series of 1931 dates at the roadway stubs indicating mining to the north from a southerly direction.
- A second series of workings and dates showing the mining places advancing again from the west to the east during 1934 to 1938.
- No geological features noted (either on the prior to 1931 workings or the later workings to 1938).
- No reduced level information although general contours are added during or after the 1960's.
- Large sections of very uniform workings, both first workings roadways and secondary pillar extraction, prior to 1931 that appear to be too regular to be reliable.
- Further along the projected alignment implied by the truncated workings are detailed sections including geology, dates and floor contours of first and second workings adjacent to Dyke D8. Dates shown here cover the late 1940's to early 1950's.

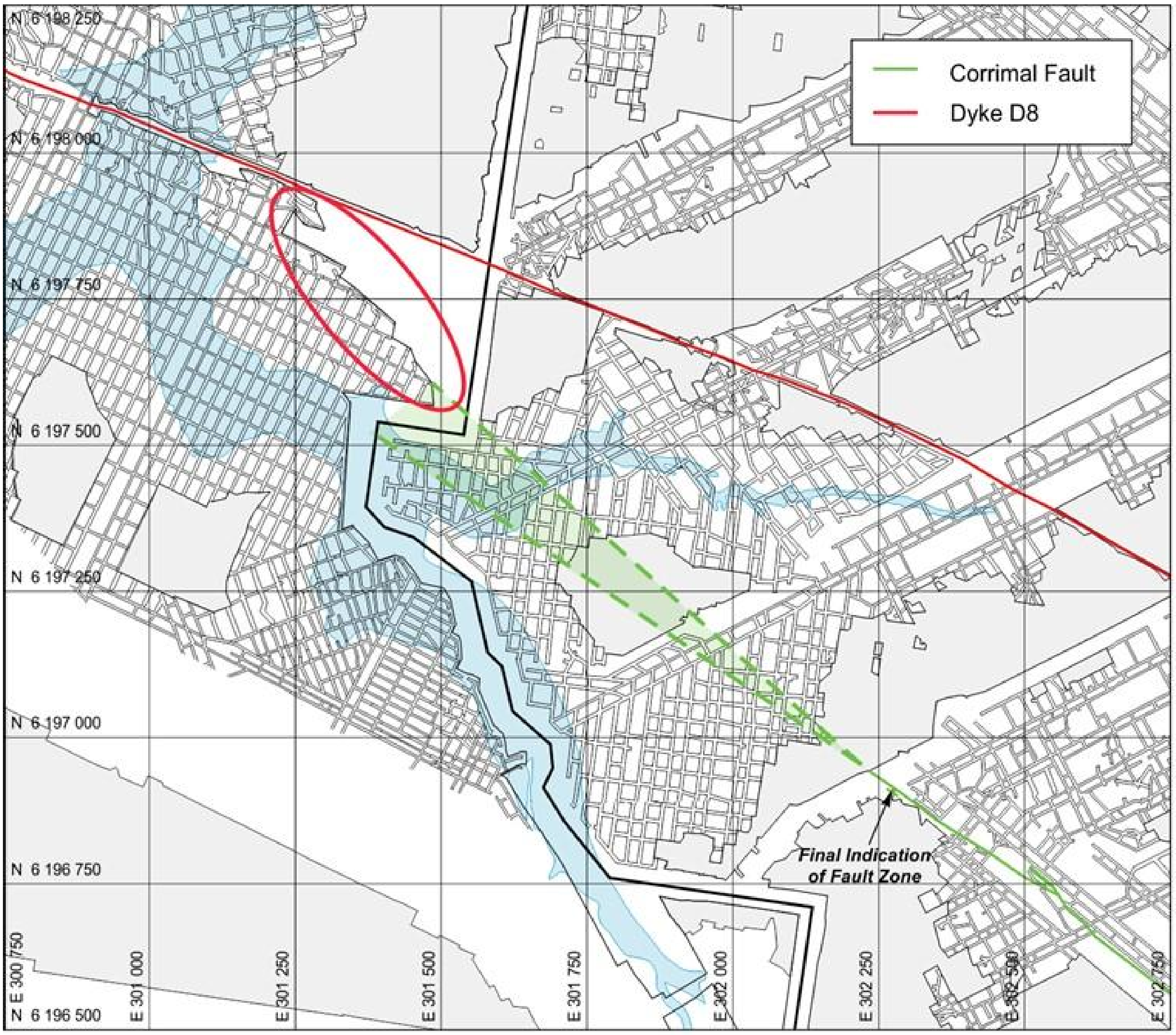


**Figure 14: Possible projections (dotted lines) approximately on the alignment of the Corrimal Fault in the Bulli Seam that extends under the Cataract Reservoir FSL to the edge of the unworked section of coal in Corrimal Colliery (circled).**

Figures 15, 16 and 17 show details of the unworked section of Bulli Seam coal on the Record Tracing of Corrimal Colliery.

Although there is no clear explanation as to why the section of coal in the corner between the lease boundary and the major Dyke D8 remains unworked, there are several plausible explanations.

The inclusion of regular dates (from 1931) shown on the mine plans for the first time allows for a line to be drawn around the extent of the working places at that time. This information and the scant date outbye allow the mining sequence for the area to be deduced. It would appear that these initial workings may have stopped during the late 1920's. The reason the workings stopped here, is considered most likely to have been a practical mining issue or number of issues combined (e.g. access to coal haulage systems, production targets – easier coal elsewhere, restrictions on the type of mining, sequencing and scheduling, ventilation and water management) rather than geology.

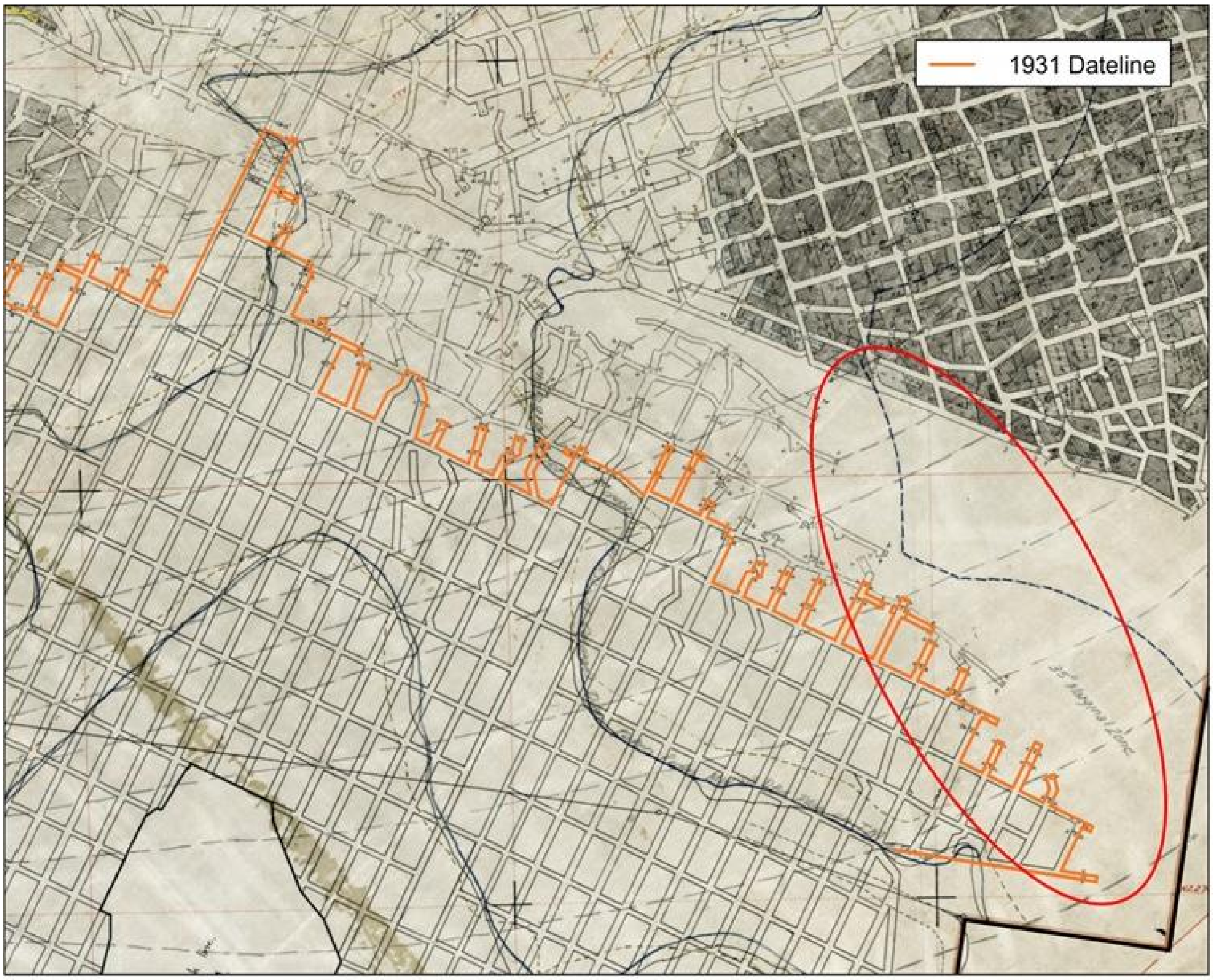


**Figure 15: Snapshot of the Record Tracing for Corrimal Colliery with unworked piece of Bulli Seam coal in corner against lease boundary and major Dyke D8 (circled). The 1931 dateline is also included.**

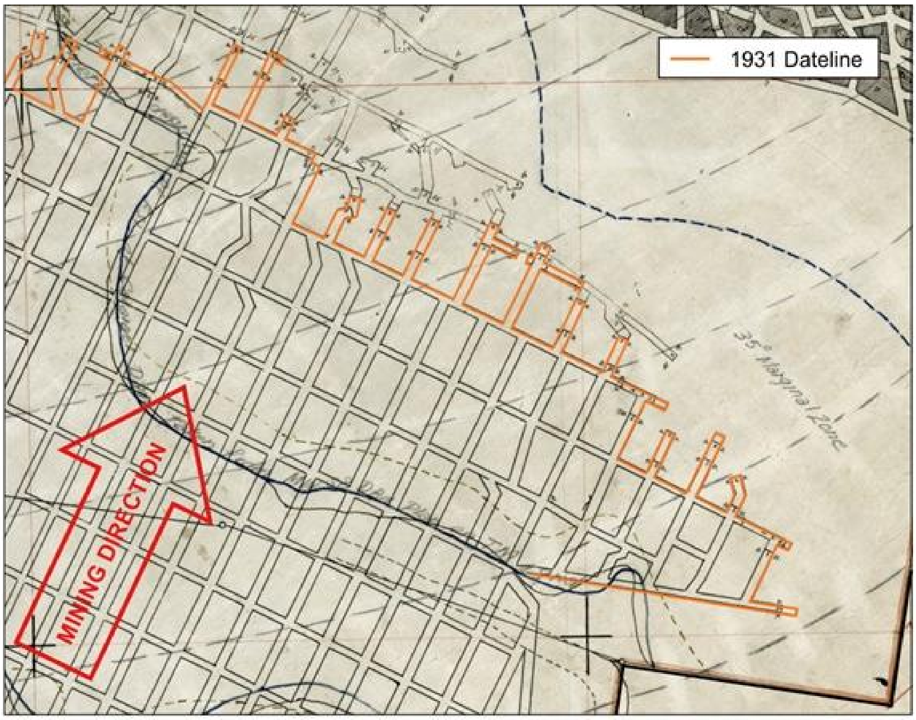


**Figure 16: A dateline highlighting the initial series of 1931 dates at the roadway stubs indicating the development of mining in a northerly direction.**

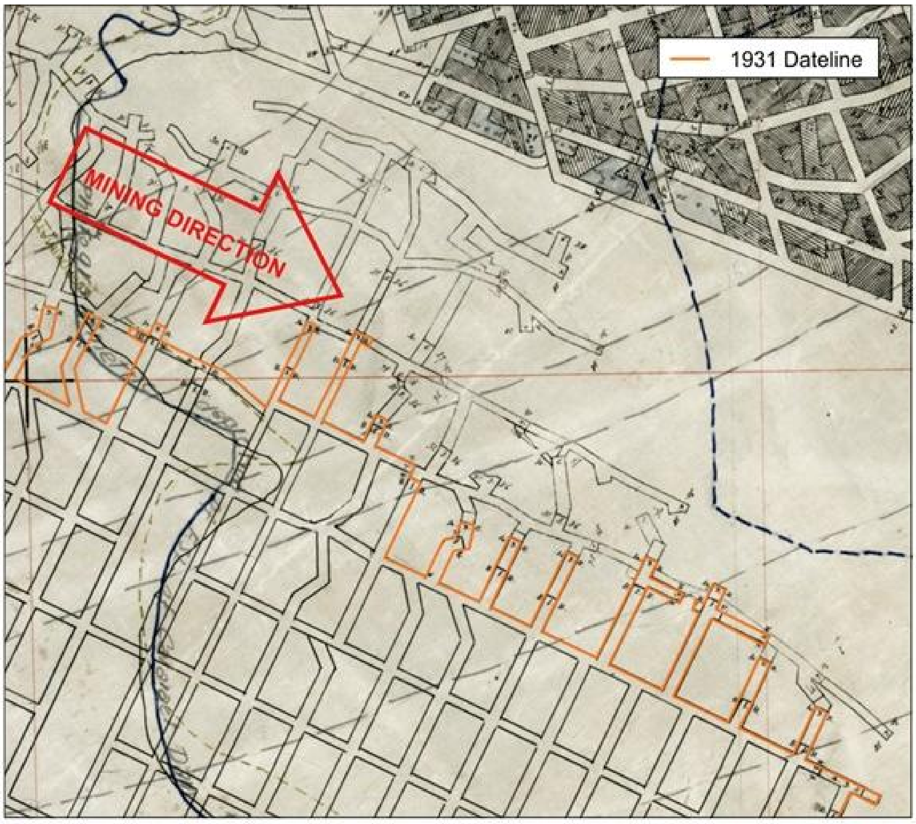


**Figure 17: A second series of workings and dates after the highlighted 1931 dateline indicating the mining places advancing again from the west to east during 1934 to 1938.**

The return to the area from 1934 to 1938 appears sporadic and less than fully productive. Mining at this time could have been influenced by production targets. Areas of easier working or areas of higher return for effort would tend to have priority over areas of difficult mining conditions or areas of limited potential. This small remote corner of the Corrimal Colliery lease with coal extraction limited by proximity to the stored waters of the Cataract Reservoir is likely to have been less favourable than nearby secondary extraction areas adjacent to the main headings. Extension of leases to the south into the newly closed Mt Pleasant Colliery reserves occurred around this time and may have opened up more profitable areas.

Minor faulting or high stresses may have contributed to poor roof conditions and the early truncation of the workings in this area. The Bulli Seam is approx. 2.2m thick in this area and a fault with up to about 1.2m throw would have had little influence on the hand mining techniques of that period so it is possible that there are a number of smaller faults in the area.

There are two minor dykes on the south side of, and parallel to Dyke D8 in the South Bulli Colliery Bulli Seam workings. These features may extend through the lease boundary coal barrier and into this section of Corrimal Colliery. These features did not appear to restrict the mining in South Bulli Colliery when encountered there and it is considered likely that they would have had a minimal impact to the mining layout if they exist in this part of Corrimal Colliery so this explanation seems unlikely.

The 1932 District Plan shows minor fault zones with displacements totalling 3 feet (0.9m). It is possible that minor faulting may exist in this area unrelated to the Corrimal Fault. The unworked piece of coal in Corrimal Colliery and the presence of the South Bulli Syncline support this theory.

However, workings in South Bulli Colliery along about a kilometre of the projected alignment of the fault between the final marked position of the fault and the apparently truncated workings appear unconstrained by geology. Figures 18 and 19 show the Record Tracing for the Bulli Seam in this area.

This mining was carried out from the late 1930's to the late 1940's and includes areas of first workings and secondary pillar extraction. There are no records of any faults in this area and the workings are regular. There are two main central haulage panels that have detailed reduced level information included on the plans. Close examination of this data indicates that if faulting were to be present, throws could not be greater than 2 feet (0.6m) to be consistent with this level data.

The same reduced level information is shown on both the mine plan and Record Tracing for the Bulli Seam in this part of South Bulli Colliery. The correlation of reduced levels and seam floor contour information between Corrimal and South Bulli Collieries has been reviewed in the recent past resulting in increased confidence in the reliability of this data. Along this projection there are approximately 40 roadways (excluding extraction) that would have intersected the faulting if it existed. In this situation, it is difficult to imagine a significant continuous geological feature not being recorded and shown on some plan of the mine during a 10 year period of mining.

**Figure 18: Shows a section of the Bulli Seam Record Tracing for South Bulli Colliery along the suggested projection (dotted line) of the Corrimal Fault below the Cataract Reservoir. The '5 Chains Margin' and 35° Angle of Draw (0.7D barrier) Marginal Zone is also shown. Reduced Levels are in feet on a datum 1000' below MWSDB standard datum.**

**Figure 19: An enlargement of the Bulli Seam Record Tracing along the projection to show the Reduced Levels details.**

While it is still possible that this fault zone continues for more than a kilometre without ever being recorded on the mine plans or Record Tracings, it is difficult to see how any such fault would have any significance in the context of inflows from the surface more than 300m above.

Figure 20 shows detail of the 1932 District Plan in the area of interest. The 1932 District Plan confirms the seam floor contours as they are understood today and most importantly for this study the extent of the geological features uncovered to that time. Note that the level of detail includes minor fault zones with throws totalling as low as 3 feet (0.9m). The contours in front of what was then the unmined sections of South Bulli Colliery and the correlation with the Corrimal Colliery contours compare closely with what was to be proven later by future workings. The extent of both the Corrimal Fault and Dyke D8 are shown in this area.

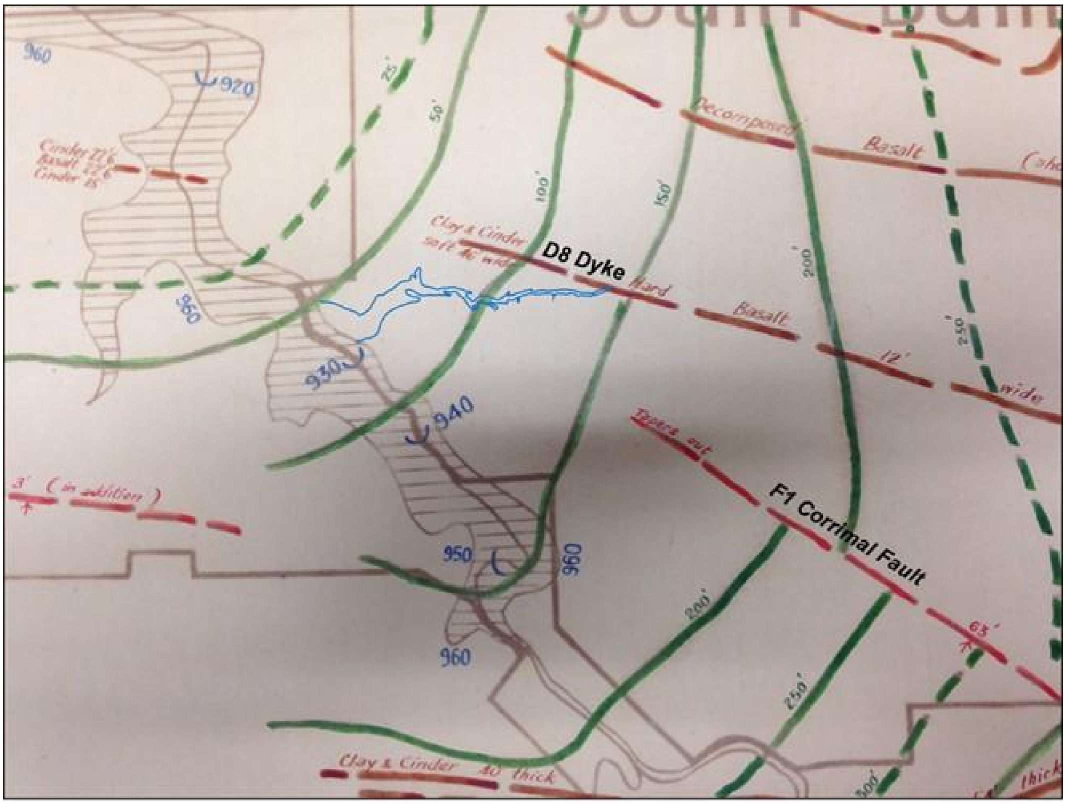


**Figure 20: Detail of the extent of the Corrimal Fault F1 and Dyke D8 on a section of the 1932 District Plan (approximate position of FSL in Cataract Creek added).**

The extent of Dyke D8 in South Bulli Colliery coincides with the dates for the working faces shown on the mine plan and Record Tracing. Dyke D8 is not shown to extend to the lease boundary because the workings had not yet reached that far and proven the dyke. Likewise, the first exposure and extent of the Dyke D8 in Corrimal Colliery (adjacent to and below the stored waters of Cataract Reservoir) coincides with the shape of the limit of the workings at that time in Corrimal Colliery.  Any extension of the Corrimal Fault toward the edge of the unworked section of Corrimal Colliery lease would also be expected to be shown.

The comment "Tapers out" appears on this plan at the end of the Corrimal Fault. The end position indicted coincides with that part of the workings in the late 1930's to late 1940's where it appears the mining layout was no longer constrained by the presence of the fault zone. The annotation of 63 feet throw further to the southeast is consistent with other data sources and discussions in this report.

The exclusion of the Cataract Creek channel from the stored water is also noted on this plan. This was a fairly common omission on plans from this period. For instance, the early Cataract Dam construction drawings do not include this watercourse in their storage volume calculations.

## 5.2 Surface Investigations

The general geological features of the Russell Vale East mining domain and a detailed report on the Corrimal Fault are discussed in WCL (2013) and WCL (2014). The key conclusions and comments pertaining to the extent of the Corrimal Fault are summarised in this section.

WCL geologists conducted traverses around the upper reaches of the FSL of Cataract Reservoir along the Cataract River and the Cataract Creek in 2013 and 2014. The purpose of these traverses was to locate any evidence of faulting or dykes at the surface. The path of their traverse is shown in Figure 21. Their observations reinforce the interpretation of the extent of the Corrimal Fault. This fieldwork was undertaken after desktop analysis of the correlation between surface features from the aerial photography systems and LiDAR surface topography data with projections of the underground Bulli Seam geological structures considering hade angles for the Corrimal Fault. Minor jointing of similar orientation to the Corrimal Fault zone on the projected alignment was detected on the western edge of the Cataract Reservoir but no evidence of displacement was found.

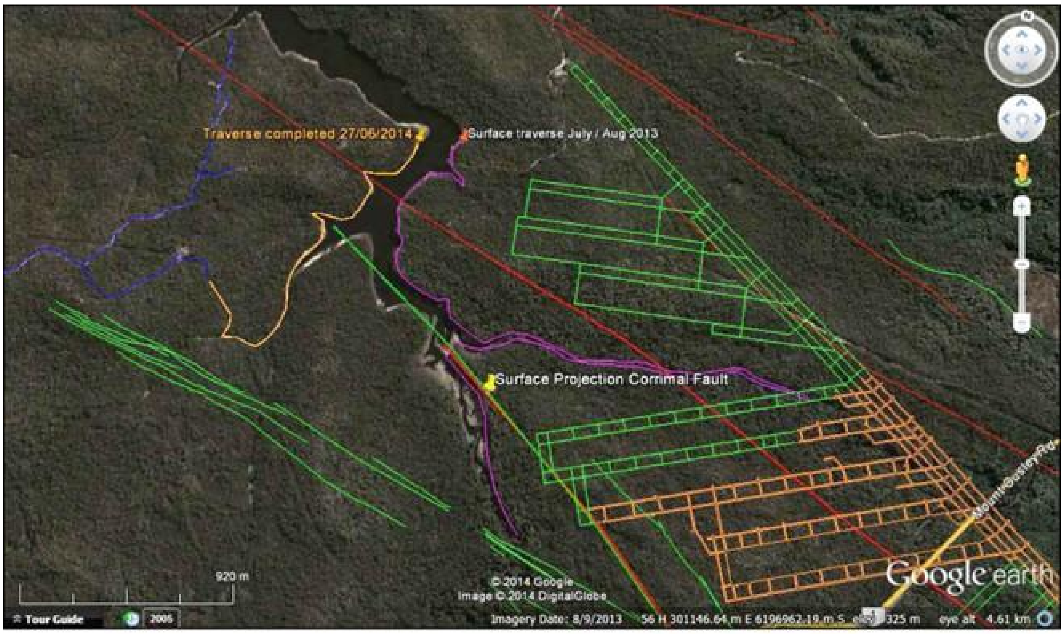


**Figure 21: Shows the surface projection of the Corrimal Fault and surface traverse routes (reproduced from WCL2014).**

Figure 22 shows a plan of the surface LiDAR data and the location of the Corrimal Fault and Dyke D8 at Bulli Seam level. Also shown is Wongawilli Seam existing and proposed longwalls and Corrimal Fault intersections.

A possible surface expression of the fault zone is indicated in watercourses approximately 1.3km northwest of the Bulli Seam outcrop. This location is about 840m west of the escarpment and 1.5km east of the Cataract Reservoir FSL where the throw of the fault is estimated to be about 25m and the depth of overburden strata is about 250m. These first order streams may be the surface expression of the fault displacement where the natural erosion processes have interacted with the displaced stratigraphy to create the surface topography observed today. There are a series of erosion features further to the west that correspond approximately with the alignment of the fault at seam level. These features are still apparent even after the fault is no longer apparent at seam level. Other surface lineaments remote from the Corrimal Fault are also oriented on this alignment suggesting that these lineaments may be a result of regional jointing rather than having any direct association with the Corrimal Fault.

## 6. DISCUSSION

In this section, the information presented above from various investigations is synthesised in one place.

### 6.1 Alignment and Extent of Corrimal Fault

Figure 12 shows the information presented in Figures 8, 9 and 10 plotted on the one diagram at the same scale. The hade of the Corrimal Fault dipping to the north at approximately 45° is evident in the relative locations of the fault in each of the three seams. The throw or vertical offset across the fault is diminishing to the west although the fault splinters in some areas and coalesces in others. The fault reduces in offset upward through the seams. In Longwall 6, the Bulli Seam offset is recorded as 1.2m but is locally 2.9m in the Wongawilli Seam.

Figure 23 shows the Wongawilli Seam fault observations plotted relative to the Cataract Reservoir and the 0.7 times depth barrier to the FSL. This diagram indicates that there is approximately 540m at seam level between the western goaf edge of Longwall 7 and the edge of Cataract Reservoir along the projected alignment of the Corrimal Fault. This distance is reduced at the surface if the hade of the fault continues to the surface at a hade of 45°, but with no significant displacement at seam level it is not meaningful to project the fault upward to the surface at any hade. The fault itself has tapered to less than about 1m of offset in Maingate 6 and is not evident in the Bulli Seam beyond this location.

The possible alignment of apparently truncated workings in Corrimal Colliery is thought likely to be associated with a change in reporting standards but may be associated with difficult mining conditions and minor faulting that is on a different alignment to the Corrimal Fault and separated laterally by about a kilometre of workings in the Bulli Seam where there is no record or evidence of any faulting despite the alignment being intersected by more than 40 entries and an area of pillar extraction.

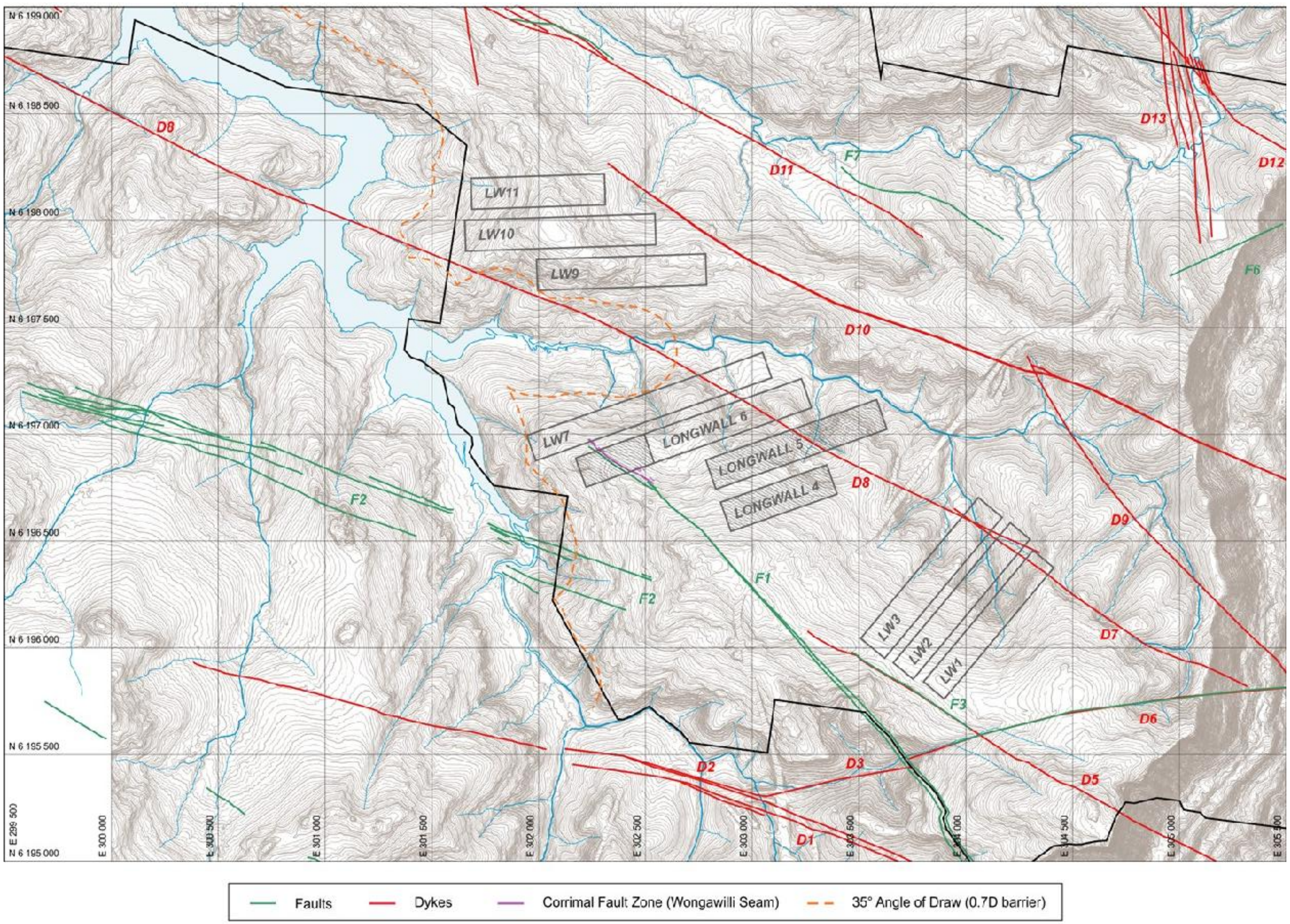


**Figure 22: LiDAR data showing detail of surface topography and defined watercourses in relation to the dykes and faulting (Bulli Seam) with existing and proposed Wongawilli Seam longwalls and Corrimal Fault intersections also shown.**

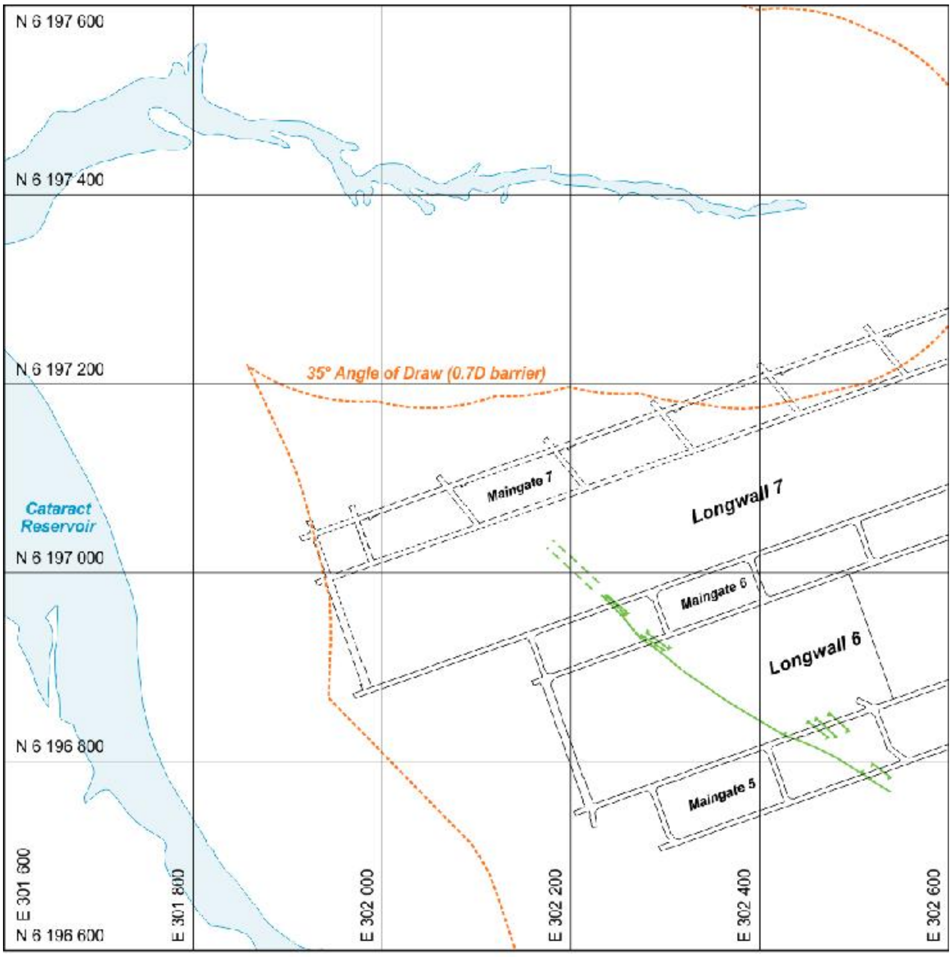


**Figure 23: Wongawilli Seam workings with the intersected fault zone positions relative to the 35° Angle of Draw (0.7D barrier) around Cataract Reservoir FSL.**

Alignment of faulting at seam level with these workings is not consistent with any alignment with surface lineaments attributed to regional jointing.

As discussed by Shepherd (1990) the major NW-SE trending faults dominate the structural map of the Southern Coalfield. The mapping of these faults at the Bulli Seam horizon show that they are normal, dip-slip type modified by some oblique-slip movements. Plots of the throw versus trace length of individual faults show that they can maintain high displacements for long distances but also that the throw can decay very rapidly near their end points. Experience in the thicker coal sections of the Wongawilli Seam shows significant local variation to direction, type and throw where these regional features terminate.

## 6.2 Visualisation of Displacement Across the Corrimal Fault

Figure 2 shows a three dimensional visualisation of the displacement across the Corrimal Fault in the Russell Vale East area based on available information of seam floor contours and direct observation of seam displacements. The location of the FSL of Cataract Reservoir is also shown.

It is clear from this visualisation that the Corrimal Fault tapers to become insignificant well before Cataract Reservoir and does not present any credible threat to the stored waters of Cataract Reservoir.

Shepherd (2003) discusses the Sydney Basin coal seam normal faults geometry in a context useful to coal mines with regard to the prediction of faulting. An analysis of fault displacement versus trace length reproduced in Figure 4 indicates that the tapering characteristics of the Corrimal Fault presented in Figure 2 are consistent with other experience in the Southern Coalfield.

### 6.3 Dyke D8

Dyke D8 extends below Cataract Reservoir and is intersected at numerous locations in all the three seams that have been mined in the Russell Vale East mining area. There has been no documented or anecdotal evidence of Dyke D8 being water bearing or hydraulically conductive even in areas where longwall mining in the Balgownie Seam occurred directly below Cataract Creek (although the dyke was isolated in a barrier in these instances).

The strategy to protect the stored waters of Cataract Reservoir is not to mine through the dyke in close proximity to the reservoir. The nearest direct goaf intersection with Dyke D8 in the proposed PPR layout is approximately 1.7km from the FSL of Cataract Reservoir and at this distance at an overburden depth in excess of 300m, there is considered to be no credible path for inflow from the reservoir into the mine.

Dyke D8 passes under Cataract Creek close to the FSL but not under the reservoir and close to the end of Longwall 9 but not through the goaf. The presence of intact strata between the dyke and the reservoir and the dyke and the goaf of Longwall 9 are expected to provide further protection. However, the primary protection is the horizontal distance along the dyke alignment and the vertical separation provided by over 300m of overburden strata.

There is not considered to be any credible potential for significant inflow through Dyke D8 from the stored waters of Cataract Reservoir through into the mine.

### 6.4 Hydraulic Conductivity

Geological structures are recognised as having potential to compromise the effectiveness of the any barriers left between the stored waters of Cataract Reservoir and the mining horizon.

The maximum recorded inflow on a geological structure was observed in Blue 2 Panel at Wongawilli Colliery in 1982 at a nominal depth of 110m below surface. An inflow rate of about 2.4Ml/day occurred in a location where a significant dyke/silll system that extended below the reservoir was intersected by pillar extraction workings mined to within about 100m of the FSL of Avon Reservoir (Doyle and Poole 1986). This inflow rate decreased over time to be less than 0.8Ml/day within 3 years. Another inflow event occurred when Kemira Colliery mined under Gondarrin Arm in Cordeaux Reservoir at shallow depth but SCT is not aware of the detail of this event.

Based on this experience at 110m overburden depth, there is considered to be no potential for any significant inflow from the reservoir into the mining horizon at an overburden depth of approximately 300m and a minimum lateral offset of 200m.

Mining adjacent to and through the Corrimal Fault in all three seams in the Russell Vale East area has not been associated with any significant inflows of water indicating the fault is not water bearing. Based on the observations of intersections in the Bulli, Balgownie and Wongawilli Seams at the time and subsequently, the Corrimal Fault is not considered to be hydraulically conductive.

## 7. CONCLUSIONS

The assessment indicates that there is no credible risk of inflow through either the Corrimal Fault or Dyke D8 as a result of the proposed mining.

The Corrimal Fault tapers to become insignificant with less than 1m of throw at seam level some 540m from the edge of the reservoir at an overburden depth of greater than 300m. The fault has not been found to be hydraulically conductive or water bearing at any of numerous intersections in all the three seams including the most recent intersection where the fault was mined through in Longwall 6. Furthermore, proposed mining does not have potential to enhance connection between the seam and the reservoir along the projected alignment of the fault.

Previous mining in the Bulli Seam provides a strong basis to determine the location and throw or offset across the Corrimal Fault. This mining indicates that there is no disruption to mining layouts and no significant offset in the coal seam along the alignment of the Corrimal Fault beyond the area of the proposed Longwall 7. The Corrimal Fault has a maximum recorded throw of about 29m near the escarpment several kilometres to the east of the proposed mining of Longwall 7 but, as is typical of faults in the Southern Coalfield, the throw tapers out along the alignment of fault. The fault either does not extend under the reservoir at all or has such a small throw as to be insignificant for all practical purposes.

Apparent truncation of historic workings in Corrimal Colliery on the northern side of Cataract Creek across an arm of the reservoir has been investigated as an indication of a possible extension of the fault below the reservoir. The changed nature of the workings depicted on mine plans is considered to be primarily a result of a change in reporting standards for mine workings that were introduced in 1931, coincidentally between two campaigns of mining in this area, one from the south prior to 1931 shown as an idealised layout and the second from the west with all the detail of individual roadways. The layout of the second campaign is consistent with difficult mining conditions in this area potentially associated with the confluence of several dykes. The seam floor contours do not show a steep change in elevation that would be associated with a significant fault.

The area of apparently truncated workings is not closely aligned with a projection of the Corrimal Fault and there are approximately 40 intersections over about 1km along this alignment including an area of pillar extraction where there has been no indication of faulting either in mine plans or in the alignment of mine workings. Although it not possible to be completely definitive, on balance, the apparently truncated workings on the northern side of the Cataract Creek arm of the reservoir are not considered to indicate that the Corrimal Fault continues under the reservoir and if it does, the throw across the fault is of such a low magnitude as to be insignificant for all practical purposes.

Dyke D8 passes below the reservoir and is intersected by the mine workings. There has been no history of inflow through this dyke at numerous intersections in all three seams. The lateral offset of the proposed longwall goafs from the reservoir along the alignment of the dyke is sufficiently large at 1.7km for there to be no credible risk to the stored waters of Cataract Reservoir.

The additional research undertaken as part of this assessment has increased the understanding of the characteristics of the Corrimal Fault and Dyke D8 but this increased understanding has not changed the original interpretation that proposed mining does not present a credible pathway for inflow from Cataract Reservoir through either the Corrimal Fault or Dyke D8. There is no significant water make from Dyke D8 through a Bulli Seam goaf that is close to the reservoir but sufficiently far that reactivation by proposed mining is not credible.

## 8. REFERENCES

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WCL 2013 – Gujarat NRE Technical Service Department – Gujarat NRE No.1 Colliery – Geological Report on the Wonga East Area – August 2013

WCL 2014 – Gujarat NRE Technical Service Department – Wollongong Coal Russell Vale Colliery – Geological Report on the Corrimal Fault – 30 June 2014

## *APPENDIX G*

## Response to Residual Matters from Independent Risk Assessment Panel Comments (Subsidence)

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12 September 2015

David Clarkson
Group Environment Manager
Wollongong Coal
PO Box 924
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Dear Dave

**RESPONSE TO RESIDUAL MATTERS FROM INDEPENDENT RISK ASSESSMENT PANEL COMMENTS**

Wollongong Coal is proposing to longwall mine coal in the Russell Vale East area of Russell Vale Colliery about 9 km north-north-west of Wollongong as part of the Underground Expansion Project (UEP). The approvals process has included a review of the project by an Independent Risk Assessment Panel (IRAP). The IRAP has provided feedback on a range of issues following a review of the UEP Risk Assessment conducted by Wollongong Coal and its specialists. This document addresses those residual matters relating to subsidence that have not been addressed elsewhere.

The key issues addressed in this report are:

1) Reliability of the mine plans in the Bulli Seam at the start of Longwall 7
2) Clarification of the closure movements on Cataract Creek
3) Uncertainty of subsidence predictions
4) A discussion on the effectiveness of seals at Russell Vale Colliery
5) Potential for horizontal shears to influence mine inflow.

## 1. RELIABILITY OF MINE PLANS IN THE BULLI SEAM AT START OF LONGWALL 7

The IRAP raised the reliability of the mine plans at the start of Longwall 7 in the context of pillar instability as a potential hazard that might compromise the effectiveness of the barrier between the reservoir and the end of Longwall 7. The issue of pillar stability is addressed in SCT Report WCRV4440B dated 10 August 2015, but the issue of reliability of the mine plans was not addressed in that report.

Figure 1 shows a reproduction of the mine operating plan for this area with dates of mining recorded for each of the roadways and the detail of two full extraction areas mined up to the 3 chain barrier to the Full Supply Level (FSL) of Cataract Reservoir, the standard at that time. The area was mined from about 1944 to 1948. As per the discussion of mine surveying standards presented in Section 3.6 of SCT Report WCRV4466A dated 19 August 2015,

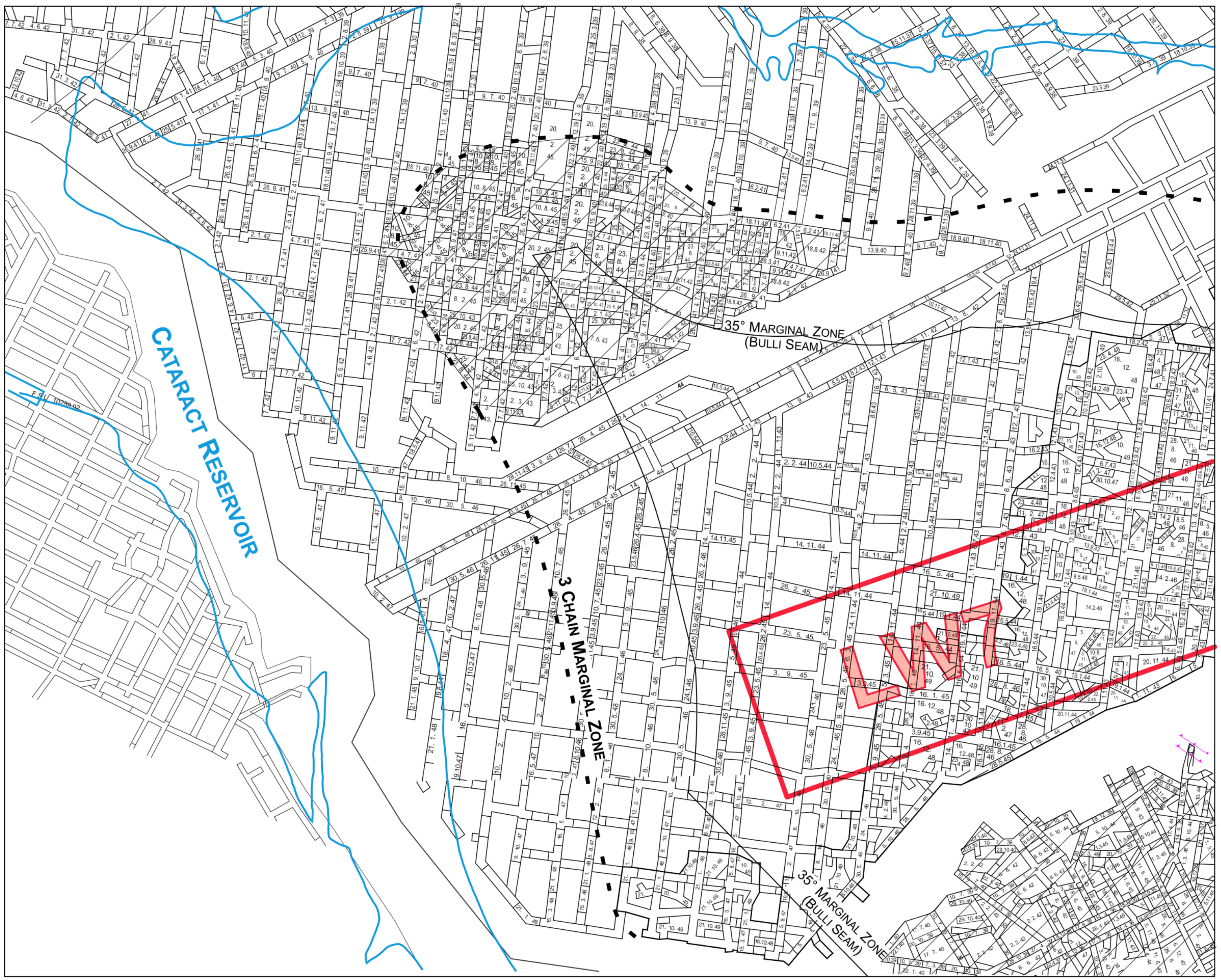


**Figure 1: Site Plan showing digitised ISG Mine Plan for Bulli Seam workings between the end of Longwall 7 and Cataract Reservoir.**

the standards from 1931 onward required a surveyor to certify the plans and from 1941 onwards, there was a requirement for mining surveyors to have certificates of competency. Thus this area was surveyed and recorded by surveyors that were required under law to keep accurate records of the mine workings and have a certificate of competency.

The plan shows extraction in two areas adjacent to the 3 chain barrier that was the standard at that time to protect the stored waters of Cataract Reservoir.

The dates associated with mining each of the roadways in the area and the detail of extraction in the pillar extraction is shown on the mine operating plan from this time.

Although it is not possible to be completely definitive about the accuracy or reliability of the mine plans in this area, there is a strong body of evidence to suggest that the mine plans are indeed an accurate reflection of the state of the mine workings in the area. The requirement in law at that time for a competent surveyor to keep accurate records, the attention to detail indicated by dates for each roadway, and the presence of adjacent goaf areas right up to the edge of the permitted barrier combine to give a high level of the confidence that the mine plans are an accurate reflection of the state of the roadways in this area of the mine.

The possibility that the pillars in this area are destabilised in the long term is credible although unlikely given their size and the geological conditions. The discussion presented in SCT Report 4440B around the nature of any instability and the increase in vertical compression that would be required to induce this instability is still considered relevant in the context of any long term instability of the pillars.

## 2. Clarification of closure movements across Cataract Creek

The IRAP sought clarification of the monitoring history for the closure points across Cataract Creek, the background to step changes, and the reasons that the lines do not extend further from the creek.

Four closure points were set up across Cataract Creek following the completion of Longwall 4. Closure movements associated with Longwall 4 were not measured so the measurements to date relate primarily to Longwall 5. Movements observed during mining of Longwall 5 began when Longwall 5 was about 450 m from Cataract Creek. Longwall 4 finished about 420 m from Cataract Creek so it is unlikely that significant closure movement occurred during mining of Longwall 4. However, it is noted that cracks were observed on Mount Ousley Road at the ridgeline during mining of Longwall 4, so some closure movements are likely to have occurred during this period of mining.

A step change of about 4 mm occurred near the start of monitoring. This change is reflected equally on all the closure lines and is thought to be a result of a change of instrument between these two survey rather than a real change. The raw data is presented in Figure 23 of SCT Report WCRV4263 dated 18 June 2014. Actual closure is more likely to have been slightly less and may have been reported as such in some contexts. The tolerance of the closure movements is about ±5 mm.

Ideally, the survey lines would be extended further up the slopes on either side of the valley to get a measure of full closure as recommended by IRAP. However, the terrain is dense bushland unfavourable for surveying and WaterNSW (formerly Sydney Catchment Authority) has preferred a minimum impact approach. To keep the survey accuracy sufficiently high to allow change in the river channel to be identified, the length of the closure lines has been kept short. Accurate measurement of closure across the river channel has been given a higher priority than being able to compare measurements with predicted valley closure based on a longer base length. It is recognised that overall valley closure is likely to be better represented by the longer base length, but impacts on the creek itself are better represented by high resolution surveying across the creek channel.

## 3. Uncertainty of subsidence predictions

IRAP noted that several government agencies expressed concern about the levels of uncertainty associated with subsidence predictions and some consideration should be given in the risk assessment to this possibility. In this section, an explanation of the context of the earlier predictions for Longwall 4 is provided and then a discussion of the risks should the subsidence be greater than predicted in SCT's assessment.

The subsidence predictions in the original UEP submission were made prior to any mining in the Russell Vale East mining area and were based on an assumption the bridging characteristics of the overburden strata would be similar to the bridging characteristics of undisturbed strata. Subsidence monitoring above Longwall 4, in an area where any additional subsidence was not likely to have a significant impact, indicated that the bridging characteristics were indeed softer and greater subsidence occurred as a result. Consistent with an adaptive management strategy, the layout of the Russell Vale East longwall panels were significantly modified once it was recognised that the bridging characteristics of the overburden strata were reduced by previous mining.

In the area of monitoring above Longwall 4, two seams had been mined previously and the bridging capacity of the overburden strata was significantly reduced as a result. All future areas are expected to have experienced equal or less disturbance from previous mining than the area above Longwall 4 so overburden bridging characteristics are expected to be better in future panels. Relatively less subsidence than experienced over Longwall 4 is expected once differences in overburden depth are taken into account.

The risk assessment conducted by Wollongong Coal for the IRAP process was focused on impacts to the stored waters of Cataract Reservoir and upland swamps. The mine design provides a barrier to Cataract Reservoir of greater than 0.7 times overburden depth. The size of this barrier and its effectiveness in relation to protecting the stored waters of Cataract Reservoir is not particularly related to the magnitude of subsidence above the longwall panels. Any difference between predicted subsidence and actual subsidence does not reduce the effectiveness of the barrier. It is likely there will be differences in measured subsidence compared to actual subsidence. These differences are expected to be generally such that actual subsidence is less than predicted, but even if actual subsidence is greater than predicted the effectiveness of the barrier to the reservoir is not expected to be changed.

The upland swamps that are mined under are expected to be impacted by mine subsidence. An increase in subsidence greater than predicted may increase the level of subsidence effects, but is not expected to greatly change the nature of the impacts or the consequences for the swamps. There is not a linear relationship between subsidence magnitude and impacts to the swamps once a threshold has been exceeded. It is predicted that this threshold is expected to be exceeded for all swamps located above longwall panels and impacts are not expected to be sensitive to differences in actual subsidence versus that predicted. A discussion of any negative environmental consequences arising from these subsidence impacts is presented elsewhere.

## 4. EFFECTIVENESS OF SEALS AT RUSSELL VALE COLLIERY

There is not considered to be any long term practical benefit in trying to seal the mine portals in an attempt to prevent outflow to the surface. In the unlikely event that there is an uncontrolled flow into the mine, there is a significant volume available down dip within the existing mine to allow time to develop and implement an effective management strategy such as treating the water to drinking water standards and using the mine volume as an underground storage facility.

Sealing the portals to prevent ingress of people and to make the mine safe is entirely appropriate once mining is finished, but water should be allowed to continue to exit once it reaches a level where overflow occurs.

## 5. POTENTIAL FOR HORIZONTAL SHEARS TO CONTRIBUTE TO MINE INFLOW

The phenomenon of horizontal shearing at a level near the base of valleys and its remobilisation by mining subsidence has been recognised since the 1980's. Recent work at Sandy Creek Waterfall and other similar sites has greatly increased the understanding of how basal shear planes develop both naturally and in response to nearby mining.

The hydraulic conductivity of basal shear planes has not been routinely measured so it is difficult to be sure of the magnitude of hydraulic conductivity at a scale that can be easily included into numerical modelling studies. Instead, basal shear planes are typically regarded as just one of the many phenomena that are captured generically by generalised characterisations of the strata developed for numerical modelling studies.

The presence of horizontal shear planes are recognised to be mobilised naturally by stress relief processes associated with valley formation over geological time and by mining subsidence over the much shorter timeframe of active mining nearby. The shear planes continue to be vertically loaded by the super incumbent strata in the valley slopes and the water head available to drive water along horizontal shear planes is generally small so inflows are not expected to be large.

By providing horizontal barriers to mining of the order of 0.7 times depth, historical experience has been that any inflows are reduced to sufficiently low levels to be effectively indistinguishable from other sources of inflow. Much smaller barriers equivalent to 10° angle of draw (0.17 times depth) to pillar extraction have proven to be effective historically and were for many years the standard. However, several experiences of uncontrolled inflows have indicated that these relatively smaller barriers at shallow depth can be compromised by geological structure and the larger 0.7 times depth barriers are generally adopted today as being more acceptable.

It is noted that the flow path length along a bedding plane provided to a 0.17 times depth barrier to a goaf at 300 m below the valley floor is about 150 m (allowing for the angle of goaf break) compared to 310 m for a 0.7 times barrier and the same angle of goaf break. Inflow is nominally linear with horizontal flow path length so a 0.7 times barrier is likely to reduce inflows by half compared to a 0.17 times depth barrier for an overburden depth below the valley floor of 300 m.

Mine water balance includes any contribution from flow along horizontal bedding planes as well as from multiple other sources. Further work targeting the hydraulic conductivity of bedding plane shears is required to quantify the actual magnitude of basal inflows because such inflows are likely to more directly take water from stored waters and creeks, but overall, the magnitude of inflows into Russell Vale East has been relatively small from all sources and flow along basal shear planes including basal shear planes that were mobilised by previous mining is expected to be only a relatively small proportion of this total inflow. The presence of such shear planes in an environment where they are known to exist but total inflows are relatively modest suggests that the magnitude of inflows along these basal shear planes is unlikely to be very significant. Nevertheless further work aimed to quantify the hydraulic characteristics of these shear planes is recommended as the opportunity arises.

If you have any queries, or require further clarification of any of these issues, please don't hesitate to contact me.

Regards

Ken Mills
Principal Geotechnical Engineer

## REFERENCES


SCT Report WCRV4440B "Response to Galvin and Associates Pty Ltd Report dated 3 March 2015" Letter Report addressed to David Clarkson dated 10 August 2015.

SCT Report WCRV4466A "Assessment of Corrimal Fault and Dyke D8 at Russell Vale East as Risks to the Stored Waters of Cataract Reservoir" SCT Report addressed to David Clarkson dated 9 August 2015.

SCT Report WCRV4263 "Update of Subsidence Assessment for Wollongong Coal Preferred Project Report Russell Vale No 1 Colliery" SCT Report addressed to David Clarkson dated 18 June 2014.

*APPENDIX H*

## Russell Vale East

## Revised Groundwater Assessment

GeoTerra

Groundwater
Exploration Services

WOLLONGONG COAL LTD

# RUSSELL VALE COLLIERY
# UNDERGROUND EXPANSION PROJECT
# RUSSELL VALE EAST
# REVISED GROUNDWATER ASSESSMENT

Bellambi, NSW

NRE12 – R1B

15 SEPTEMBER, 2015

NRE12 - R1B (15 September, 2015)

Wollongong Coal Ltd
PO Box 281
Fairy Meadow NSW 2519

Attention: Rhys Brett

Rhys,

**RE: Russell Vale Colliery – Underground Expansion Project Russell Vale East Revised 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 |

| | | |
|---|---|---|
| Distribution: | Original | GeoTerra Pty Ltd / GES Pty Ltd |
| | 1 electronic PDF copy | Wollongong Coal Ltd |
| | 1 electronic copy | Hansen Bailey / HydroSimulations |

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| Authorised on behalf of GeoTerra Pty Ltd / GES Pty Ltd: | |
|---|---|
| **Name:** | Andrew Dawkins / Andy Fulton |
| **Signature:** |  |
| **Position:** | Principal Hydrogeologist / Principal Hydrogeologist |

| Date | Rev | Comments |
|---|---|---|
| 05/08/2015 | | Draft |
| 18/08/2015 | A | incorporate WCL / Hansen Bailey / HydroSimulation edits |
| 15/09/2015 | B | incorporate IRAP / Water NSW / OEH / HydroSimulation reviews |
| | | |
| | | |
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## APPENDICES

# 1. INTRODUCTION

As part of the proposed Russell Vale East Underground Expansion Project (UEP), Wollongong Coal Ltd (Wollongong Coal) proposes to extract the Wongawilli Seam by longwall extraction from Longwalls 1 to 3, the remainder of Longwall 6, as well as Longwall 7 and Longwalls 9 to 11 in the Russell Vale East mining domain.

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

This document describes a revised groundwater modelling based assessment and updated reporting of the regional groundwater system in the overall groundwater model Study Area prior to, during and after the proposed extraction within the Wongawilli Seam.

The Study Area is defined as the region covered by the extent of the groundwater model domain, with a focus on the Wongawilli Seam workings within the Russell Vale East mining area as shown in **Figure 1**.

The extent of historic and proposed mining within the Russell Vale East mining domain is shown in **Figure 2**.

This report has been prepared following installation of an additional 5 open standpipe and 5 vibrating wire piezometer arrays, additional data collection in existing basement piezometer, swamp and stream sites within Russel Vale East, as well as regulatory reviews by NSW and federal agencies of the previous groundwater assessment for the UEP area (GeoTerra / GES, 2014).

Following the UEP Preferred Project groundwater assessment (GeoTerra / GES, 2014) and subsequent regulatory and PAC reviews, additional groundwater data has become available.

As a result, an updated understanding of the local groundwater system and Wollongong Coal (Russell Vale) mine inflow dynamics has evolved to enable re-conceptualisation of the local groundwater system, implementation of an updated predictive groundwater model and an updated interpretive report.

The Wongawilli Seam has been mined by Longwalls 4 and 5, as well as the western 340m of Longwall 6, between April 2012 and July 2015 at Russell Vale East.

The proposed and historic workings are predominantly located within the Metropolitan Special Area, which is a restricted area managed by Water-NSW.

This report is designed to address the relevant PAC groundwater related issues outlined for the previous assessment (GeoTerra / GES 2014) as outlined in the scope of works in Section 1.1 and summarises where they are addressed in **Appendix A**.

The current report has also been through a consultation and review process involving:

- HydroSimulations Pty Ltd (peer reviewer);
- Independent Risk Assessment Panel, and;
- The NSW OEH, Water-NSW and NSW Office of Water regulatory agencies.

The latest version of this document has taken into account all of the reviews provided by the above entities. The HydroSimulations peer review is contained in **Appendix F**.

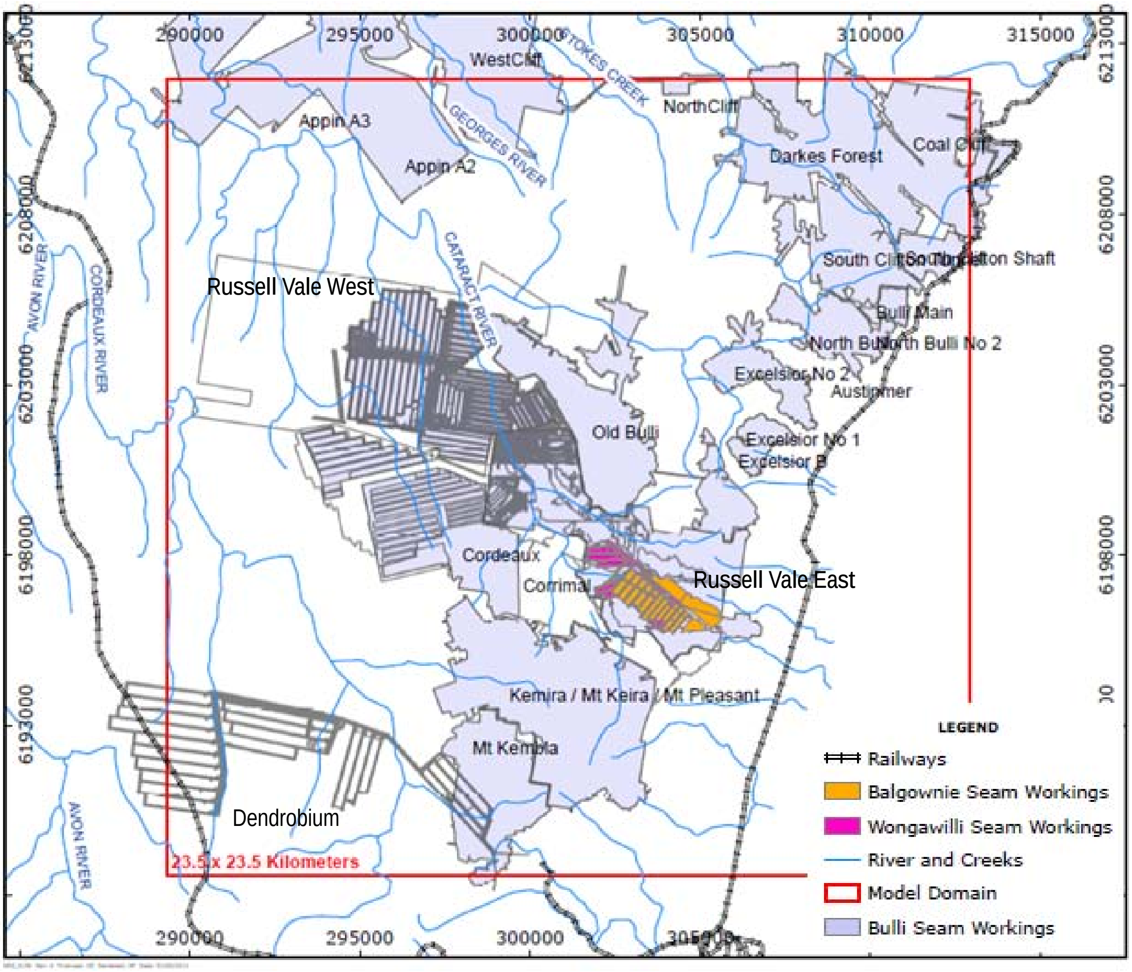



**Figure 1 Study Area Extent**

Risk Management Zones (RMZ) are outlined within 400m of the creek centre line for the Cataract River, Cataract Creek and Bellambi Creek as well as from the perimeter of upland swamps within the mining area and include the predicted 20mm subsidence zone (SCT Operations, 2014).

Within Russell Vale East, 1st and 2nd order tributary creeks drain into the 3rd, and subsequently 4th order catchment of Cataract Creek, downstream of Mount Ousley Road, and the 3rd order catchments of Cataract River.

The Russell Vale East catchments drain directly into Cataract Reservoir and subsequently, to Broughton's Pass weir. Cataract River subsequently drains downstream to the off-take to the Macarthur Water Treatment plant at Broughton's 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 Russell Vale East mining area assessments are focused on the main channel, catchments and swamps of Cataract Creek, with Bellambi Creek on the northern periphery and Cataract River in the western region.

There will be no secondary extraction beneath the main creek channels of these streams.

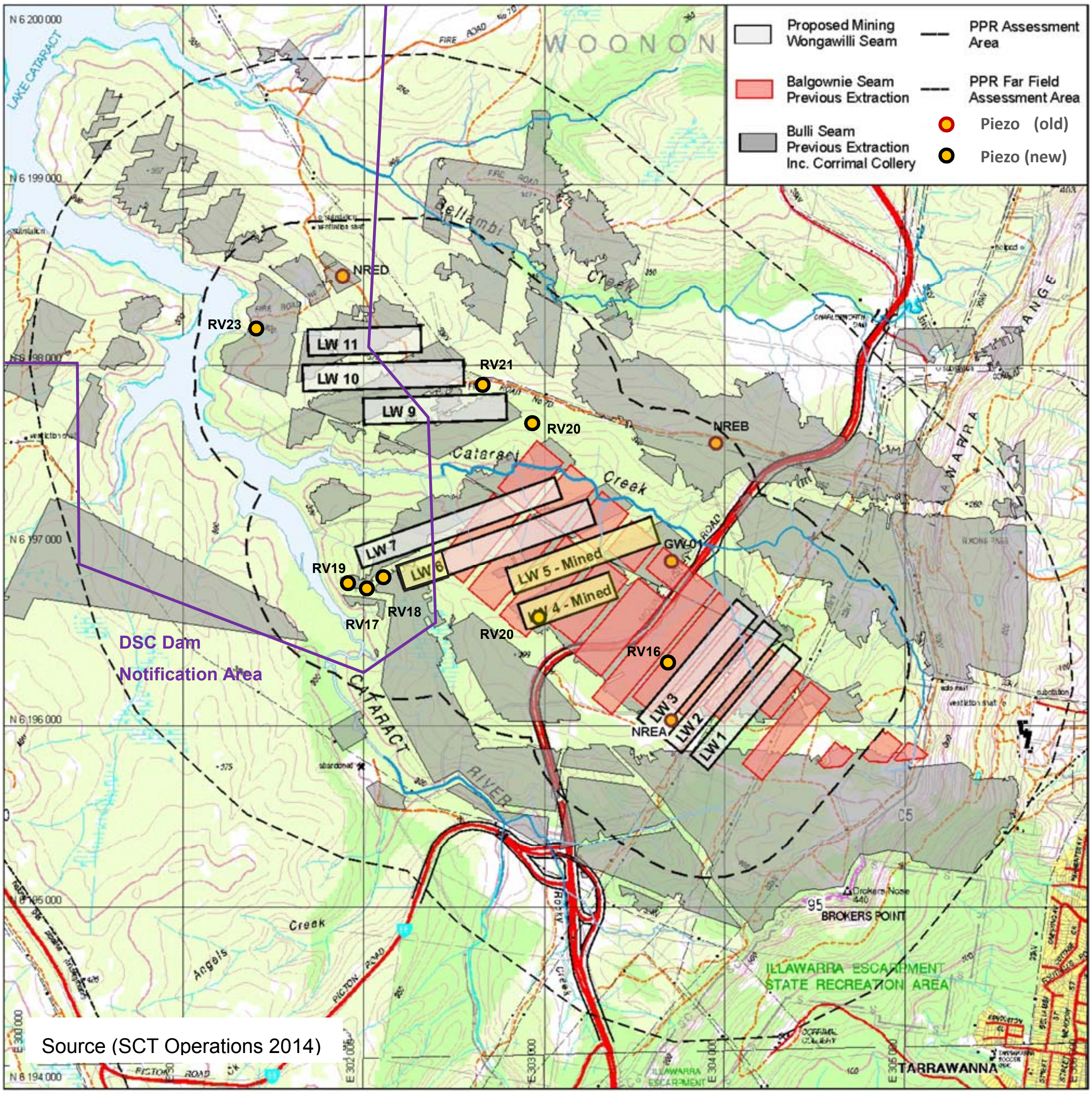



**Figure 2 Russell Vale East Historic and Proposed Mining and Piezometers**

Russell Vale East contains steep gradient valleys that drain off the western slopes of the Illawarra Escarpment to Cataract Reservoir in the west, whilst the proposed workings predominantly underlie the Cataract Creek catchment, and to a lesser degree, the Cataract River and Bellambi Creek catchments.

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

Land use within Russell Vale East generally consists of undeveloped bushland, including some limited fire access and electricity transmission line easements.

This study provides a baseline assessment of the current status of potentially affected groundwater systems within the proposed mining area in accordance with the NSW Department of Planning and Environment (DP&E) Director-General's Requirements (DGRs), as well as subsequent Preferred Project Report, federal Department of Environment (DoE) and NSW PAC correspondence for the project.

Desktop 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 Russell Vale East and the overall 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 Russell Vale East 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 the 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 the Study Area has been conducted through longwall mining of the Bulli Seam in Wollongong Coal's lease areas 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 Russell Vale East (SCT Operations, 2014) through:

- bord and pillar, as well as pillar extraction of the Bulli Seam at Russell Vale 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 Russell Vale East.
- longwall extraction of the Balgownie Seam at Russell Vale East, and;
- extraction of Longwalls 4, 5 and 340m of Longwall 6 in the Wongawilli Seam at Russell Vale East.

The proposed mine plan has been specifically re-designed (as part of the Preferred Project Report) to avoid secondary extraction directly beneath 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 LWs 4, 5 and 6. This will be undertaken in liaison with regulators as part of the development of management plans for Cataract Creek.

The Russell Vale Vale East stream assessment is discussed separately in WRM Water and Environment (2014), which has been updated in WRM Water and Environment (2015), whilst the swamp assessment is detailed in Biosis (2014).

## 1.1 Scope of Work

In accordance with the DGRs 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 addresses submissions from the relevant NSW based regulators in response to the Underground Expansion Project Preferred Project Report provided by Gujarat NRE Coking Coal Ltd (now Wollongong Coal) to DP&E, on 28 August 2013.

The document addresses issues raised by the federal Department of the Environment (DoE) and, subsequently, specific issues regarding the revision of groundwater modelling and associated reporting that were raised by the NSW PAC and its independent peer reviewer. The PAC recommended that changes and further discussion be made to a number of facets of the groundwater model and the modelling code utilised to derive predictive outcomes. These include:

- reasoning behind the use of the same value of drainable porosity for all strata in the groundwater model since this parameter significantly influences the evolution of the phreatic surface and mine inflows;
- discussion of revised model calibrations including presentation of hydrographs showing measured and predicted pressure heads using the 'pseudo soil' option;
- illustration of model pressure heads (in plan) in the coal seams, Bulgo Sandstone and Hawkesbury Sandstone prior to, during and after mining (50 and 100 years);
- assessment of the long term steady state groundwater flow systems post mining

and identification of shallow and surficial areas that are likely to be dewatered;
- assessment of potential leakage via the adit and assessment of the role played by the abandoned overlying workings (and their adits) in constraining the recovery of pore pressures;
- risk assessment associated with potential leakage from Cataract Dam via the proposed panel extractions and adit; and
- mitigation measures that might be invoked to minimise impacts.

Sections where the PAC issues are addressed in this report are summarised in **Appendix A**.

GeoTerra Pty Ltd (GeoTerra) and Groundwater Exploration Services Pty Ltd (GES) were commissioned by Wollongong Coal to address any potential groundwater impacts relating to the proposed extraction and associated subsidence of the Wongawilli Seam in the Russell Vale 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 methods 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 NSW / FEDERAL LEGISLATION AND GUIDELINES

Discussion of these details is outlined in Geoterra / GES (2014).

### 2.1 NSW PAC Comments on the Russell Vale Colliery Underground Expansion Project

The pertinent items relating to the revised groundwater modelling and updated reporting requirements as outlined by the PAC review are outlined in this document's Scope of Works (Section 1.1).

## 3. PREVIOUS GROUNDWATER RELATED STUDIES

Within the Wollongong Coal Russell Vale 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 Russell Vale East and Russell Vale West proposed mining domains as part of the original Underground Expansion Project Part 3A (Pt3A) application.

GeoTerra / GES (2014) subsequently updated the groundwater model and associated reporting for the UEP Preferred Project Report.

The extent of historic fracturing and overburden depressurisation due to subsidence over previous Wollongong Coal workings was assessed in SCT Operations (2014) and also updated by their assessment of the hydraulic and geological characteristics of the Corrimal Fault and Dyke D8 (SCT Operations, 2015). Their findings are discussed in subsequent sections of this report.

Ongoing monitoring of stream water quality, groundwater seepage and stream flow studies conducted since 2001, up to the completion of Longwalls 4 and 5 is discussed in GeoTerra, (2014B).

Installation and monitoring of an additional 5 open standpipe and 5 vibrating wire piezometer arrays up to the completion of 340m of extraction in Longwall 6 is reported in GeoTerra (2015).

# 4. PREVIOUS AND PROPOSED MINING

## 4.1 Previous Mining

Three coal seams have been mined at Russell Vale Colliery.

The uppermost is the 2.0 - 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 3.0 - 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 mechanised 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 Russell Vale East area using hand worked methods for a brief period. Mining restarted in the late 1960s 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

Installation of the Wongawilli Seam mining access started in 2008 at Russell Vale East, with subsequent secondary extraction occurring as shown in **Table 1**.

**Table 1 Russell Vale East Wongawilli Seam Longwall Extraction Summary**

| Longwall | Start | Finish | Depth of Cover (mbgl) | LW Width (m) | LW Length (m) |
|---|---|---|---|---|---|
| **4** | 21/4/2012 | 21/9/2012 | 267 - 275 | 140 | 523 |
| **5** | 15/01/2013 | 12/01/2014 | 272 - 279 | 140 | 844 |
| **6** | 04/05/2015 | 08/07/2015 | 312 - 333 | 140 | 340* |

**Total length of LW 6 is 1,120 m, but only 340 m has been extracted to date.*

## 4.2 Proposed Mining

Wollongong Coal is proposing to mine additional longwall panels in the Russell Vale East mining area within Russell Vale Colliery.

After consideration of submissions from the community as well as NSW government agencies to its earlier Underground Expansion Project Part 3A (Pt3A) application, Wollongong Coal (then Gujarat NRE Coking Coal) significantly modified its application to DP&E through a Preferred Project Report assessment. The Preferred Project groundwater study excluded mining in the Russell Vale West area.

The current proposal includes the extraction of the remainder of Longwall 6, as well as Longwall 7 in the Wongawilli Seam to the south of Cataract Creek, and Longwalls 9 to 11 to the north of Cataract Creek, between Mt Ousley Road and Cataract Reservoir, within Water-NSW managed land. It should be noted that Longwall 8 was excluded from the Underground Expansion Project application during the Preferred Project Report mining plan revision.

To the east of Mt Ousley Road, Wollongong Coal proposes to extract Longwalls 1 to 3 in the Wongawilli Seam on private land as shown in **Figure 2**.

### 4.3 Observed and Predicted Subsidence

**Table 2** summarises subsidence that has occurred as a result of mining the Bulli Seam (estimated), Balgownie Seam (measured) and Wongawilli Seam (measured subsidence for Longwalls 4, 5 and the westernmost 340m of Longwall 6) within the Russell Vale East domain.

For further discussion of the relevant subsidence observations and predictions, refer to GeoTerra / GES (2014).

**Table 2 Predicted and Measured Subsidence**

| | Previous Subsidence (m) | Predicted (Measured) Subsidence (m) | Predicted (Measured) Tilt (mm/m) | Predicted (Measured) Tensile Strain (mm/m) | Predicted (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) closure site CS4** |
| **LW6** | 1.5 | 2.1 **(0.42)** | 38 (TBA) | +11 **(+1.3)** | -23 **(-2)** | 400 **(59) CS4** |
| **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
Longwall 6 measurements relate to 340m of extraction advance
**(measured parameters are shown in brackets)**

# 5. RUSSELL VALE EAST AREA DESCRIPTION

## 5.1 Russell Vale 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 (2015).

The following sections describe individual catchments within Russell Vale East.

### 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 full supply level of Cataract Reservoir.

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 slopes at 2.5%.

Approximately 2.5km of the stream reach is located upstream, 2km within and 0.9km is 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 Cataract Reservoir 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 Russell Vale East workings and the 20mm subsidence line do not underlie the Cataract River.

### 5.1.3 Bellambi Creek

Bellambi Creek is a 3rd order stream upstream for the first 5.5km, then 4th order to the Cataract Reservoir backwater. It is approximately 6.4km long from its headwaters to the full supply level of Cataract Reservoir.

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%.

The predicted 20mm subsidence zone also does not intersect Bellambi Creek.

## 5.2 Climate

### 5.2.1 Rainfall

Daily rainfall has been recorded by the Bureau of Meteorology (BOM), Water-NSW 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, 2015).

Annual rainfall at Cataract Dam between 1889 and 2013 varied from 480mm in 1944 to 2,293mm in 1950, with a mean annual rainfall of 1,085mm/a.

Cataract Dam rainfall is highest between January and June, and lowest between July and December as shown in **Figure 3**.

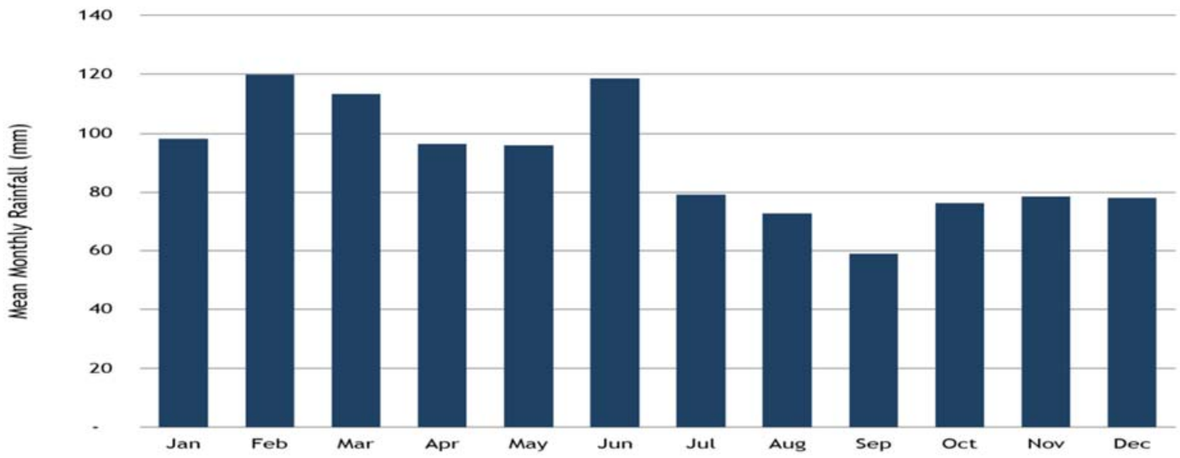



**Figure 3 Variation in Mean Monthly Rainfall at Cataract Dam**

**Figure 4** shows a plot of cumulative rainfall residual at Cataract Dam for the period 1889 to 2013 that was prepared using the PPD, shown as a solid dark blue line, with the raw data for the station shown as an overlaid wider light blue line 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 Southern Oscillation Index (SOI) residual has been overlaid on the rainfall residual for comparison.

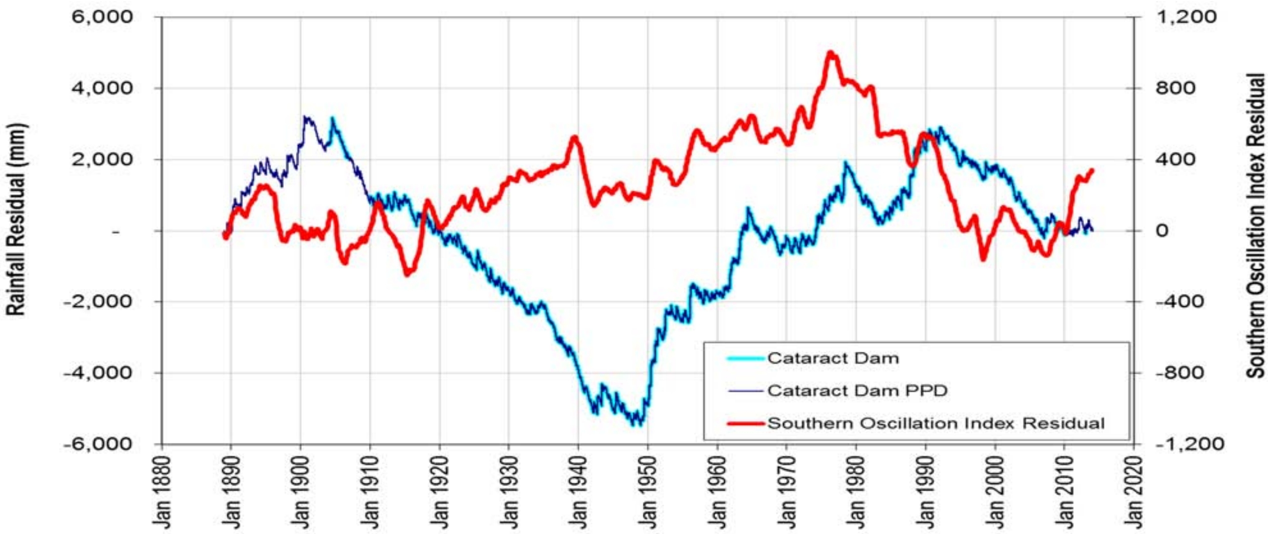



**Figure 4 Rainfall Residual at Cataract Dam (1889 – 2013)**

### 5.2.2 Evaporation

The mean annual pan evaporation at Cataract Dam is approximately 1,420mm/yr as shown in the PPD data in **Figure 5**, and is highest in the summer months. There is no Bureau of Meteorology evaporation data available for this location.

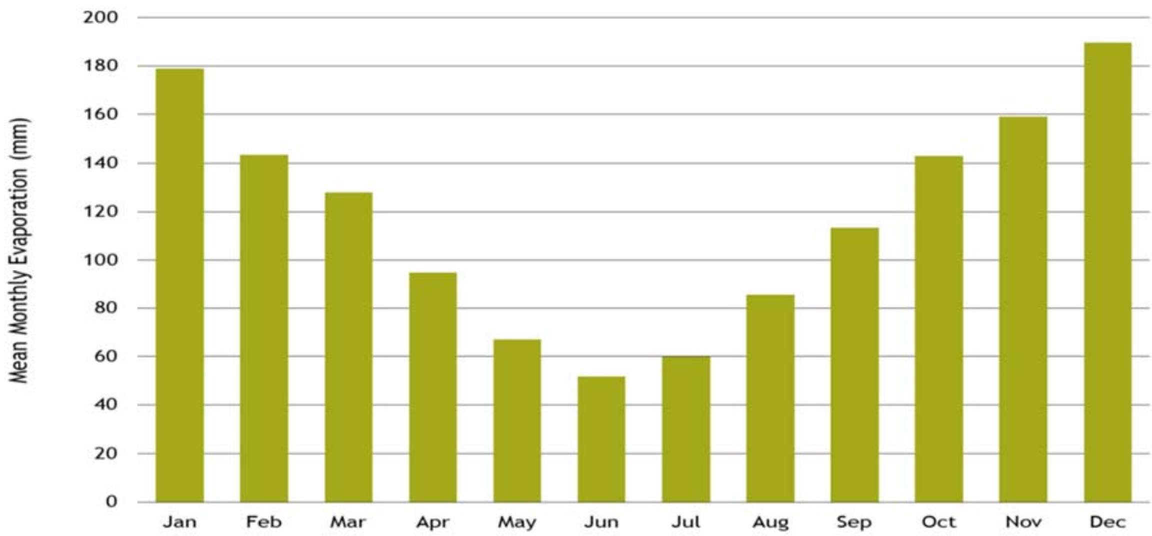



**Figure 5 Monthly Pan Evaporation at Cataract Dam (PPD)**

On the basis that the reservoir has a surface area of 8,500ha, this equates to an average annual evaporation rate (at 1,420mm/yr) of 120,700ML/year off the surface of the reservoir (when it is at Full Supply Level).

### 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 Wongawilli seams.

The Russell Vale East 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 6**.

Outside of the upland swamps, there are no alluvial deposits of any significance within the Wollongong Coal lease area except for possibly within, or under, Cataract Reservoir.

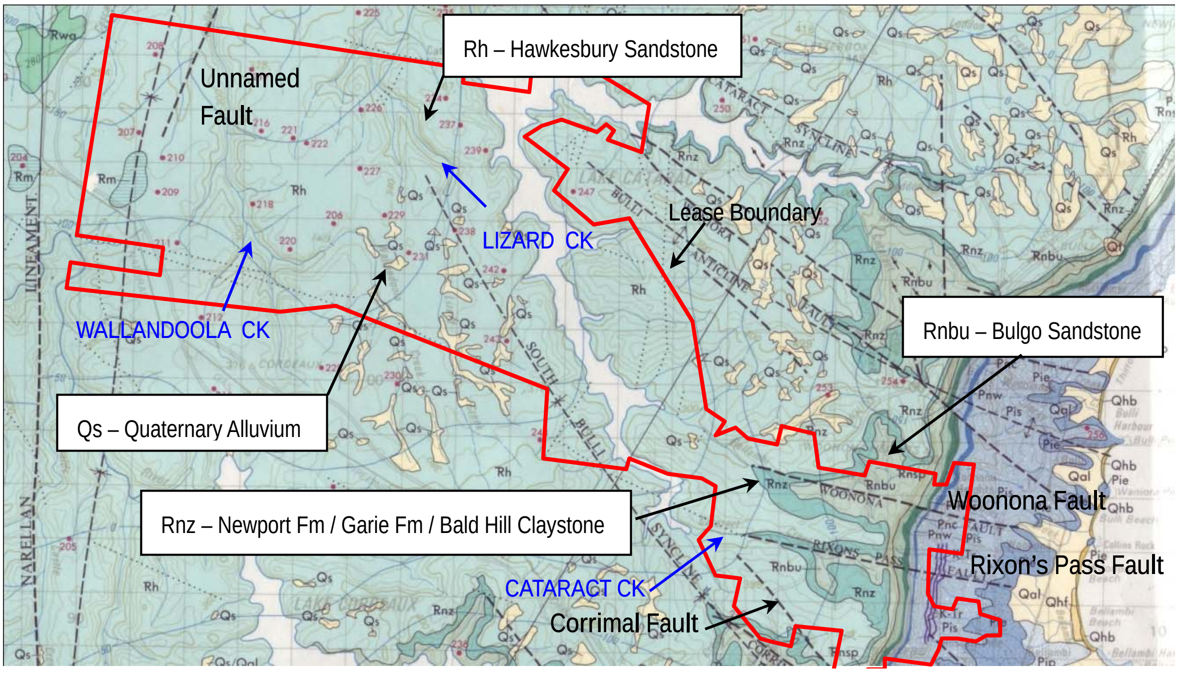



**Figure 6** **Published Regional Surface Geology**

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 Russell Vale East area are, in turn, sequentially underlain by the:

**Wianamatta Group** (due to erosion, this formation is absent at Russell Vale 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 Russell Vale 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 Russell Vale 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 Russell Vale 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 Russell Vale 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 Russell Vale 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 Russell Vale East Geological Mapping

### 5.4.1 Outcrop Mapping

Outcrop mapping of the surface geology, faults and dykes in the Russell Vale East area was completed by Wollongong Coal geologists in 2013 (Gujarat NRE Coking Coal, 2014) as shown in **Figure 7**.

For discussion of the Russell Vale East geology, refer to Gujarat NRE Coking Coal (2013).

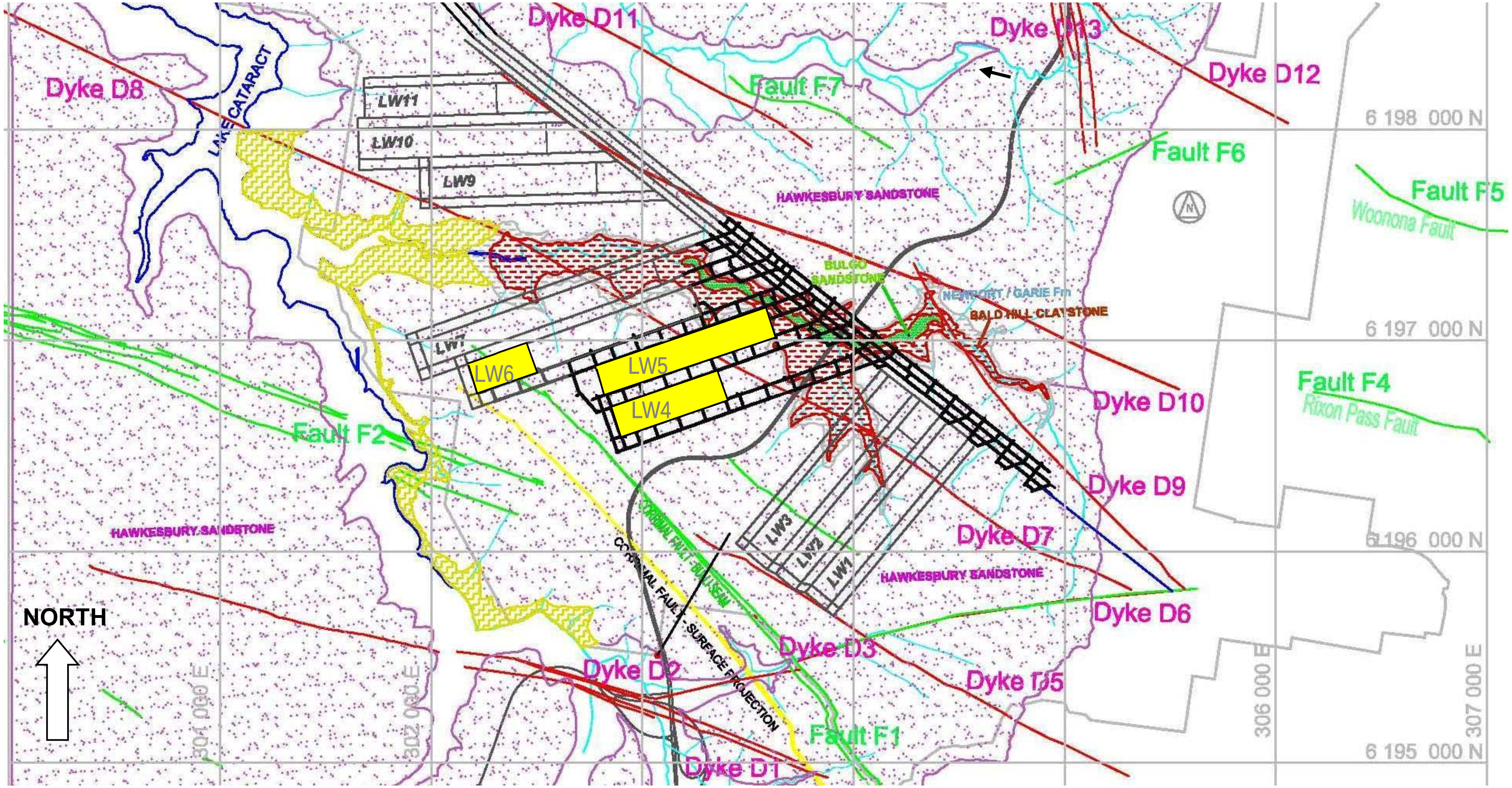



**Figure 7 Russell Vale East Outcrop Geology and Structures**

#### 5.4.2 Underground Mapped Faults

There are no known major faults in the overburden above the proposed Russell Vale East workings, apart from the Corrimal Fault which has only been mapped in the Bulli workings in the western periphery of Russell Vale East as shown in **Figure 8**.

No known or observed groundwater inflows have been associated with any faults intersected by the workings at Russell Vale East in the Bulli, Balgownie or Wongawilli Seams (SCT Operations, 2015).

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, and is not interpreted to be present between LW7 and Cataract Reservoir (SCT Operations, 2015).

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 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 LWs 1 to 3 as well as LWs 4 to 7.

No inflows to any of the three seams of workings have been observed in association with Dyke D8 (SCT Operations, 2015).

No diatremes have been identified within the proposed subsidence area, however a large sill is located to the east and north of Russell Vale East.

For further discussion of the Russell Vale East underground structures and intrusives, the reader is referred to Gujarat NRE Coking Coal (2014) as well as SCT Operations (2015).

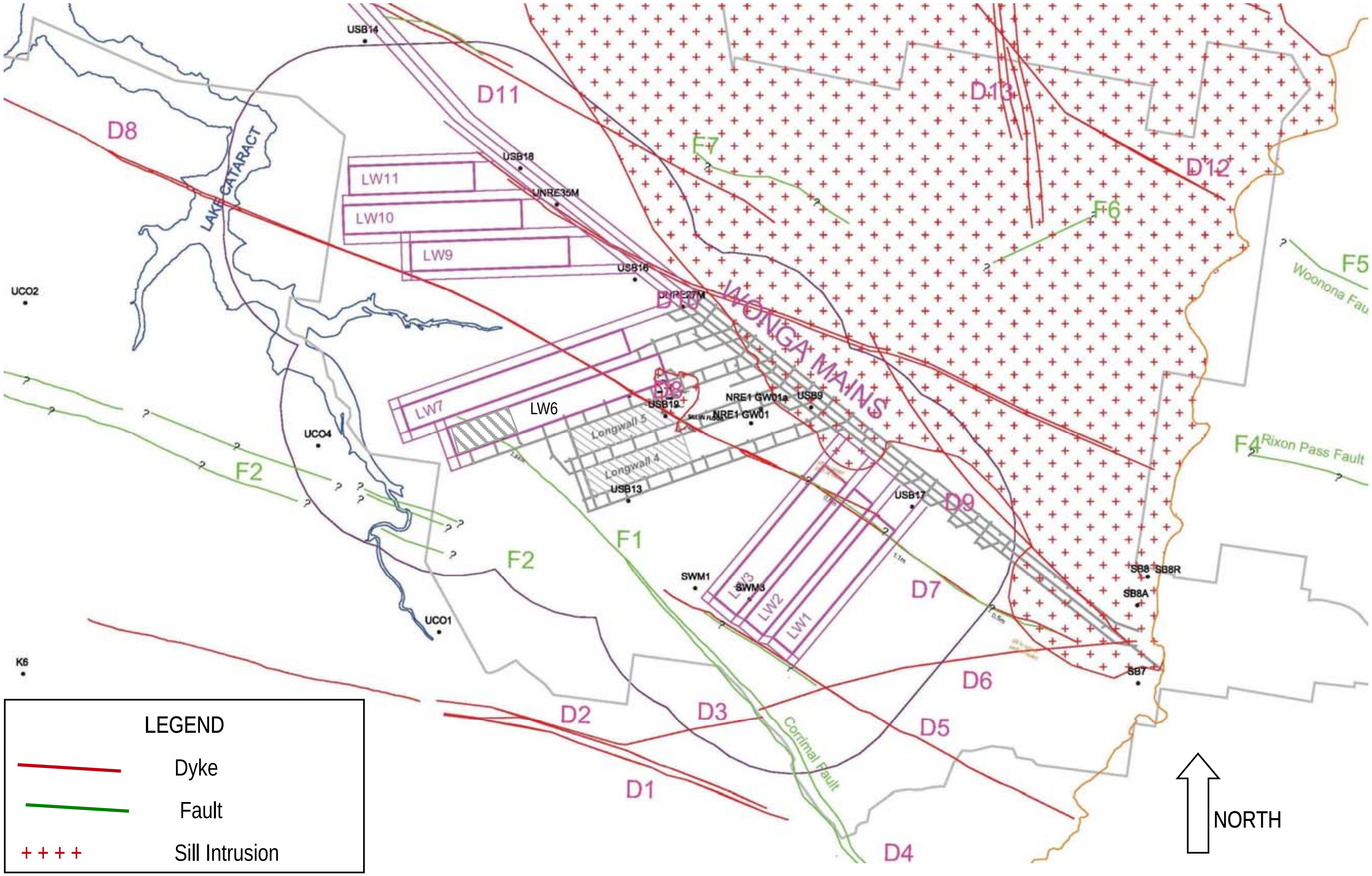



**Figure 8** Russell Vale East (Wongawilli Seam) Structures and Intrusives

### 5.5 Basement Hydrogeology

Six general hydrogeological domains are present in the Russell Vale East and overall Study Areas, 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 as shown in **Figure 2**, 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 within Russell Vale East.

#### 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 Water-NSW 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 Russell Vale lease 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 Russell Vale lease area as shown in **Figure 8** 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 Russell Vale 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 Russell Vale East Area. The nearest registered bore on the Woronora Plateau is a test bore at Appin Colliery registered to BHP, 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.

### 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 Russell Vale 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 Russell Vale East 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.

Conversion of stream pool depths to volumetric flows at Sites CC3, CC4, CC8 and CR2 has been conducted and is presented in WRM Water and Environment (2015).

Based on drilling information and site observations, streams are interpreted to be “losing” in the Russell Vale 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 within the lease area.

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 back into the creek system from temporary seeps in the swamps and creek beds along preferential horizontal flow regimes in the shallow outcropping bedrock.

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 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 Russell Vale 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

As no change to the potential effects on groundwater dependent ecosystems has occurred since the last report, further discussion of the stream and upland swamp groundwater dependent ecosystems is contained in GeoTerra / GES (2014).

## 6. PREVIOUS GROUNDWATER SYSTEM SUBSIDENCE EFFECTS

As no new assessment has been derived since GeoTerra / GES (2014) in relation to the historical groundwater system subsidence effects within the adjacent BHP or Russell Vale West workings, the reader is referred to GeoTerra / GES (2014) for further details.

## 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 Russell Vale East area, SCT Operations Pty Ltd (2014) has 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 9**.

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 plane (or multiple en-echelon 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 shearing 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.

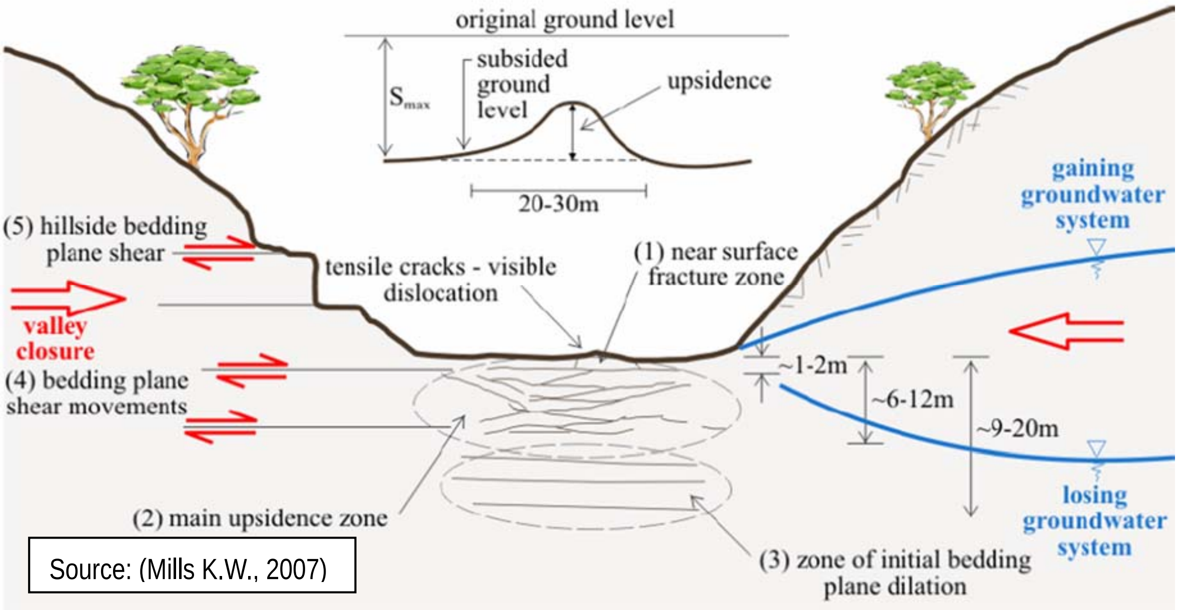



**Figure 9 Conceptual Valley Closure Shearing**

A definitive assessment of the location, presence and complex nature of the potential shear plane/s is not possible with current field / drilling data in the valleys and hillslopes overlying subsided areas at Russell Vale East, however, the horizontal shear zones do not pose a risk of direct hydraulic connection of stream flow from the stream beds in the upper catchments to the mine workings.

### 7.2 Height of Fracturing and Associated Strata Depressurisation Prediction

Two empirical based methods for the height of fracturing (Tammetta, 2012) as well as Ditton and Merrick (2014), and by association, the height of groundwater depressurisation, have been proposed using the height of single seam longwall extraction, width of extraction and the depth of cover (as well as a geological factor in Ditton and Merrick (2014)) over the centre of single seam longwall panels.

No reliable comparison between the theoretically predicted and observed Russell Vale East in-situ height of depressurisation was able to be established from VWP data over the Russell Vale East multiple seam workings.

Comparison of the predicted versus observed depressurisation height is also complicated in that a VWP array may not directly overlie the centre of secondary extracted workings, as most of the VWPs at Russell Vale are installed to the side of the Balgownie and Wongawilli Seam workings. As a result, the observed depressurisation response in the subsided strata does not conform to a tacit assumption in the strata depressurisation theories, in that a VWP is located over the centre of a single longwall panel.

Neither of the two theoretical approaches are applicable to the Russell Vale East triple seam extraction environment as discussed further in **Section 9.13**.

Accordingly, this document is based on an updated conceptual groundwater model using additional in-situ VWP data and further development of an analytical groundwater model since GeoTerra / GES (2014) to predict the impacts consequences and effects of the proposed Wongawilli Seam extraction on the groundwater system at Russell Vale East.

Further discussion of in-situ depressurisation profiles within open standpipe and VWP arrays at Russell Vale Colliery is outlined in **Sections 8.2** and **8.3**.

## 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 Russell Vale East and West areas 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 investigations in the Russell Vale lease area have involved installation of:

- 8 open standpipes, with 5 additional piezometers installed since September 2014, as well as;
- 7 vibrating wire array piezometers, with 5 additional VWP arrays installed since July 2014

as shown in **Figures 10** and **11**, with drilling extending to 374m below surface.

Drilling was contained within the Russell Vale 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.

A summary of the open standpipe and vibrating wire piezometers is presented in **Appendix B**.

Under clause 18 and Schedule 5 of the *Water Management (General) Regulation 2011*, which was gazetted on 30 June 2011, a Water Access License *under the Water Management Act 2000* is not required for monitoring bores.

Piezometers installed prior to that date were licensed by Wollongong Coal.

All relevant approvals from Water-NSW (or its predecessor, the Sydney Catchment Authority) were obtained prior to drilling.

Where VWP arrays have been installed, the drill holes were sealed to surface with a slurry of cement and bentonite.

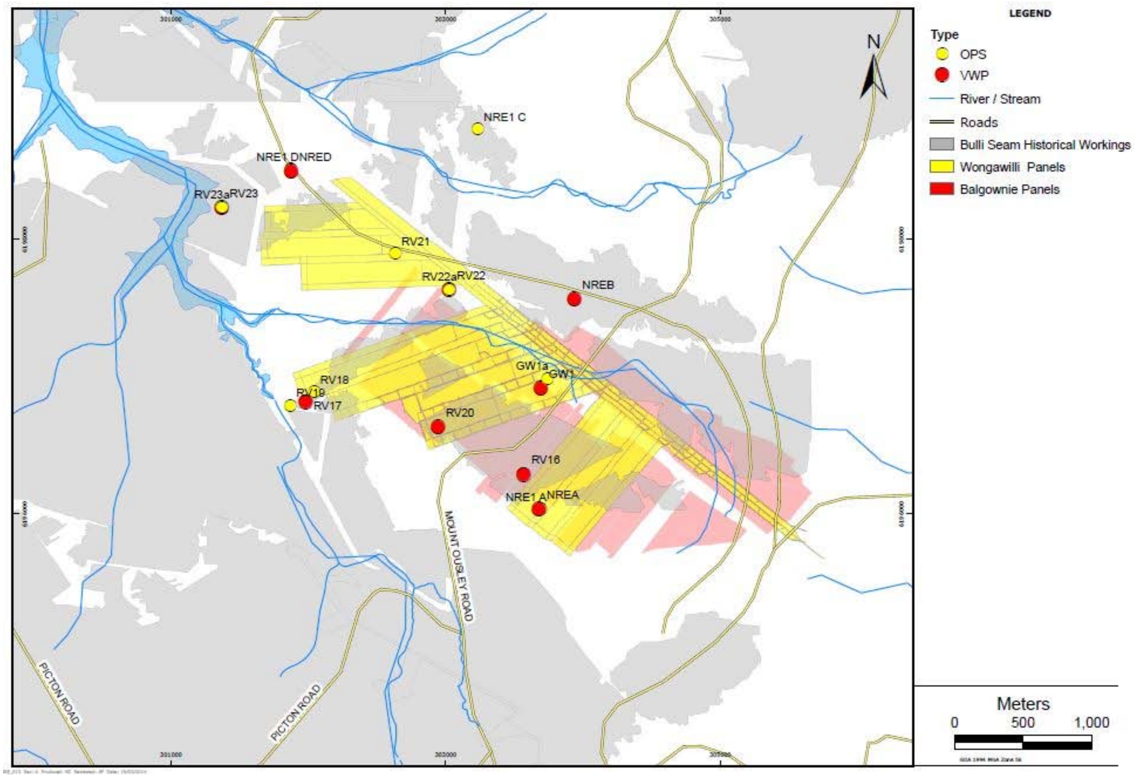



**Figure 10 Russell Vale East Colliery Piezometer Locations**

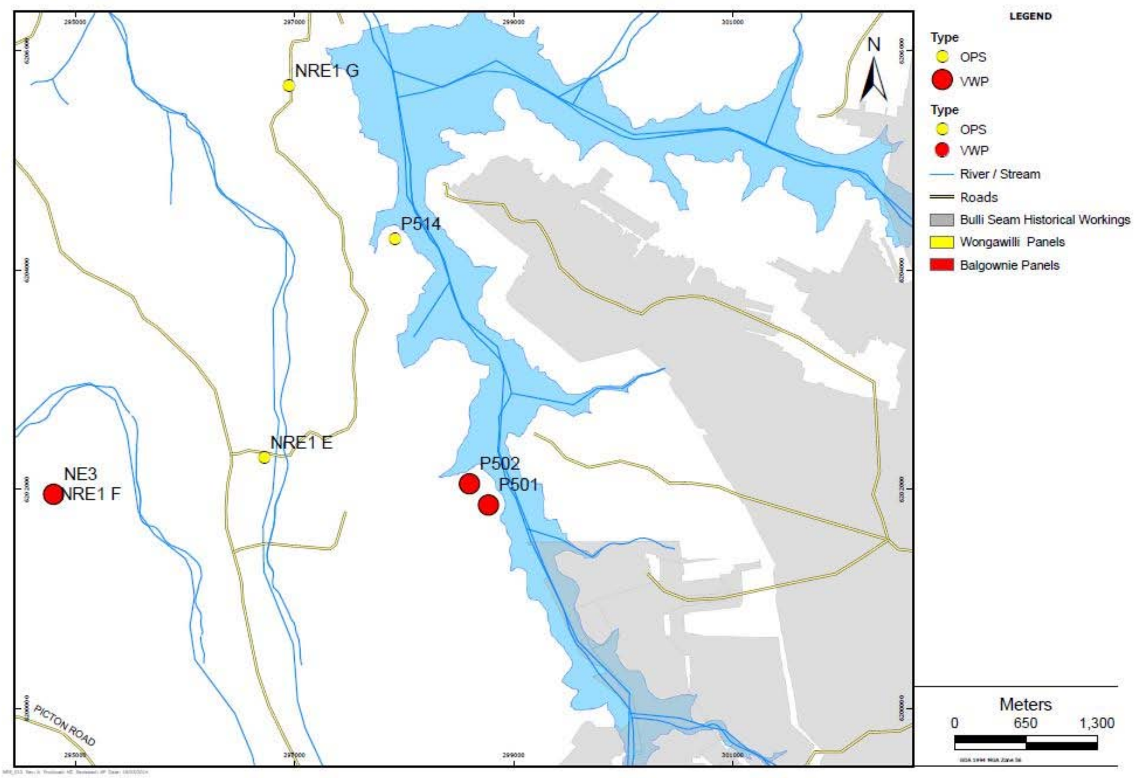



**Figure 11 Russell Vale West Colliery Piezometer Locations**

### 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) and subsequently in the newer bores installed in 2014.

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.

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 Russell Vale groundwater model.

### 8.2 Hawkesbury Sandstone Open Standpipe Shallow Groundwater Levels

Water level variability has been measured in open standpipe piezometers that were installed in the upper Hawkesbury Sandstone as shown in **Figures 12** and **13**.

The monitoring data indicates that the Russell Vale East piezometers are generally more responsive to rainfall than in the western part of the lease area, with the variability principally due to the degree of subsidence and overburden fracturing that has occurred over the Russell Vale East workings.

The open standpipe piezometers in the vicinity of the recently active Wongawilli Seam Longwalls 4, 5 and 6 (i.e. GW1A, RV18 and RV19) do not show depressurisation resulting from subsidence induced fracturing of the overburden, whilst other piezometers such as NRE A and NRE D exhibit a heightened response to rainfall recharge as a result of shallow sandstone overburden subsidence induced fracturing.

The high water level variability in NRE F is unusual, and is interpreted to be 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.

All of the shallow sandstone piezometers show a variable responsiveness to climatic variability and rainfall recharge that replicates, in a subdued manner, the variability of the rainfall residual plot.

#### 8.2.1 GW1A

GW1A was installed to a depth of 27m in September 2012 after completion of Longwall 4. It is located above 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 VWP array in bore GW1.

The bore is located between the VWP piezo (GW1) and Cataract Creek, which is approximately 105m to the north east. It is approximately 420m from the northern end of LW4 and 125m to the southeast of LW 5.

The piezometric pressure profile in GW1A is essentially the same as the 30mbgl VWP intake water level within the Bulgo Sandstone.

The water level in GW1A is near the level of Cataract Creek (RL300m) with a moderate correlation to the rainfall residual plot.

The slight reduction in the phreatic surface that commenced soon after LW5 started and continued throughout the period of mining LW5 correlates to a reducing trend in the rainfall residual plot and is not definitively associated with Longwall 5 subsidence effects.

The intake zone of GW1A may be hydraulically connected to Cataract Creek, possibly via a horizontal shear/s located just below the level of Cataract Creek, where rainfall recharge and / or stream water is able to flow within the shear horizon.

#### 8.2.2 RV18 and RV19

RV18 is located on the southern edge of Wongawilli Seam Longwall 7 and approximately 135m west of Longwall 6, whilst RV19 is located approximately 330m west of Longwall 6 and 145m southwest of Longwall 7, with both piezometers overlying first workings within the Bulli Seam. RV18 was installed to 20mbgl and RV19 to 17.5mbgl in the Hawkesbury Sandstone.

Both piezometers lie between the Longwalls 6 and 7 and Cataract Reservoir and both have a moderate correlation to the rainfall residual plot.

The water level in RV18 ranges from 7.5 to 9.0mbgl, or 332.1 - 330.6 mAHD, which is at least 40.7m above the reservoir FSL of 289.87 mAHD.

The available data does not indicate a correlation to, or particularly, depressurisation resulting from, extraction of Longwall 6 (340m) in either piezometer, although there is a definitive rise and fall in associated with an east coast low rain event in mid to late April 2015 that occurred whilst LW6 was being mined.

#### 8.2.3 NRE A

NRE A is located next to the VWP array (also called NRE A) on a ridge in the Hawkesbury Sandstone in an area with only first workings in the Bulli Seam (approx. 285 mbgl), with nearby longwall mining in the Balgownie Seam and no nearby mining in the Wongawilli Seam.

Pre-existing tension cracks are present close to NRE A, with the high level of vertically connected cracking and consequently a high level of vertical conductivity observed in NRE-A considered to result from vertical fractures and opening of existing joints caused by horizontal tensional stretching of the shallow overburden (SCT Operations, 2014).

NRE A was installed to 47mbgl in Hawkesbury Sandstone. It is located approximately 750m south east (and upgradient) of Wongawilli Seam Longwall 4 and is well outside the area of depressurisation influence from Longwalls 4, 5 or 6. It is also located approximately 450m southwest of Cataract Creek and, like NRE A (VWP) has a strong correlation to the rainfall residual plot.

#### 8.2.4 NRE C

NRE C is located on a ridge in the Hawkesbury Sandstone in an area with predominantly first workings in the Bulli Seam and no workings in the Balgownie or Wongawilli Seams.

No pre-existing tension cracks have been observed near NRE C.

NRE C was installed to 24mbgl in Hawkesbury Sandstone. It is located well outside the area of depressurisation influence from Longwalls 4, 5 or 6 and is located approximately 430m north of Bellambi Creek, with a moderate correlation to the rainfall residual plot.

#### 8.2.5 NRE D

NRE D is located on a ridge in the Hawkesbury Sandstone, adjacent to NRE D (VWP) in an isolated area of pillar extraction and first workings in the Bulli Seam and no workings in the Balgownie or Wongawilli Seams.

No pre-existing tension cracks have been observed near NRE D.

NRE D was installed to 52mbgl in Hawkesbury Sandstone and is located well outside the area of depressurisation influence from Longwalls 4, 5 or 6. It is located approximately 580m east of Cataract Reservoir and has a moderate to strong correlation to the rainfall residual plot.

#### 8.2.6 RV21, 22A and RV23A

RV21 and RV22A are located on a ridge and south facing hillslope to the north of Cataract Creek, whilst RV23A is located approximately 85m east of the reservoir FSL over first workings in the Bulli Seam of Corrimal Colliery, with no workings in the Balgownie or Wongawilli Seams.

No pre-existing tension cracks have been observed near any of the three piezometers.

RV21 was installed to 22.7mbgl, RV22A to 37.4mbgl and RV23A to 26.6mbgl in Hawkesbury Sandstone, and they are all located well outside the area of depressurisation influence from Longwalls 4, 5 or 6.

RV21 has a low to moderate, whilst RV22 and Rv23 have a moderate to strong correlation to the rainfall residual plot.

#### 8.2.7 NRE F, NRE G and NRE3

All three piezometers are located in the Russell Vale West mining area, to the west of Cataract Reservoir and all overlie first workings and longwalls in the Bulli Seam.

No pre-existing tension cracks have been observed near any of the three piezometers.

NRE F was installed to 60mbgl, NRE G to 53mbgl and NRE3 to 60mbgl in Hawkesbury Sandstone.

NRE F and NRE G have a low correlation to the rainfall residual plot, whilst NRE3 appears to have a poor annular seal and responds significantly to rain events.

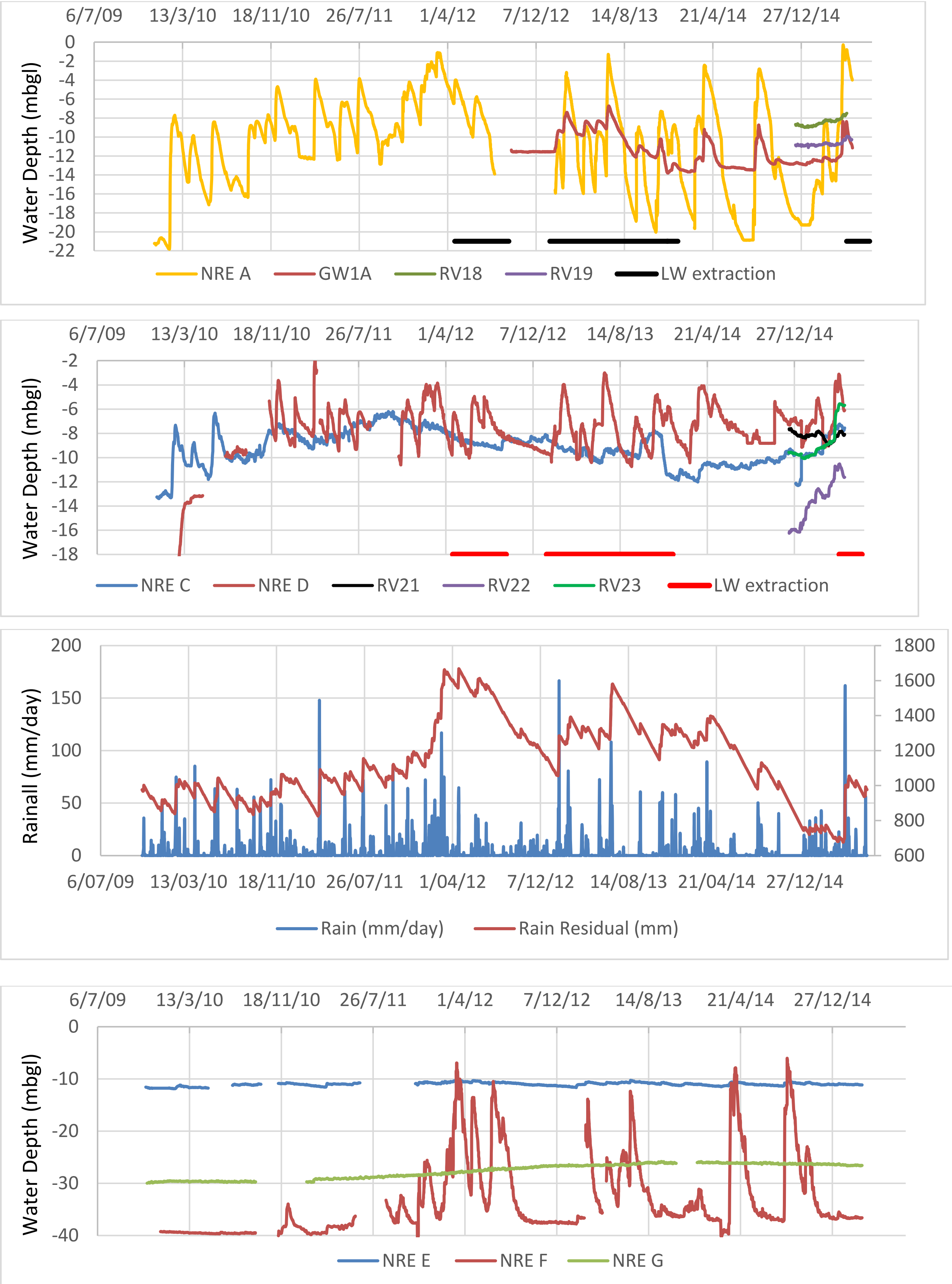



**Figure 12 Open Standpipe Groundwater Levels (mbgl) and Rainfall**

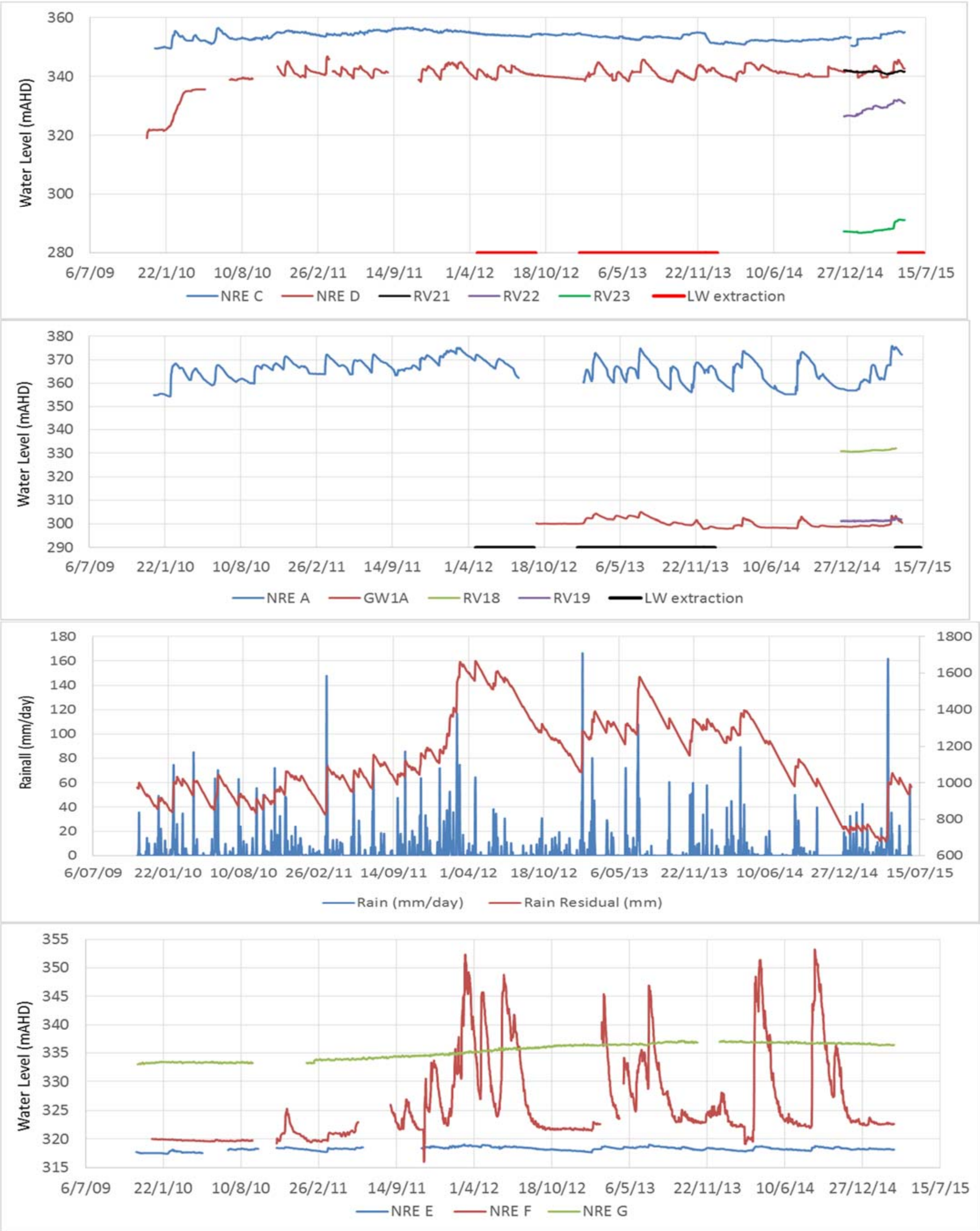



**Figure 13 Open Standpipe Groundwater Levels (mAHD) and Rainfall**

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 14**.

The plot indicates a general flow at Russell Vale East toward Cataract Reservoir.

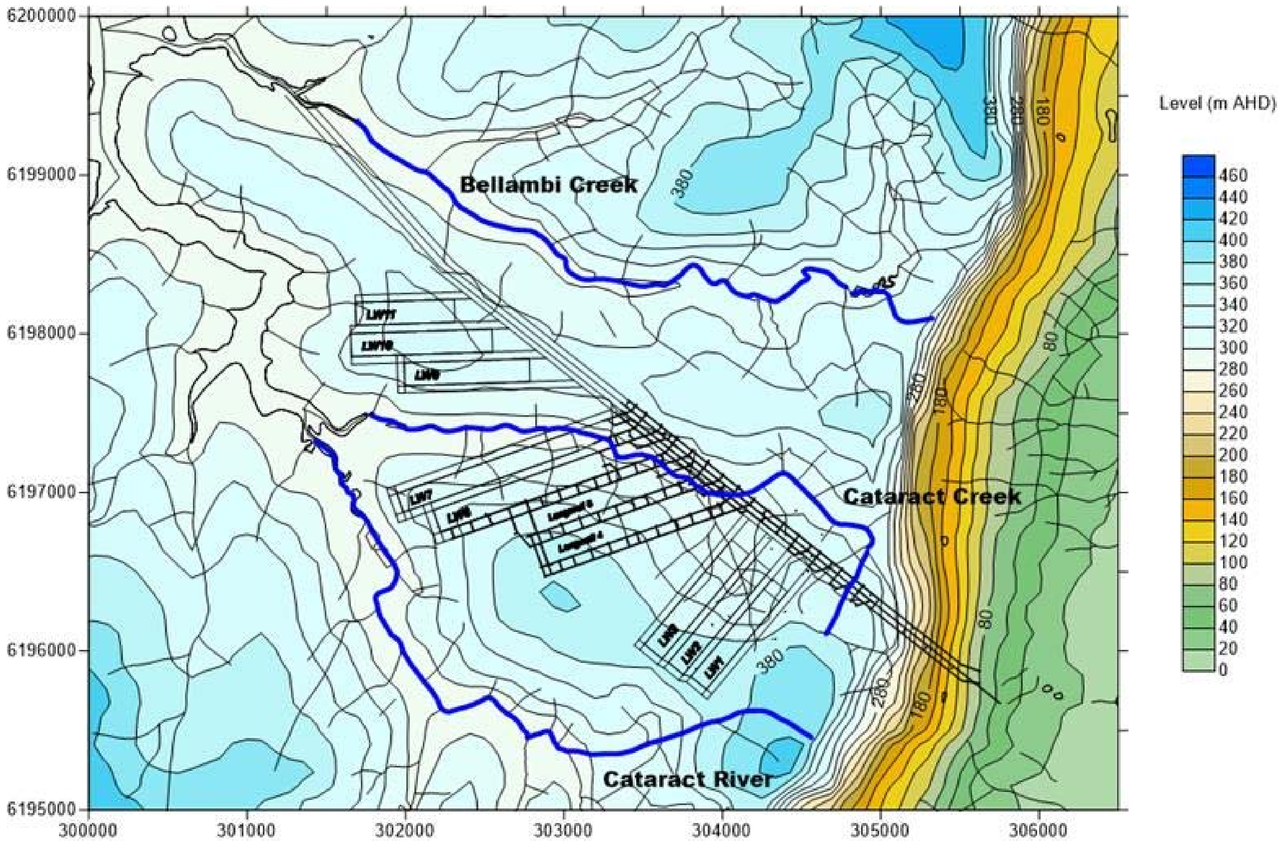



**Figure 14 Russell Vale Colliery Phreatic Surface Groundwater Contours**

## 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 nine bores at Russell Vale East and one at Wonga West as summarised in **Appendix B**.

Vibrating wire piezometers arrays were also installed in 1992 as part of an investigation of the Russell Vale West 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 Russell Vale East and Wonga West as discussed in GeoTerra / GES (2014).

### 8.3.1 GW1

GW1 was installed in September 2012 to 165mbgl into the Scarborough Sandstone after completion of Longwall 4 and prior to extraction of Longwall 5.

It is approximately 350m east of Longwall 4 and 130m south east of Longwall 5, in an area mined by Bulli Seam bord and pillar, Bulli Seam pillar and Balgownie Seam longwall extraction.

GW1 is located above the goaf of Balgownie Seam Longwall 7B where the Hawkesbury Sandstone has been completely eroded away, and is approximately 175m west of Cataract Creek.

Two groundwater systems are indicated in the VWP array, with a near surface perched water table around 30mbgl and a deeper system within the Bulgo Sandstone and below with limited vertical hydraulic connection between the two as shown in **Figure 15**.

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.

Apart from the 30mbgl intake, the VWP array has a weak responsiveness to rainfall, with a slightly enhanced response in the deepest two intakes.

The array responded to extraction of Longwall 5, particularly in the mid to lower Bulgo Sandstone and Stanwell Park Claystone, but not in the Scarborough Sandstone, with depressurisation in the shallow Bulgo Sandstone intakes possibly due to basal shear plane activation whilst the lower responses were due to enhanced secondary fracture porosity and enhanced vertical and horizontal permeability in the overburden.

Longwall 5 was extracted in stages, with the VWPs showing depressurisation whilst the longwall was active and recovery when it temporarily stopped. A longer term depressurisation response occurred when the longwall was completed, which was sympathetic with the decline in rainfall shown in the rainfall residual plot.

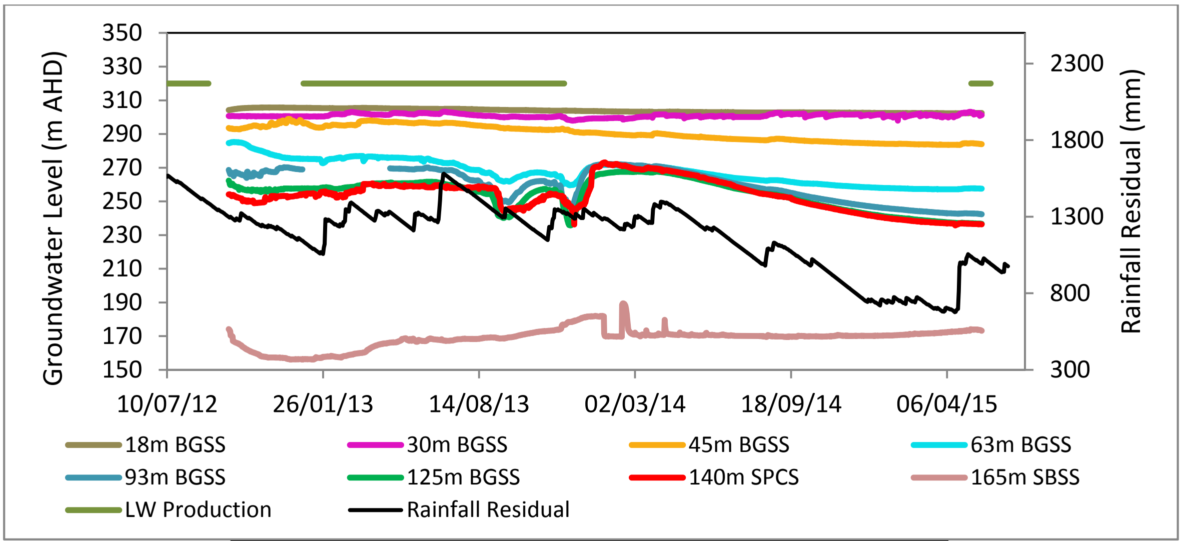
The uppermost piezometer at 18m below the surface does not change significantly over time whilst the 30m intake shows enhanced responsiveness to rainfall and catchment runoff / streamflow after the extraction of Longwall 5, although there is no long term depressurisation at that intake depth.

The 45mbgl intake has a muted response to rainfall but shows a definitive depressurisation during and after extraction of Longwall 5.

The relative pressure heads shown by the shallowest three piezometers indicates a slight downward gradient, with flow into the lower overburden, with a downward hydraulic gradient also being evident throughout the Bulgo Sandstone.

The height of depressurisation in GW1 lies between 140 and 165mbgl.

The pressure profile indicates that the vertical flow rate is likely to be relatively insignificant in comparison with rainfall recharge.



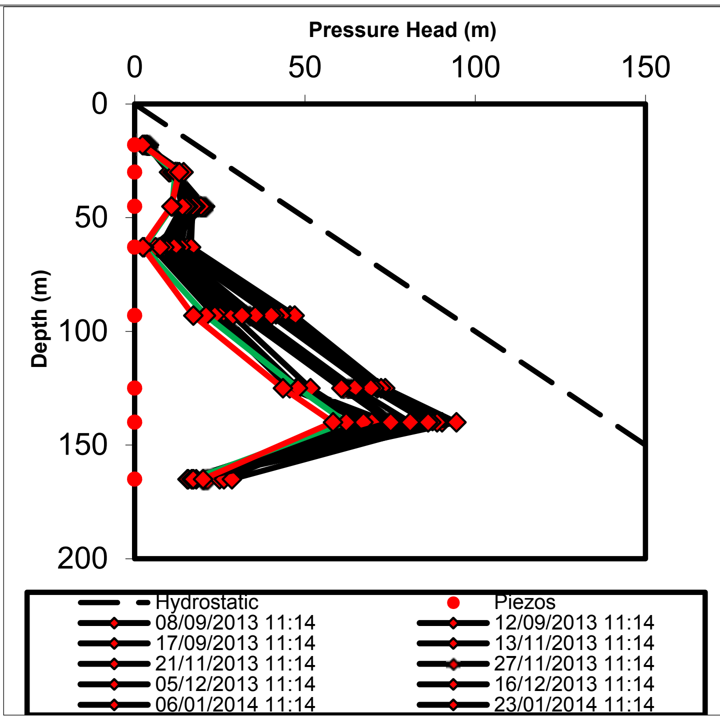




**Figure 15 GW1**

### 8.3.2 RV20

RV20 was installed in mid December 2014 to a depth of 134mbgl in the lower Bulgo Sandstone, after Longwall 5 was completed but prior to extraction of Longwall 6 (340m).

It is located over the Wongawilli Seam Longwall 5, as well as Bulli Seam pillar and Balgownie Seam longwall extraction areas.

RV20 is in an area with remnant Hawkesbury Sandstone and is approximately 715m south southwest west of Cataract Creek.

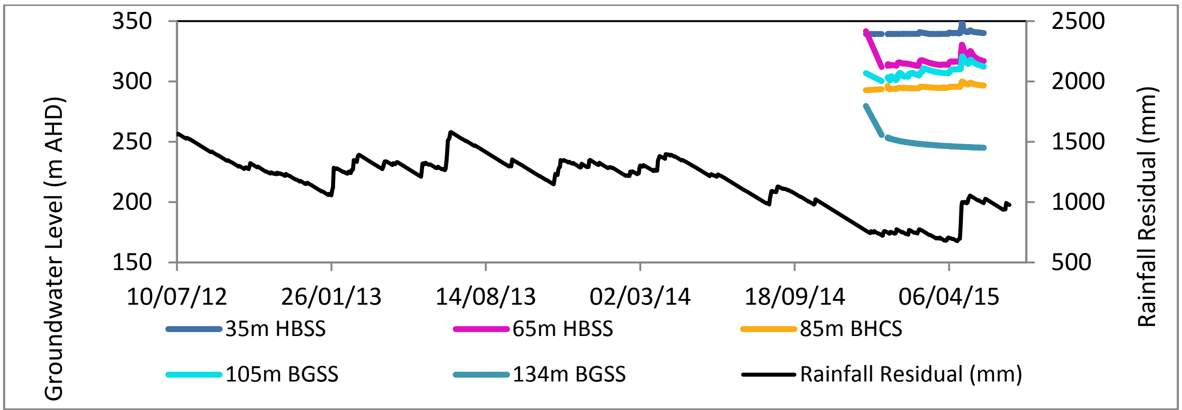
No definitive shallow system perched water table is evident, with a deeper pressurised system in the mid to lower Bulgo Sandstone, whilst the lower Bulgo Sandstone contains limited pressures. As a result of drilling difficulties, no data is available deeper than 134m in the Bulgo Sandstone as shown in **Figure 16**.

The VWP array has an overall weak responsiveness to rainfall, with no responses observed at 134mbgl in the Bulgo Sandstone, whilst a weak response is evident at the shallower 105mbgl intake in the Bulgo Sandstone.

The array did not observably respond to extraction of Longwall 6 (340m), but did respond, down to approximately 105mbgl, to a high rainfall event associated with an east coast low system in mid to late April 2015 which occurred whilst extraction of Longwall 6 (340m) was underway.

The height of depressurisation in RV20, as a result of triple seam extraction, lies between 105 and 134mbgl, whilst there is no significant pressure in the upper overburden between 35 and 85mbgl, with pressure being maintained in the 105mbgl intake.

The pressure profile indicates that the vertical flow rate is likely to be enhanced at this location.



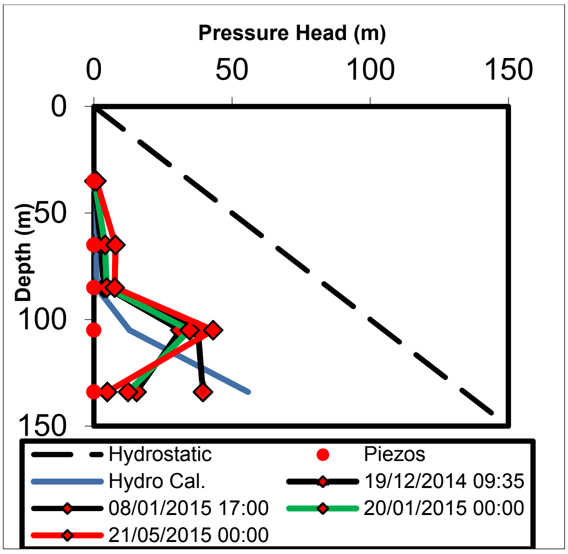




**Figure 16 RV20**

### 8.3.3 RV17

RV17 was installed in mid September 2014 to a depth of 79.5mbgl in the upper Bulgo Sandstone, after Longwall 5 was completed, but prior to extraction of Longwall 6 (340m).

It is located approximately 205m west of Longwall 6 and overlies Bulli Seam first workings, with no Balgownie or Wongawilli extraction.

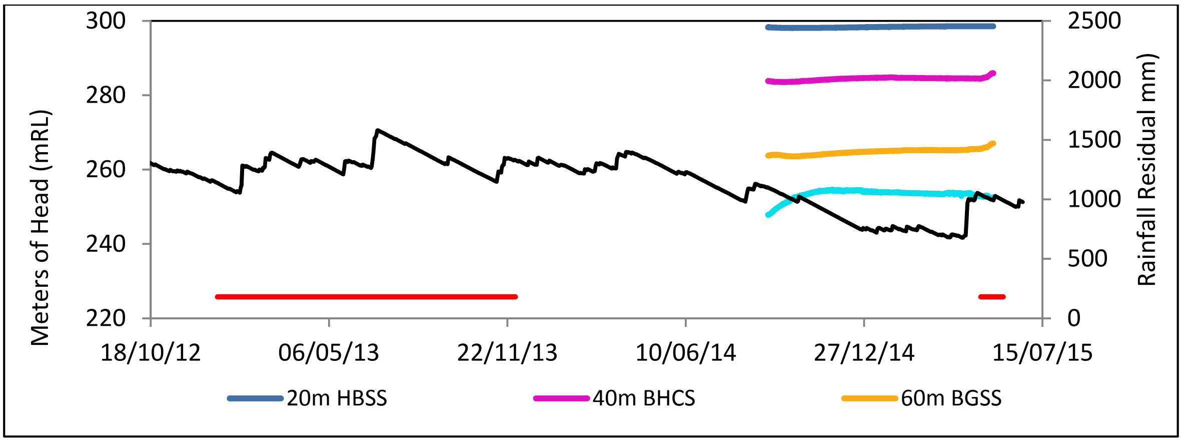
RV17 is in an area with remnant Hawkesbury Sandstone and is approximately 220m east of Cataract River. Shallow pressures within the Hawkesbury Sandstone remain stable at 298m AHD and are slightly elevated above the adjacent Cataract River.

No definitive shallow system perched water table is evident, with a reduced hydraulic gradient down to the base of the bore at 79.5mbgl as shown in **Figure 17**.

The VWP array has a minor, delayed responsiveness to rainfall at 40mbgl in the Bald Hill Claystone and 60mbgl in the upper Bulgo Sandstone.

The array did not observably respond to extraction of longwall 6 (340m), but did respond, down to approximately 60mbgl, to a high rainfall event associated with an east coast low system in mid to late April 2015 which occurred whilst extraction of Longwall 6 (340m) was underway.

The height of depressurisation in RV170, as a result of single seam first workings in the Bulli Seam has not been identified as the drill hole was not deep enough (due to drill rig limitations).



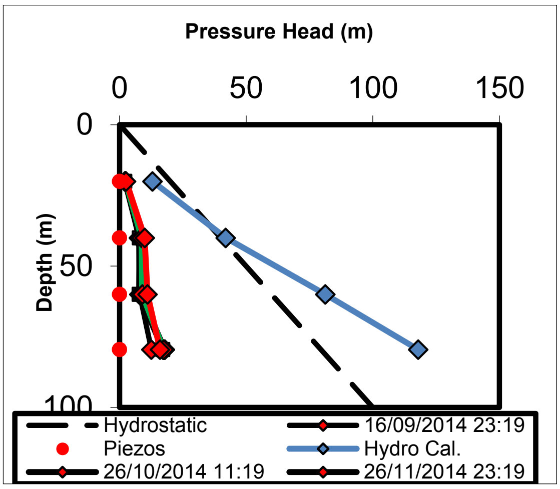




**Figure 17 RV17**

#### 8.3.4 NRE A (VWP)

NRE A (VWP) was installed in mid November 2009 to a depth of 140mbgl in the mid to lower Bulgo Sandstone.

It 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), with nearby longwall mining in the Balgownie Seam and no nearby mining in the Wongawilli Seam.

Pre-existing tension cracks are present close to NRE A (VWP), with 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).

It is located approximately 750m south east (upgradient) of Wongawilli Seam Longwall 4 and is well outside the area of depressurisation influence from Longwalls 4, 5 or 6.

The VWP array is located approximately 540m north of Cataract River and 485m south west of Cataract Creek.

The elevation of the phreatic surface ranges from RL340m to RL360m which is at the level of the upper headwaters of Cataract Creek and is likely to be contributing to an intermittent to perennial base flow into Cataract Creek as shown in **Figure 18**.

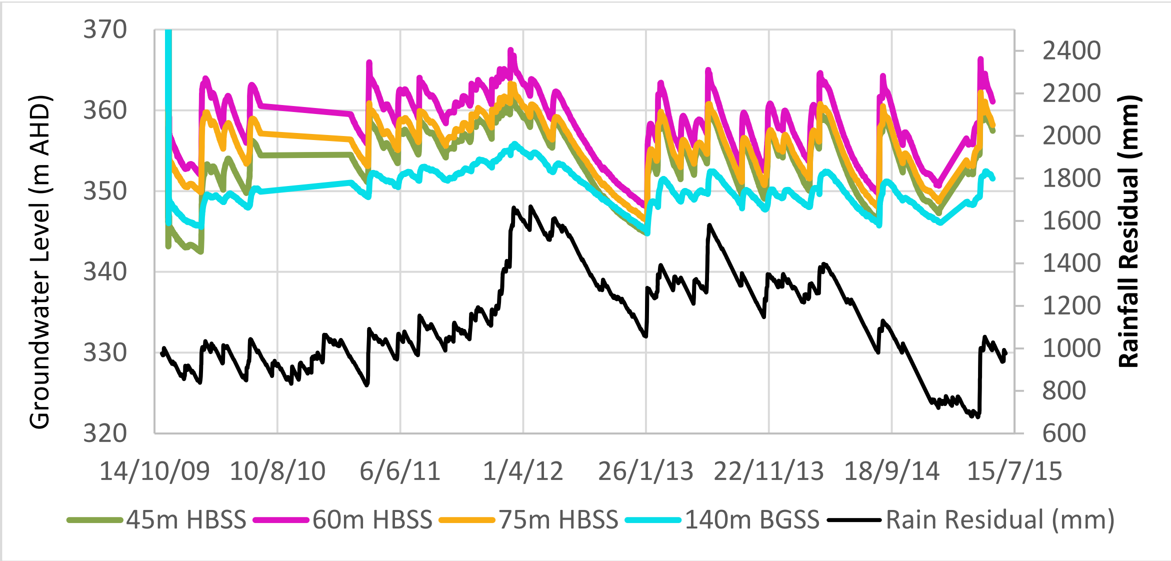
No definitive shallow system perched water table is evident, and it has an essentially hydrostatic gradient from 45 – 140mbgl.

The VWP array has a strong responsiveness to rainfall in all intakes, albeit slightly subdued at 140mbgl 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 indicating a high degree of vertical connectivity, with the Bald Hill Claystone not reducing vertical downward flow at this location.

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 significant area of rainfall recharge.

The array did not respond to extraction of longwalls 4, 5 or 6 due to its separation distance from the workings.

The height of depressurisation is not evident in the data available from NRE A (VWP) as the bore was not drilled deep enough.



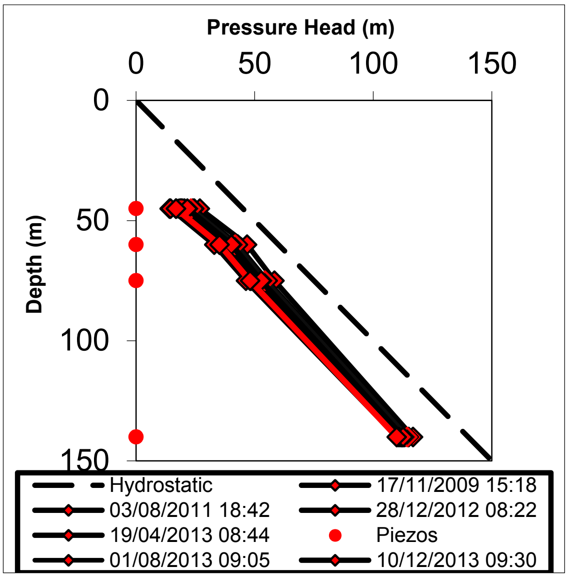




**Figure 18 NRE A (VWP)**

### 8.3.5 RV16

RV16 was installed in early July 2014 to a depth of 242mbgl in the Scarborough Sandstone.

It is located on a lower elevation of the same ridge line as NREA in Hawkesbury Sandstone in an area with pillar extraction in the Bulli Seam and is over a chain pillar between two longwalls in the Balgownie Seam, with no nearby mining in the Wongawilli Seam.

No pre-existing tension cracks are present close to RV16, and it shows a low degree of vertical conductivity.

It is located approximately 460m southeast (upgradient) of Wongawilli Seam Longwall 4 and is well outside the area of depressurisation influence from Longwalls 4, 5 or 6 (340m).

The VWP array is located approximately 850m north of Cataract River and 570m southwest of Cataract Creek.

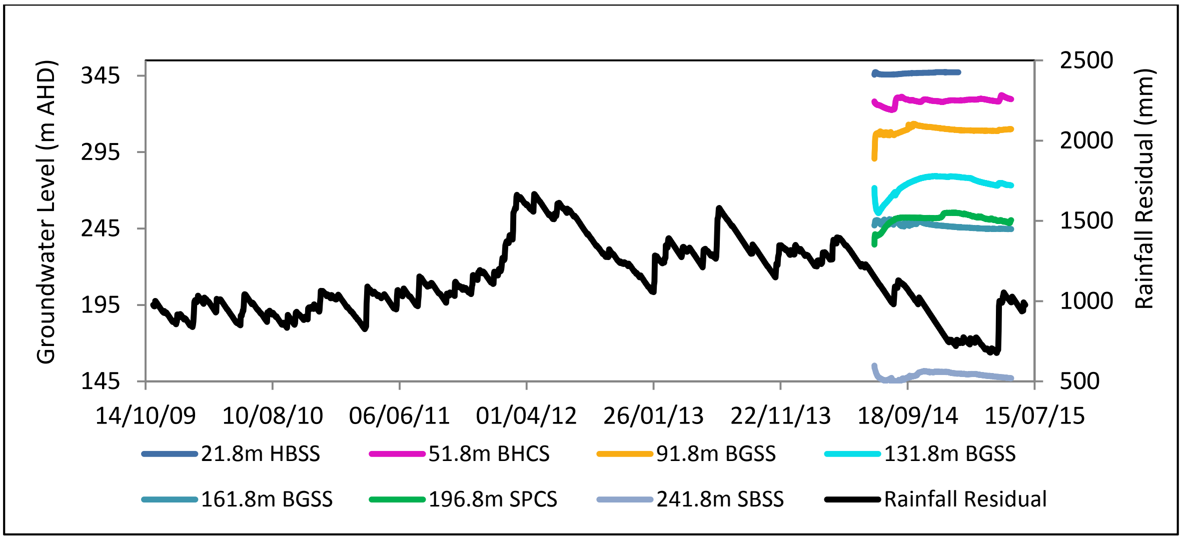
The elevation of the phreatic surface a ranges from RL340m to RL360m which is at the level of the upper headwaters of Cataract Creek and is likely to be contributing to an intermittent to perennial base flow into Cataract Creek as shown in **Figure 19**.

No definitive shallow system perched water table is evident.

The VWP array has an overall low responsiveness to rainfall, albeit slightly more enhanced in the Bald Hill Claystone at 52mbgl.

The array did not respond to extraction of longwalls 4, 5 or 6 due to its separation distance from the workings.

The height of depressurisation lies between 197 and 242mbgl at RV16.



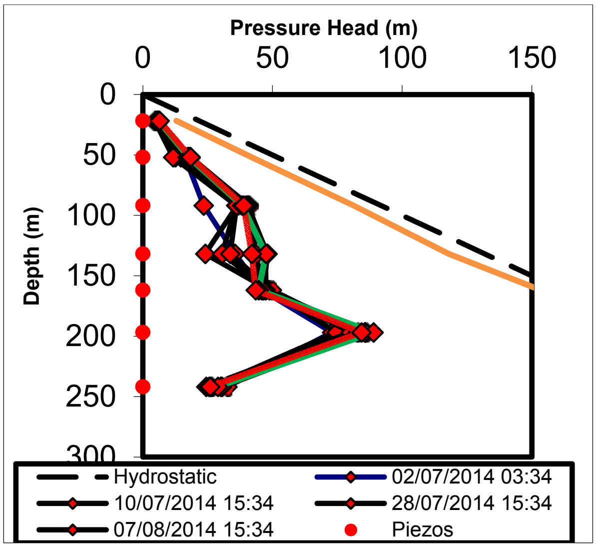




**Figure 19** **RV16**

#### 8.3.6 NRE B

NRE B was installed in late November 2009 to a depth of 168mbgl into the Bulgo Sandstone.

It is located on a watershed in Hawkesbury Sandstone in an area with only pillar extraction in the Bulli Seam and is approximately 790m ENE of the proposed eastern end of Longwall 6 in the Wongawilli Seam and is well outside the area of depressurisation influence from Longwalls 4, 5 or 6 (340m).

No pre-existing tension cracks are present close to NRE B, and its shows a low degree of vertical conductivity.

The VWP array is located approximately 515m north east of Cataract Creek.

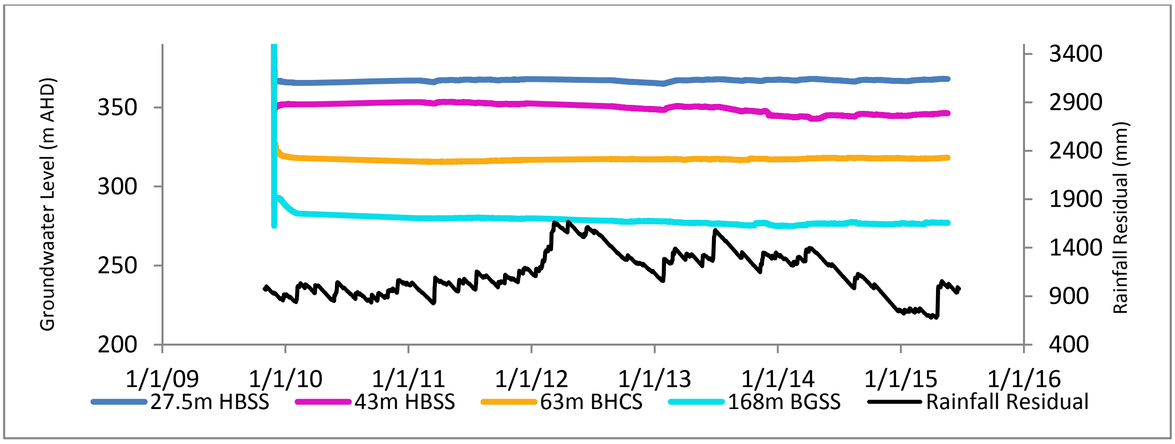
An elevated phreatic surface is present to approximately 43mbgl (RL330m) which is likely to be contributing to base flow in Cataract Creek, however the profile is essentially depressurised at 63mbgl as shown in **Figure 20**.

The VWP array has an overall low responsiveness to rainfall.

Pore pressures in the Hawkesbury Sandstone are perched well above the level of Cataract Creek and the Cataract Reservoir, whilst pore pressure in the Bulgo Sandstone is below the 289.87mAHD Full Supply Level (FSL) of Cataract Reservoir.

The VWP array did not respond to extraction of longwalls 4, 5 or 6 due to its separation distance from the workings.

The bore does not extend deep enough to assess the height of depressurisation, however, the data indicates there is a downward hydraulic gradient, although the hydraulic properties of the overburden is sufficiently low to generate a very small downward flow component.



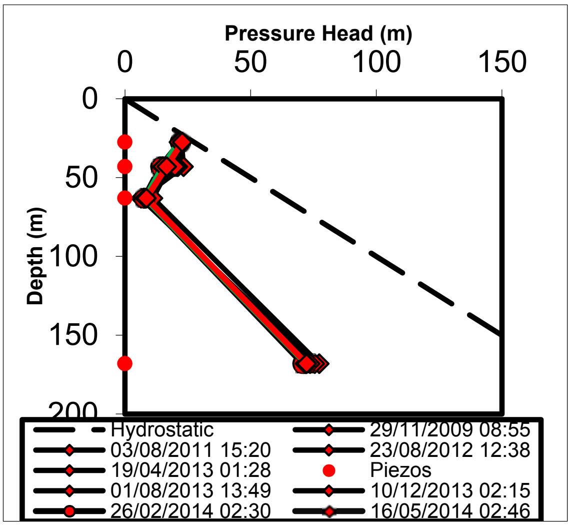




**Figure 20 NRE B**

### 8.3.7 NRE D

NRE D was installed in December 2009 to a depth of 160mbgl into the Bulgo Sandstone.

It is located on a watershed in Hawkesbury Sandstone in an area with limited pillar extraction in the Bulli Seam and is approximately 1650m north of Longwall 6 (340m) and is well outside the area of depressurisation influence from Longwalls 4, 5 or 6 (340m).

No pre-existing tension cracks are present close to NRE D, and its shows a low degree of vertical conductivity.

The VWP array is located approximately 1030m north of Cataract Creek and 575m east of the full storage level of Cataract Reservoir.

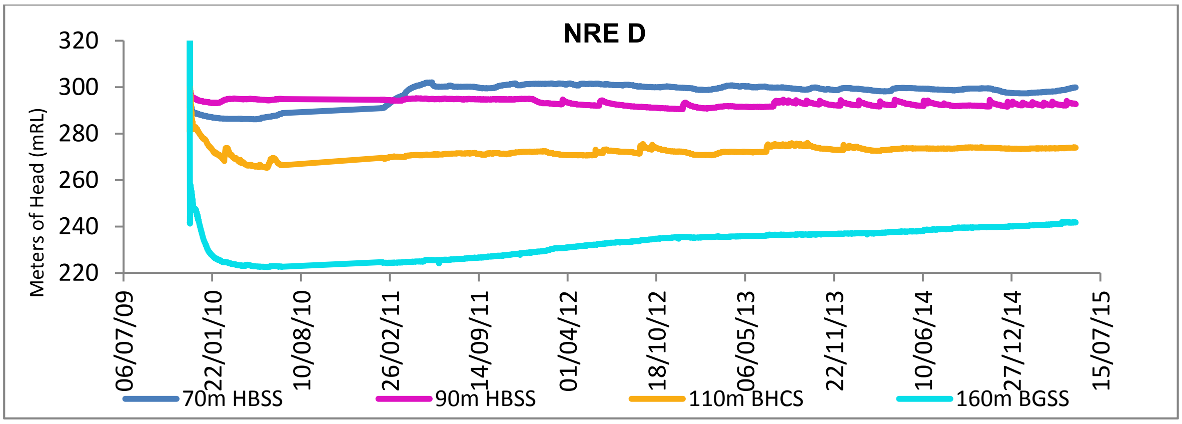
Insufficient shallow depth VWP intakes are present to assess the presence of an elevated phreatic surface, as the shallowest intake lies at 70mbgl as shown in **Figure 21**.

The VWP array has an overall low responsiveness to rainfall at 70mbgl in the Hawkesbury sandstone, and a moderate responsiveness at 90 and 110mbgl.

Pore pressures in the Hawkesbury Sandstone are perched at approximately 5m above the Cataract Reservoir 289.87mAHD Full Supply Level (FSL) in the 90mbgl intake.

The VWP array did not respond to extraction of longwalls 4, 5 or 6 due to its large separation distance from the workings.

The bore does not extend deep enough to assess the height of depressurisation, however, the data indicates there is a downward hydraulic gradient, with the overburden hydraulic properties being sufficiently low to generate a very small downward flow component.



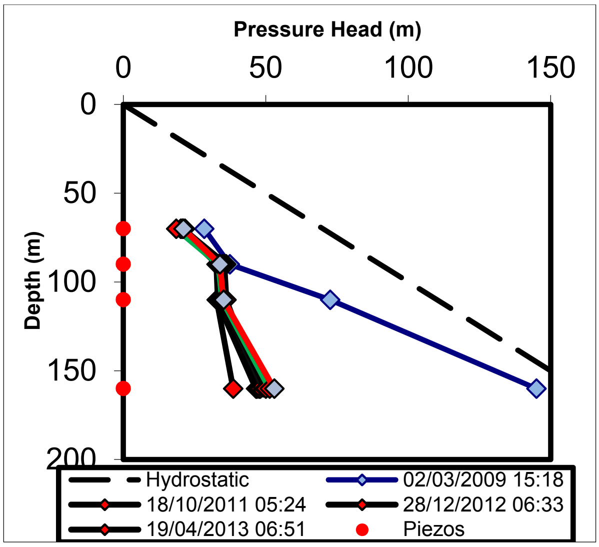




**Figure 21 NRE D**

### 8.3.8 RV23 (VWP)

RV23 (VWP) was installed in late November 2014 to a depth of 220mbgl into the Scarborough Sandstone.

It is located approximately 85m east of Cataract Reservoir FSL in the Bald Hill Claystone in an area of first workings extraction within the Corrimal Colliery.

No pre-existing tension cracks are present close to RV23, and its shows a low degree of vertical conductivity.

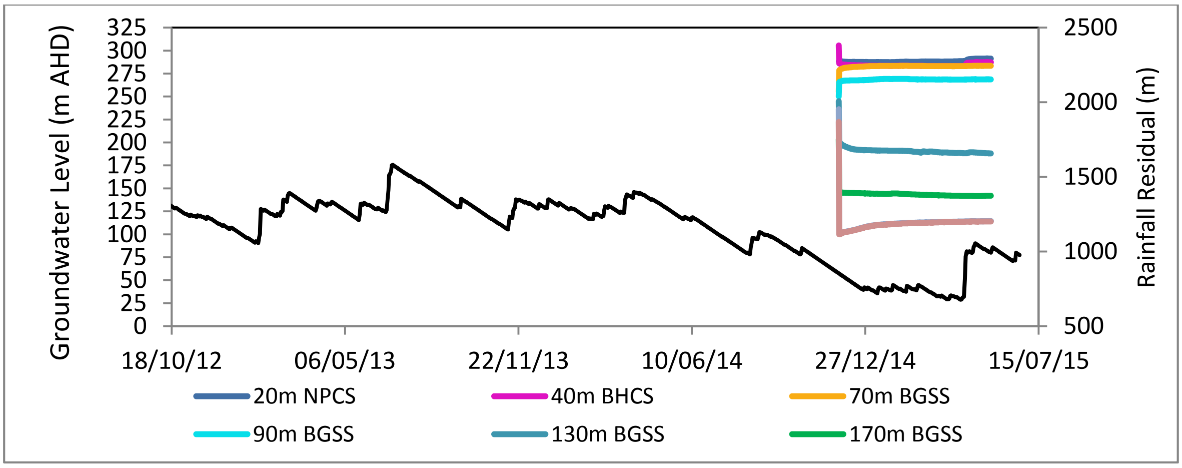
It is located approximately 1570m north west of Wongawilli Seam Longwall 6 (340m) and is well outside the area of depressurisation influence from Longwalls 4, 5 or 6.

It has an essentially hydrostatic head increase down to 90mbgl, below which a marked drop in pressure is observed, with no evident perched water table. It also has a rise in head pressures between the 200 and 220mbgl intake depths.

The VWP array has a low responsiveness to rainfall as shown in **Figure 22**.

The array did not respond to extraction of Longwalls 4, 5 or 6 due to its large separation distance from the workings.

The height of depressurisation lies between 197 and 242mbgl at RV23.



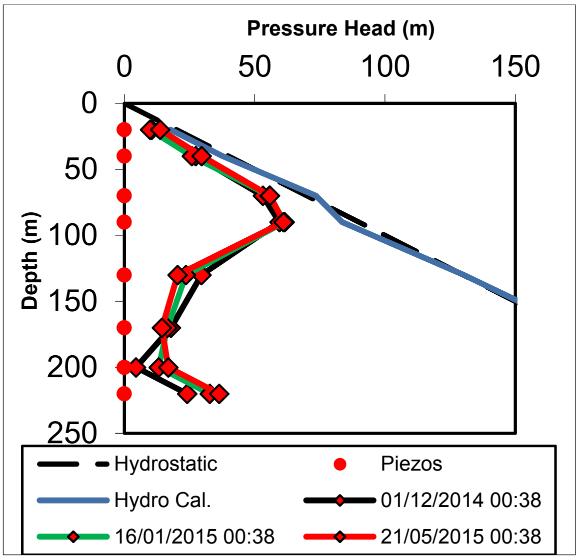




**Figure 22 RV23 (VWP)**

### 8.3.9 NRE3 (Wonga West)

NRE3 is located approximately 1,300m west of Cataract Reservoir and was installed in mid December 2009 to a depth of 255mbgl into the Bulgo Sandstone over Bulli Seam Longwalls.

No pre-existing tension cracks are present close to NRE3, and its shows a low degree of vertical conductivity.

It is located on the opposite side of the reservoir and is well outside the area of depressurisation influence from Longwalls 4, 5 or 6.

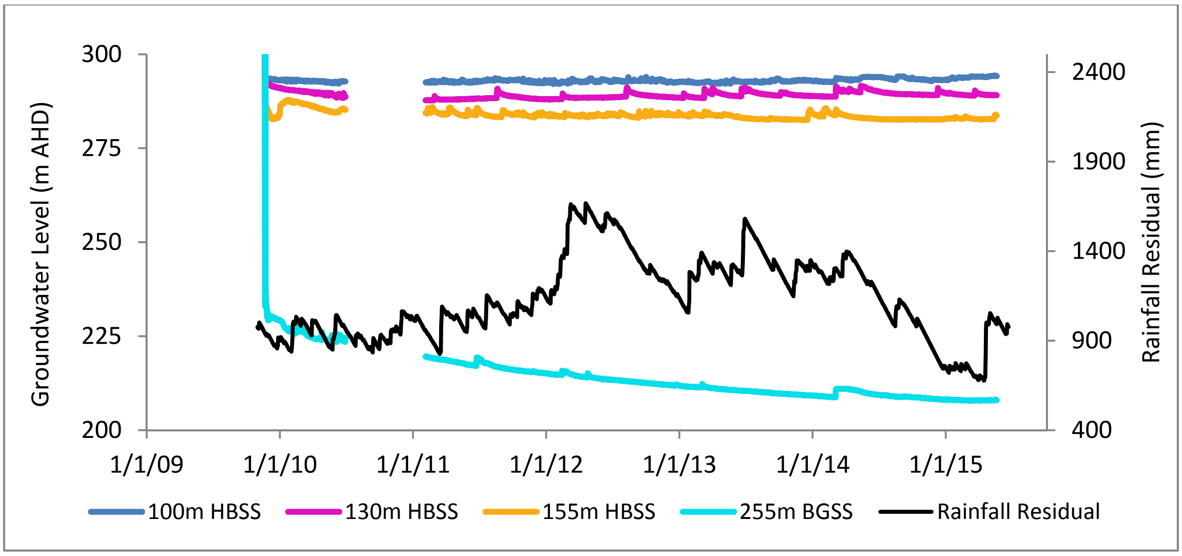
The VWP array is located approximately 190m west of Lizard Creek.

Insufficient shallow depth VWP intakes are present to assess the presence of an elevated phreatic surface, as the shallowest intake lies at 100mbgl.

It has an 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 as shown in **Figure 23**.

The VWP array has a moderate responsiveness to rainfall in the 130mbgl and 155mbgl intake depths.

The array did not respond to extraction of longwalls 4, 5 or 6 due to its very large separation distance from the workings, whilst its height of depressurisation was not established below the deepest intake of 255mbgl.



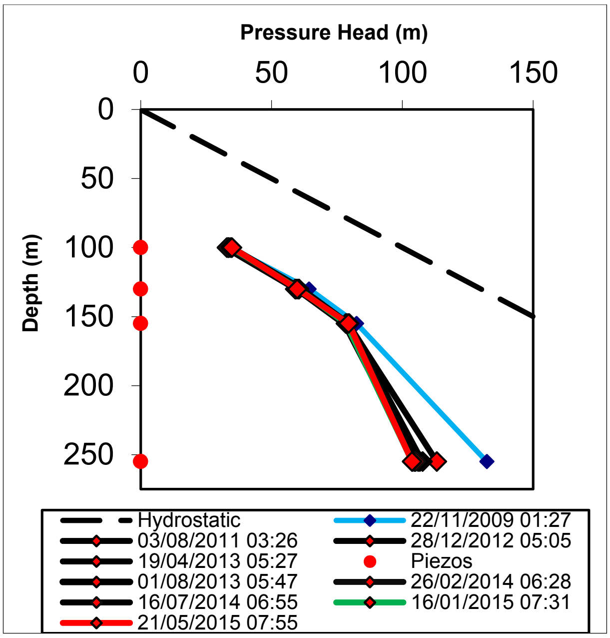




**Figure 23 NRE3**

### 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, which are located to the west of Cataract Reservoir.

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 is removed from the mine by active pumping and through passive means either by moisture content in coal removed from the mine and within ventilation system exits. Water within the mine workings occurs through groundwater entry to excavated areas and through the use of potable water for dust suppression and general service underground during periods of active mining.

The removal of water through pumping has two main components. Water is removed from the Bulli Seam where everything captured inbye from the old South Bulli Mine plus some of the trickle down through the overburden strata that occurs above Longwalls 4 and 5. This outlet also captures water in the Balgownie Seam which is pumped from 48 cut-through (C/T) to 27 C/T as shown in **Figure 24**.

It is also considered likely that there is some inflow through the barriers from Corrimal, Cordeaux, and Old Bulli mining area, but it is not possible for these various components be differentiated from the flows that come from South Bulli. It is estimated that total leakage from other mining areas is in the order of 0.2 ML/day and is likely to be dominated by leakage across the barrier with Cordeaux where down dip areas are believed to be flooded.

The removal of water from the Wongawilli Seam is from the main sump at 18 ½ C/T through to 12 ½ C/T and then via the Wongawilli portal. This captures some of the flow from up dip in the Bulli and Balgownie that makes its way down through the Wongawilli Seam goaf and through to the southern (inbye) end of Longwalls 4 and 5.

The volumetric recording of flows of water removed from the mine is calculated from the pump hours which have had flow rates calibrated to running pump rates. Active pumping is not continuous and the periodic pump operation means that the measured pump rates recorded daily are extremely variable and the recognition of trends has been undertaken using averaged data over weekly and monthly periods.

Recent investigation into the dynamics of the various inflow components has led to an improved understanding of these trends. Groundwater make to the mining areas increases as would be expected with down dip mining progression in the Wongawilli Seam. However recent scrutiny of the various components of the water inflow totals has shown that there is a component of the inflow variability which can be correlated to rainfall trends. This is particularly the case for the Bulli Seam component where a strong correlation can be seen as shown in **Figure 25** albeit with some time lag that suggests a tortuous flow path.

In the Wongawilli Seam, the inflows at first impression also suggest that rainfall recharge has an influence, however this is likely to be coincidental as increases in the flow rates also align with the mining progression down dip into saturated strata. Detailed rainfall trends are not absolutely reflected in the flow rates emanating from the Wongawilli Seam and are more representative of mining progression, however as there is a small amount of water from the Bulli Seam making its way to the Wongawilli Seam through the fracture zone, it may account for some of the small scale inflow variability along with the variable pump rates.

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 Bulli and Corrimal Collieries.

### 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 Russell Vale 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 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 Russell Vale East workings indicates there is no observed associated short term increase in mine water make from the current Russell Vale East workings following significant rain in the Cataract Creek, Cataract River or Bellambi Creek catchments.

### 8.4.3 Mine Water Pumping Volumes

The current total mine water pumping rate from the Russell Vale Colliery at the end of April 2015, before LW6 (340m) extraction in the Wongawilli Seam, was approximately 0.56ML/day (204.4ML/year) and peaked at around 2.0ML/day (730ML/yr) at the end of Longwall 5 extraction as shown in **Figure 25**.

Of the total mine water pump out volumes, inflows entering the Russell Vale mine (ie not related to strata groundwater seepage generated within the Russell Vale Colliery lease area) comprised approximately;

- 0.1ML/day background inflow from upgradient of the Russell Vale East workings;
- 0.3 ML/day background inflow from upgradient of the Russell Vale West workings, and;
- 0.22ML/day pumped into the mine for dust suppression, minus 0.07ML/day of moisture in coal during active mining periods (0.22 – 0.07 = 0.15ML/day), or 0.01-

0.02ML/day when no mining is occurring.

Therefore, strata groundwater make from within the Russell Vale Colliery lease area has ranged from;

- 2.0 - 0.1 – 0.3 - 0.15 = 1.35ML/day at the end of Longwall 5, and
- 1.1 - 0.1 - 0.3 - 0.15 = 0.55ML/day at the end of April 2015, prior to extraction of LW6 (340m)

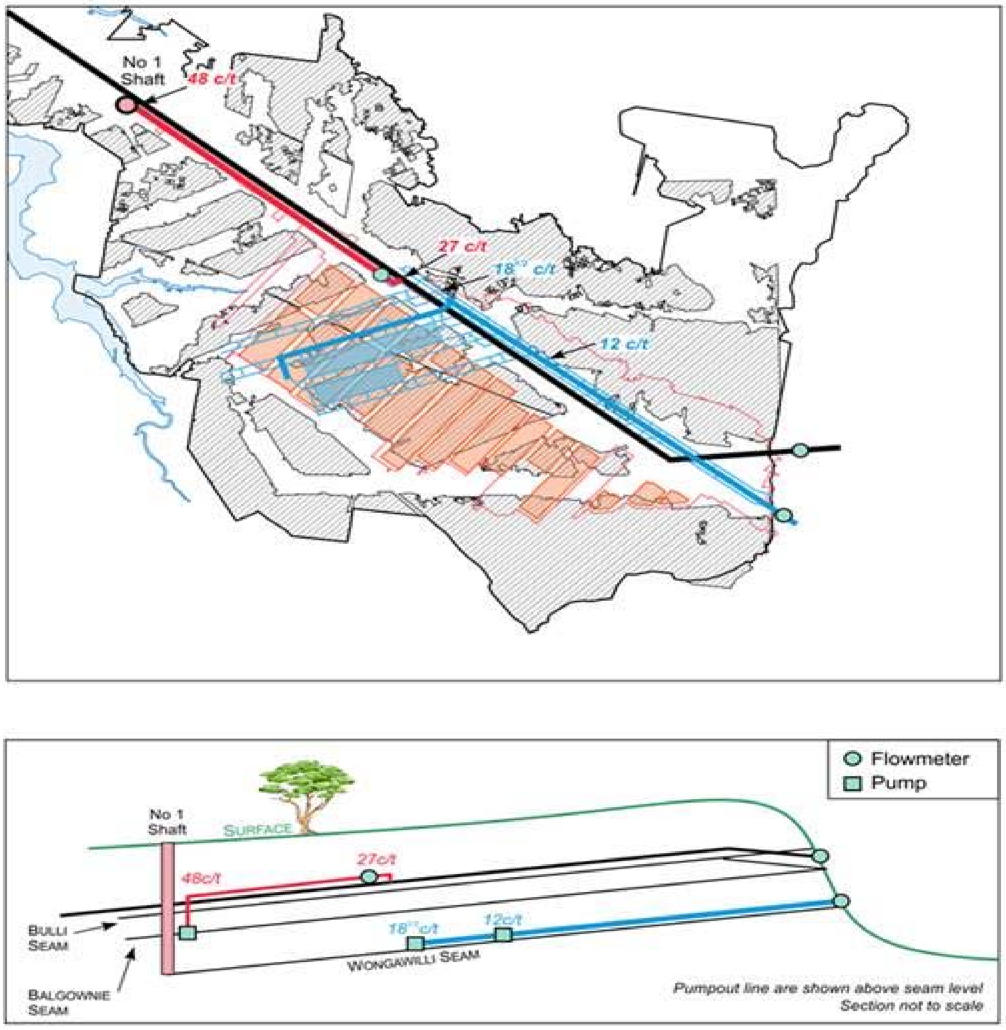



**Figure 24 Underground Water Management Schematic**

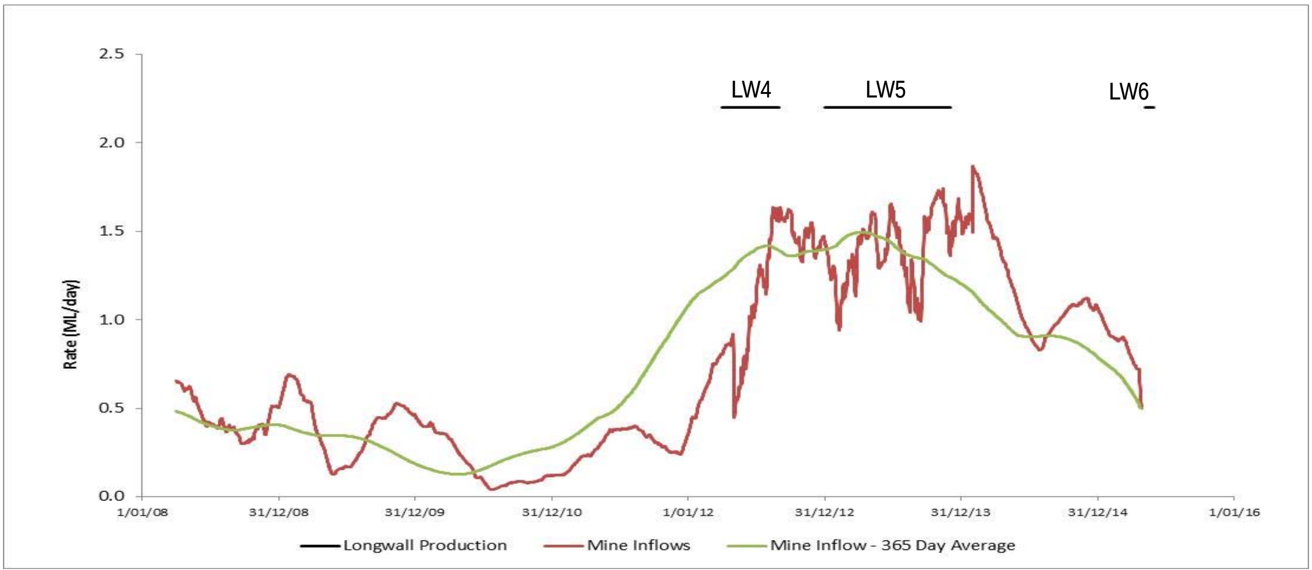



**Figure 25 Russell Vale Colliery Strata Groundwater Leakage**

## 8.5 Groundwater Chemistry

Based on data supplied by WCL, groundwater in the Hawkesbury Sandstone at Russell Vale East ranges from 76 - 776μS/cm with a pH from 3.2 – 6.8 as shown in **Figure 26**.

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. It is noted that the pH readings monitored between August and December 2013 are anomalously alkaline and may be inaccurate.

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.

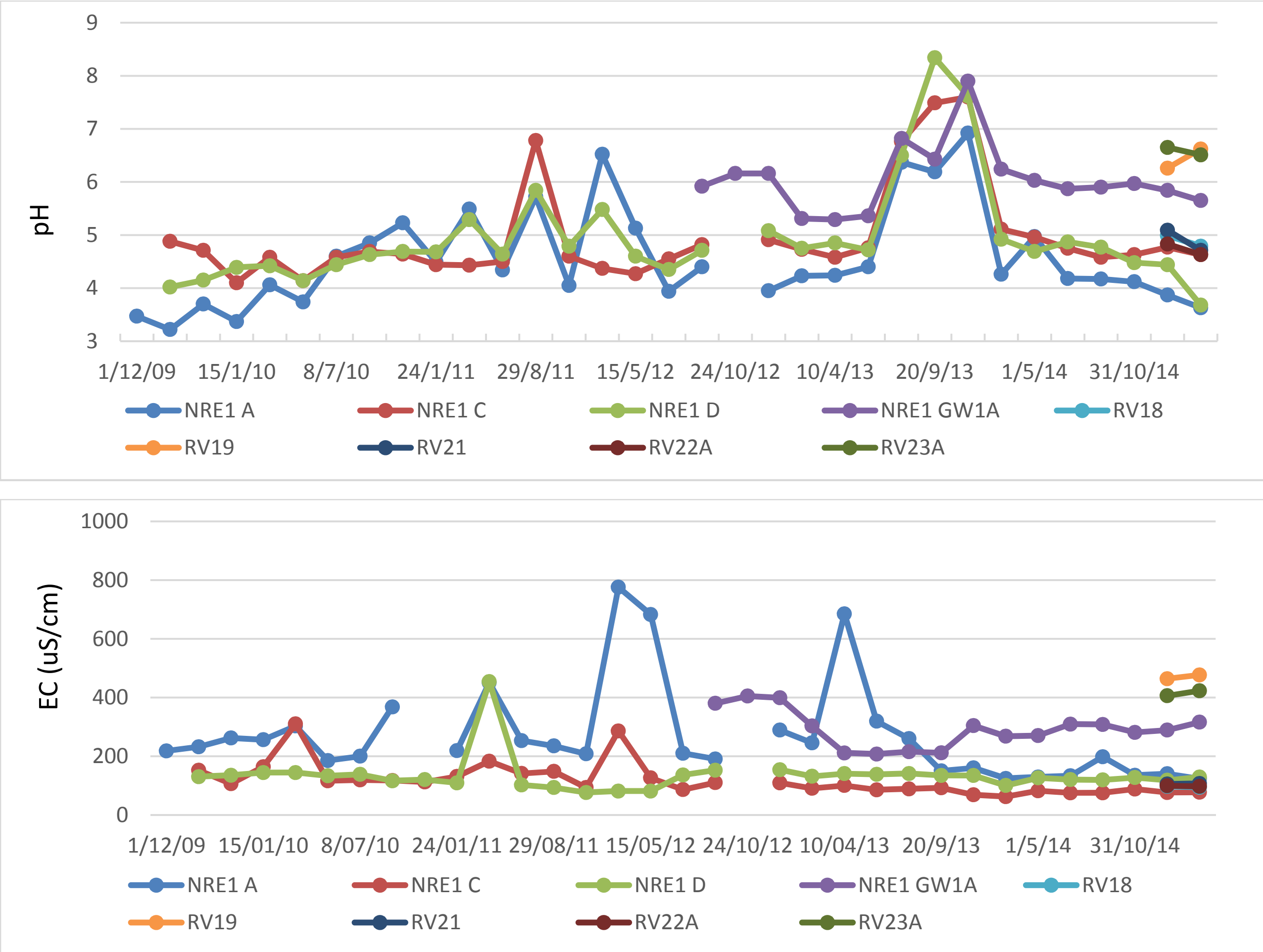



**Figure 26 Russell Vale East Hawkesbury Sandstone Salinity and pH**

Further detailed analysis of groundwater chemistry in the Russell Vale East area is contained in GeoTerra (2014A).

# 9. GROUNDWATER MODELLING

## 9.1 Background

A number of groundwater modelling studies have been undertaken within the Russell Vale Underground Expansion Project (UEP) area.

A FEFLOW groundwater model and associated interpretation was reported in GeoTerra (2012B) which assessed proposed mining in both the Russell Vale West and Russell Vale East areas.

Subsequently, a revised mine plan within Russell Vale East (Longwalls 1-7 and 9-11) was assessed via a MODFLOW SURFACT groundwater model for the UEP Preferred Project Report (PPR) in GeoTerra / GES (2014).

This version of MODFLOW SURFACT modelling and associated assessment was conducted following review of the previous assessment ad modelling by State and Federal regulatory bodies, culminating in the PAC review, and incorporates additional piezometer installations and groundwater monitoring duration. Specific aspects of the modified and updated assessment scope of work and objectives are outlined in **Section 1.1**.

Since the UEP PPR impact assessment and after the PAC review, an updated conceptual model of the groundwater system and updated understanding of mine inflow dynamics required the use of an updated groundwater modelling approach.

The current 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.**

## 9.2 Model Code and Complexity

Numerical modelling has been undertaken using the Groundwater Vistas software interface (Environmental Simulations) in conjunction with MODFLOW-SURFACT (Hydrogeologic).

MODFLOW-SURFACT is an advanced version of the MODFLOW code.

Previously this model utilised the Van Genuchten method for simulating the unsaturated zone. In accordance with the recommendations of the PAC, this current version of modelling builds on the previous MODFLOW SURFACT Russell Vale groundwater model and incorporates the Pseudo Soil option within MODFLOW-SURFACT to simulate the unsaturated zone.

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 the current model is to simulate the current and proposed mining activities within the Wongawilli Seam in the Russell Vale East area, and to understand the effects to the groundwater and surface water environment in a local and regional context.

There is extensive pre-existing depressurisation from existing workings at Russell Vale, as well as the adjoining Cordeaux, Corrimal and Bulli mines as a result of mining activities over many decades starting from the late 1800s, along with a long hiatus since mining activities in the Russell Vale East area after the Balgownie Seam was mined by longwall methods in the 1970s.

### 9.3 Model Domain

The spatial relationship of the proposed and the existing workings within the groundwater modelling domain is shown in **Figure 1.**

### 9.4 Conceptual Hydrogeological Model

A conceptual model of the Russell Vale lease area hydrogeological regime has been developed based on a review of existing hydrogeological data as described in **Section 8** and shown in **Figure 27**, 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.

It should be noted that the modelling, of necessity, requires simplification of the regional and local groundwater system in regard to strata lithological thicknesses, hydraulic properties and applied stresses including previous subsidence, rainfall infiltration, creek leakage and underground seepage.

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.

Cataract Reservoir is interpreted to be incised into the Bald Hill Claystone in the deepest sections of the storage adjacent to the proposed mining area, whereas the periphery, edge and banks of the reservoir are predominantly within the Newport and Garie Formations and subsequently at higher elevations, in Hawkesbury Sandstone.

The outcropping upper catchments and stream beds are sequentially incised down the stream thalweg into Hawkesbury Sandstone, Newport and Garie Formations, Bald Hill Claystone Formation and the Bulgo Sandstone.

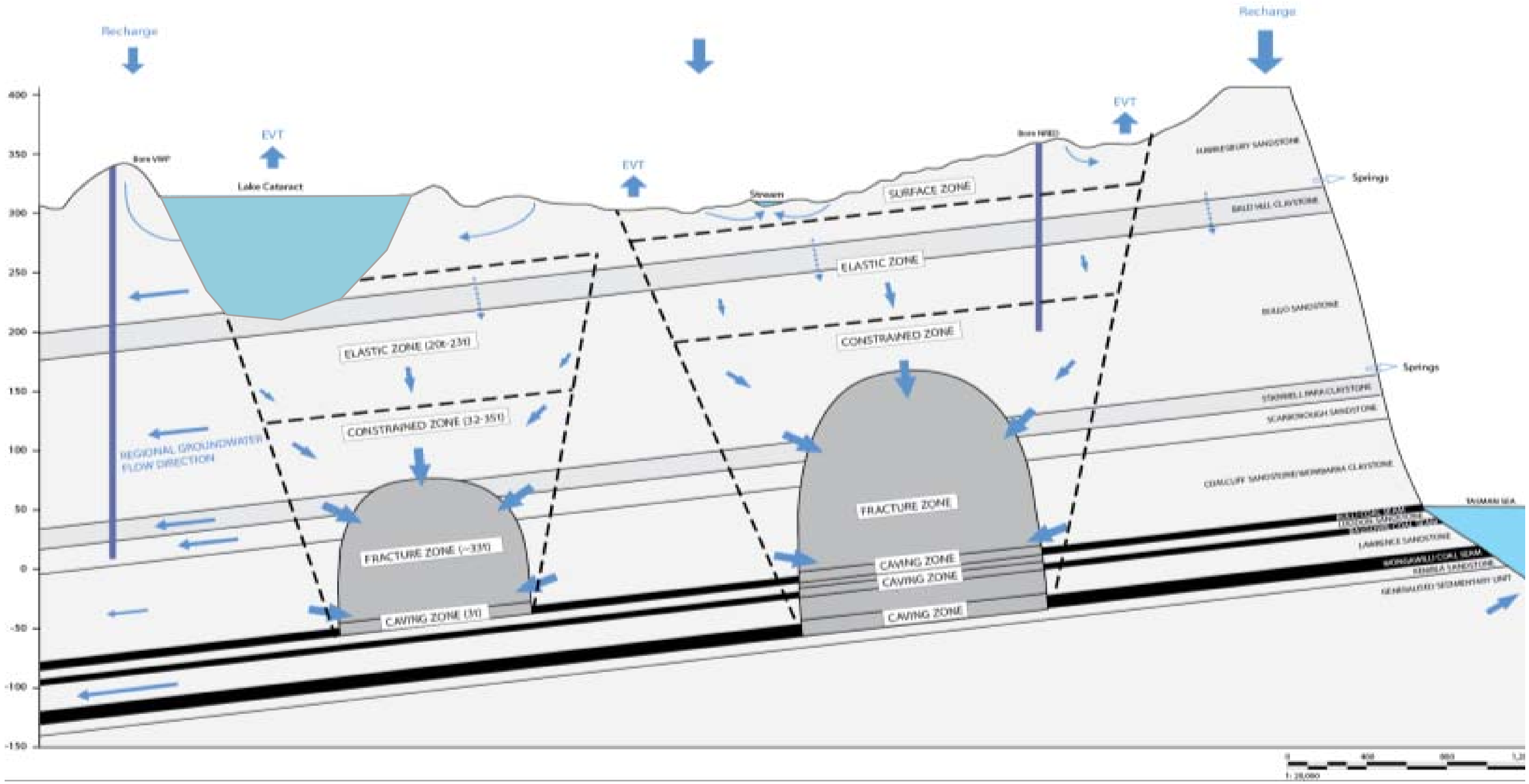



Figure 27 Conceptual Groundwater Model

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 and drilling data sourced from other Southern Coalfield projects.

Six conceptual groundwater sub-domains are present:

- intermittent to ephemeral, hydraulically disconnected (perched) upland swamps which provide limited and intermittent baseflow to local streams;
- a perched, weathered Hawkesbury Sandstone profile which provides ephemeral 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 Russell Vale West, although not at Russell Vale East, both before and after subsidence. Following mining, as has been observed in the piezometers to the east of the reservoir, the groundwater levels exhibit a heightened response to recharge and increased recharge due to higher subsidence related secondary porosity, as well as interconnected permeability of the aquifers;
- 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, which contain 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 to represent both the existing undisturbed strata lithologies and Bulli / Balgownie Seam subsidence affected areas, as well as to account for the anticipated change in hydraulic properties following extraction of the proposed Wongawilli Seam workings.

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 mine area 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 Russell Vale West area and estimated ponding levels within the Corrimal workings.

Drain cell stages were limited to elevations above the seam allowing for ponding to occur. Russell Vale West drains were limited to -140m AHD and Corrimal drains were limited to -95m AHD, which 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 effects.

The adjoining Cordeaux and Bulli workings were assumed to be separated from Russell Vale Colliery by at least a 40m wide intact coal barrier.

### 9.5 Model Layers

Nineteen layers are conceptualised for the purpose of numerical modelling as shown in **Table 3**.

The major sandstone formations (Hawkesbury and Bulgo) are split into multiple layers in order to reproduce natural or subsidence induced variations to vertical hydraulic gradients.

In the mid-reach of Cataract Creek, the Hawkesbury Sandstone and underlying Newport / Garie Formation and the Bald Hill Claystone have been eroded away to expose 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 also contains the upper Bulgo Sandstone in the eroded reach of Cataract Creek.

All subsequent underlying layers contain only one lithology.

**Table 3 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 |
| 19 | Basement |

**NOTE:** NGF = Newport / Garie Formation BHCS = Bald Hill Claystone UBS = Upper Bulgo Sandstone

### 9.6 Boundary Conditions

The model areal extent has been chosen so the peripheral boundary conditions are of a sufficient distance from the proposed workings 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:

- general head boundaries representing active mining areas in the Wongawilli Seam including Appin (to the north) in the Bulli Seam and Dendrobium in the Wongawilli Seam in the south;
- constant 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 (RBOT) 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. While this is acknowledged as not appropriate for the upper, ephemeral reaches of Cataract Creek, it is assessed as appropriate in the perennial reaches, which is where the focus was applied to address potential changes to drainage as a result of the proposal.
- Water-NSW reservoirs, Cataract Reservoir and Cordeaux Reservoir were also simulated utilising (Steady State) River Package boundary cells with levels set at 290m AHD and 305m AHD respectively.

Groundwater head pressures in Vibrating Wire Piezometer (VWP) arrays and standing water level data from open standpipe piezometers within the Russell Vale lease 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 from these locations.

Direct measurements of hydraulic parameters from bores within the Russell Vale lease area were used, and where data was unavailable, approximated parameters were sourced from other studies as starting points for calibration. Other projects include the BHPB workings to the north at Appin (Heritage Computing, 2010) and to the south at Dendrobium (Coffey Geotechnics 2012).

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.

### 9.7 Recharge and Evapotranspiration

Recharge was set at 4% of rainfall from BOM Silo data for Cataract Dam across the majority of the model domain and to 6% over the elevated terrain west of the escarpment and coastal plain.

Evapotranspiration was applied uniformly to the model with rate of 0.005 m/d and an extinction depth of 4m.

### 9.8 Grid

A variable cell size is employed across the model domain which contains a total of 1,160,782 active cells.

A grid size of 250m x 250m occupies the periphery of the model domain, reducing to 100m x 100m nearer to the Russell Vale lease area, then 50m x 50m over most of Wollongong Coal Lease area and further reduced to 50m x 25m in an east – west alignment overlying 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 baseflow effects in creeks overlying the Russell Vale East area.

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).

## 9.9 Mining Schedule

The adopted mine schedule for development and the extraction of the panels within the Bulli and Wongawilli seams is shown in **Table 4**.

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 Russell Vale West within the Bulli seam in 1993 and the initial mine development in the Wongawilli Seam at Russell Vale East, which began in early 2011. The interim period included a long period 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 Russell Vale East area as shown in **Figure 28**.

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.

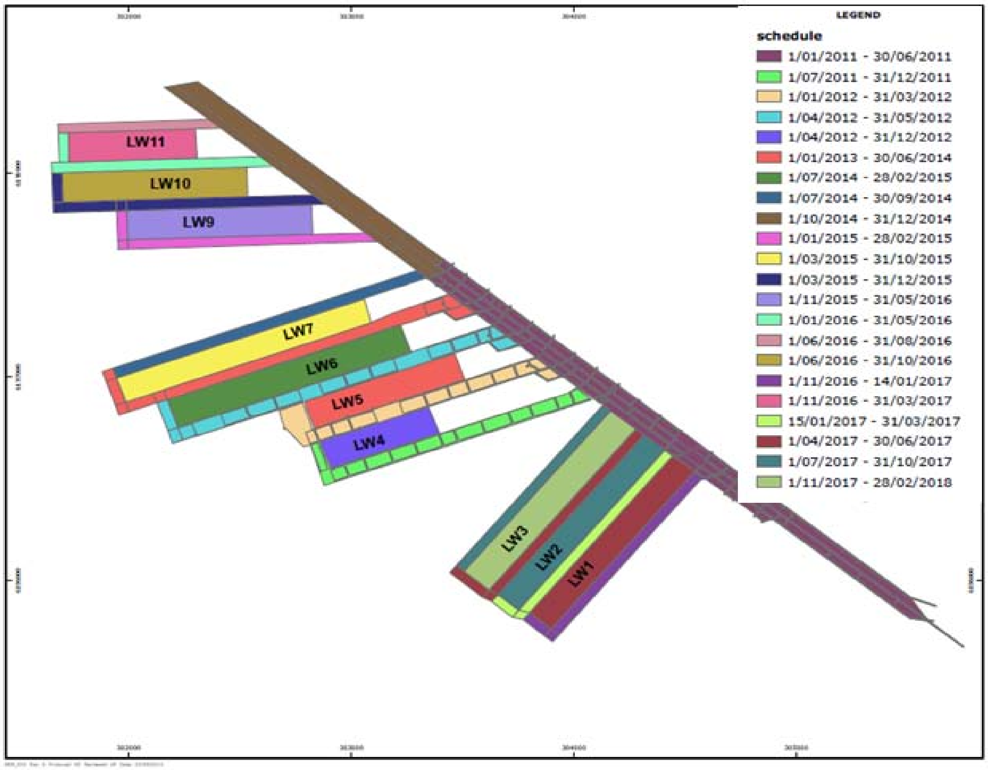



**Figure 28 Mining Schedule in Wongawilli Seam**

## Table 4 Impact Assessment Mine Schedules

| Model Type | Purpose | Stress Period | SP_START | SP_END | DAYS | start day | Wonga East Heading | Wonga East | Wonga West | Cordeaux | Other Bulli Mines |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Steady State | PRE-MINING | 1 | 01-Jan-91 | 31-Dec-92 | 731 | 0 | | | | | |
| Transient Calibration | HISTORIC | 2 | 1/01/1993 | 11/07/1993 | 192 | 732 | | | | modelled as constant | modelled as constant |
| | HISTORIC | 3 | 12/07/1993 | 13/12/1993 | 155 | 924 | | | 501 | Turn off DRN | Turn off DRN |
| | HISTORIC | 4 | 14/12/1993 | 18/05/1994 | 156 | 1079 | | | 502 | | |
| | HISTORIC | 5 | 19/05/1994 | 28/09/1994 | 133 | 1235 | | | 503 | | |
| | HISTORIC | 6 | 29/09/1994 | 6/02/1995 | 131 | 1368 | | | 504 | 1190 | |
| | HISTORIC | 7 | 7/02/1995 | 19/06/1995 | 133 | 1499 | | | 505 | | |
| | HISTORIC | 8 | 20/06/1995 | 26/11/1995 | 160 | 1632 | | | 506 | | |
| | HISTORIC | 9 | 27/11/1995 | 16/08/1996 | 264 | 1792 | | | 507 | | |
| | HISTORIC | 10 | 17/08/1996 | 25/05/1997 | 282 | 2056 | | | 508 | | |
| | HISTORIC | 11 | 26/05/1997 | 31/12/1997 | 220 | 2338 | | | 509 | | |
| | HISTORIC | 12 | 1/01/1998 | 31/12/1998 | 365 | 2558 | | | No LW | | |
| | HISTORIC | 13 | 1/01/1999 | 31/12/1999 | 365 | 2923 | | | No LW | | |
| | HISTORIC | 14 | 1/01/2000 | 31/12/2000 | 366 | 3288 | | | No LW | | |
| | HISTORIC | 15 | 1/01/2001 | 31/12/2001 | 365 | 3654 | | | No LW | | |
| | HISTORIC | 16 | 1/01/2002 | 31/12/2002 | 365 | 4019 | | | No LW | | |
| | HISTORIC | 17 | 1/01/2003 | 31/12/2003 | 365 | 4384 | | | No LW | | |
| | HISTORIC | 18 | 1/01/2004 | 31/12/2004 | 366 | 4749 | | | No LW | | |
| | HISTORIC | 19 | 1/01/2005 | 31/12/2005 | 365 | 5115 | | | No LW | | |
| | HISTORIC | 20 | 1/01/2006 | 31/12/2006 | 365 | 5480 | | | No LW | | |
| | HISTORIC | 21 | 1/01/2007 | 31/12/2007 | 365 | 5845 | | | No LW | | |
| | HISTORIC | 22 | 1/01/2008 | 31/12/2008 | 366 | 6210 | | | No LW | | |
| | HISTORIC | 23 | 1/01/2009 | 31/12/2009 | 365 | 6576 | | | No LW | | |
| | HISTORIC | 24 | 1/01/2010 | 31/12/2010 | 365 | 6941 | | | No LW | | |
| | HISTORIC | 25 | 1/01/2011 | 31/03/2011 | 90 | 7306 | Mains | | Turn off DRN | | |
| | HISTORIC | 26 | 1/04/2011 | 30/06/2011 | 91 | 7396 | Mains | | | | |
| | HISTORIC | 27 | 1/07/2011 | 31/12/2011 | 184 | 7487 | MG4 | | | | |
| | HISTORIC | 28 | 1/01/2012 | 31/03/2012 | 91 | 7671 | TG4 | | | | |
| | HISTORIC | 29 | 1/04/2012 | 31/05/2012 | 61 | 7762 | TG5 | | | | |
| | HISTORIC | 30 | 1/06/2012 | 31/07/2012 | 61 | 7823 | | | | | |
| | HISTORIC | 31 | 1/08/2012 | 31/08/2012 | 31 | 7884 | | LW4 | | | |
| | HISTORIC | 32 | 1/09/2012 | 31/10/2012 | 61 | 7915 | | | | | |
| | HISTORIC | 33 | 1/11/2012 | 31/12/2012 | 61 | 7976 | | | | | |
| | HISTORIC | 34 | 1/01/2013 | 28/02/2013 | 59 | 8037 | | | | | |
| | HISTORIC | 35 | 1/03/2013 | 31/03/2013 | 31 | 8096 | | | | | |
| | HISTORIC | 36 | 1/04/2013 | 30/04/2013 | 30 | 8127 | | | | | |
| | HISTORIC | 37 | 1/05/2013 | 31/05/2013 | 31 | 8157 | | LW5 | | | |
| | HISTORIC | 38 | 1/06/2013 | 30/06/2013 | 30 | 8188 | | | | | |
| | HISTORIC | 39 | 1/07/2013 | 31/07/2013 | 31 | 8218 | | | | | |
| | HISTORIC | 40 | 1/08/2013 | 31/08/2013 | 31 | 8249 | TG6 | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | HISTORIC | 41 | 1/09/2013 | 30/09/2013 | 30 | 8280 | | |
| | HISTORIC | 42 | 1/10/2013 | 31/12/2013 | 92 | 8310 | | |
| | HISTORIC | 43 | 1/01/2014 | 31/03/2014 | 90 | 8402 | | |
| | HISTORIC | 44 | 1/04/2014 | 30/06/2014 | 91 | 8492 | | |
| | HISTORIC | 45 | 1/07/2014 | 30/09/2014 | 92 | 8583 | | |
| | HISTORIC | 46 | 1/10/2014 | 31/12/2014 | 92 | 8675 | | |
| | HISTORIC | 47 | 1/01/2015 | 31/03/2015 | 90 | 8767 | | |
| | HISTORIC | 48 | 1/04/2015 | 31/05/2015 | 61 | 8857 | | |
| Prediction | IMPACT | 49 | 1/06/2015 | 31/07/2015 | 61 | 8918 | | |
| | IMPACT | 50 | 1/08/2015 | 30/09/2015 | 61 | 8979 | | LW6 |
| | IMPACT | 51 | 1/10/2015 | 30/11/2015 | 61 | 9040 | TG7 | |
| | IMPACT | 52 | 1/12/2015 | 29/02/2016 | 91 | 9101 | Mains | |
| | IMPACT | 53 | 1/03/2016 | 30/06/2016 | 122 | 9192 | MG9 | LW7 |
| | IMPACT | 54 | 1/07/2016 | 31/10/2016 | 123 | 9314 | TG9 | |
| | IMPACT | 55 | 1/11/2016 | 31/12/2016 | 61 | 9437 | TG9 | |
| | IMPACT | 56 | 1/01/2017 | 28/02/2017 | 59 | 9498 | | LW9 |
| | IMPACT | 57 | 1/03/2017 | 31/05/2017 | 92 | 9557 | TG10 | |
| | IMPACT | 58 | 1/06/2017 | 14/07/2017 | 44 | 9649 | | |
| | IMPACT | 59 | 15/07/2017 | 31/08/2017 | 48 | 9693 | TG11 | LW10 |
| | IMPACT | 60 | 1/09/2017 | 31/10/2017 | 61 | 9741 | | |
| | IMPACT | 61 | 1/11/2017 | 14/01/2018 | 75 | 9802 | MG1 | LW11 |
| | IMPACT | 62 | 15/01/2018 | 31/03/2018 | 76 | 9877 | TG1 | |
| | IMPACT | 63 | 1/04/2018 | 30/06/2018 | 91 | 9953 | TG2 | LW1 |
| | IMPACT | 64 | 1/07/2018 | 31/10/2018 | 123 | 10044 | TG3 | LW2 |
| | IMPACT | 65 | 1/11/2018 | 28/02/2019 | 120 | 10167 | | LW3 |
| | RECOVERY | 66 | 1/03/2019 | 31/12/2019 | 306 | 10287 | **Turn off DRN** | **Turn off DRN** |
| | RECOVERY | 67 | 1/01/2020 | 31/12/2029 | 3653 | 10593 | | |
| | RECOVERY | 68 | 1/01/2030 | 31/12/2069 | 14610 | 14246 | | |
| | RECOVERY | 69 | 1/01/2070 | 31/12/2119 | 18261 | 28856 | | |
| | RECOVERY | 70 | 1/01/2120 | 31/12/2169 | 18263 | 47117 | | |
| | RECOVERY | 71 | 1/01/2170 | 31/12/2219 | 18261 | 65380 | | |
| | RECOVERY | 72 | 1/01/2220 | | | 83641 | | |

## 9.10 Model Implementation of Mine Schedule

The underground mining and dewatering activity is defined in the model using drain cells within mined coal seams, with modelled drain elevations set to 0.1m 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 and specific yields were increased to simulate the highly disturbed nature within the caved zone and overlying variable fracture zone. Within the Wongawilli Seam, Sy was increased on host values by a factor of 150 raising Sy to 20%. Within the Wongawilli – Balgownie Interburden, Sy was increased by a factor of 20 and the Balgownie by a factor of 10. Specific Storage (Ss) was increased by the same factors in the recovery model only.

### 9.11 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 1**.

Adjacent to the proposed workings are large areas of abandoned Bulli workings to the north and south of the Russell Vale 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 at Russell Vale West, where drain cell invert levels were raised slightly to mimic reported ponding 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 not known 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 BHPB Appin workings. Additionally, active mining is occurring within the Wongawilli seam at Dendrobium at the southern boundary of the model area.

#### 9.11.1 Height of Fracturing and Associated Zone of Depressurisation

The hydraulic characteristics of the Bulli Seam and overlying or adjacent strata to the extracted Bulli, Balgownie and Wongawilli Seam 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 hillslope basal shear plane/s that may be present due to lateral shearing associated with hillslope 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. Ongoing piezometric monitoring will be used to establish the height of depressurisation when all three seams have been mined.

To date, multi-seam height of depressurisation assessment is possible at GW1 and RV20. GW1 is not located over the centre of a Wongawilli Seam longwall, however as it is located within the confines of the main gate and tailgate of Longwall 4, proximity mining activities makes this a valuable tool in understanding related impacts. Although GW1 was not installed until after Longwall 4 was completed, it captured the response to stresses imposed by Longwall 5. Ongoing in-situ field assessment in RV20 has been used to determine the height of depressurisation above the southern end of Longwall 4 where three seams have been mined.

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 Russell Vale East (SCT Operations, 2014).

In the groundwater model, it was assumed that enhanced hydraulic conductivity after extraction of the proposed longwalls could enable free drainage within the goaf and overlying fractured strata, with vertical connective fracturing up 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.

The partial “depressurisation” zone generally extends higher up into the subsided strata than the “fractured”, vertically connected, enhanced hydraulic conductivity zone.

Due to limitations of the setup, capability and 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.

## 9.12 Model Calibration

Model calibration involves comparing predicted and observed data and making modifications to model input parameters, where required, within reasonable limits defined by available data and specialist 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 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 have been observed.

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 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 Russell Vale West area and more recently in the Wongawilli Seam at Russell Vale East.

Transient calibration was to a degree restricted by the lack of monitoring locations within the Permian groundwater system, although sufficient locations were available for a reasonable calibration. 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.

### 9.12.1 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 open standpipes and multi-level vibrating wire piezometers were used for steady state calibration.

A total of 64 monitored horizons from 32 monitoring locations provided a total of 832 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 data available from beneath the Scarborough Sandstone.

Transient groundwater levels were taken from records at each borehole where data was available. A full list of the calibration targets, including the monitored layers and a comparison of actual versus modelled groundwater heads is included in **Appendix C**.

Groundwater inflows to active mining areas provide a valuable calibration measure and are critical for achieving a robust calibration.

Water balance records and, particularly mine inflow records for the Russell Vale Mine lease and other adjacent mining operations, were initially not well recorded.

Considerable effort has recently been undertaken by Wollongong Coal and SCT Operations to better understand water balance variables from available data from which a review of inflows led to revised groundwater make estimates, which were used in the calibration process.

#### 9.12.2 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 as 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, this was the best achievable option with the available monitoring data.

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 sufficient 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 4** shows that this year had a stable climate and preceded a period of drought.

In the Russell Vale East area, transient mining stresses have not occurred since completion of the Balgownie Seam extraction in the 1980s, and hence groundwater levels were assumed to have reached a relatively stable position, particularly within the shallower stratigraphy where most of the monitoring network is screened.

The pre-mining water levels in all piezometers 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.

### 9.12.3 Transient Calibration

Transient calibration against groundwater levels was carried out for the period 1993 to 2013 inclusive, utilising water head or level data from 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 lease area from 1998 to 2010, it covers two periods where groundwater hydrographs show a response to mining influences.

Following completion of mining in the 500 series longwall panels, apart from some limited areas of pillar extraction, no longwall mining was undertaken within the Russell Vale West area.

Mining was re-started at Russell Vale East with development of first workings in the Wongawilli Seam in 2011, followed by non-continuous extraction of Longwalls 4, 5 and Longwall 6 (340m) after April 2012.

The RMS value for the calibration period is 8.0m, whilst scaled root mean square (SRMS) error is 3.1%, which is within the target range of 5%.

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).

A diagram of measured versus modelled potentiometric head targets is shown in **Figure 29**, 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 a number of reasons.

These include what appears to be a delayed equilibration of vibrating wire transducers and the fact that the multilevel VWP network has doubled within the past 12 months and as a result, a short extent of data was used within the calibration data set which could be adjusted when a longer monitoring record is available. This is, however, the key area where the model has failed to simulate observed groundwater pressures and there is, accordingly, a groundwater pressure separation between the Lower Bulgo Sandstone and the Scarborough Sandstone data.

**Figure 29** illustrates both of the considerations posed above. That being, the failure to accurately simulate indicated groundwater pressures within the Stanwell Park Claystone, which in areas maintains pressures very close to, if not higher than, the Lower Bulgo Sandstone, and the complexity of the groundwater pressure response to mining activities.

In the case of GW1, the response in the Bulgo Sandstone and Stanwell Park Claystone as LW4 approached its closest point to GW1 is interpreted to be the effect of transient storage changes occurring during changing tensional and compressional stress regimes as shown in **Figure 30**.

The model has been unable to simulate these physical changes and the result is variability in observed pressures and lack of variability within the computed heads, resulting in ‘flat lining’ of heads within the observed vs. computed calibration values shown.

Quantitatively, curve matching in GW1 detracts from the calibration statistics to some degree, yet, qualitatively, the results reasonably reflect the groundwater response, with the exception of the pressures occurring in the Stanwell Park Claystone.

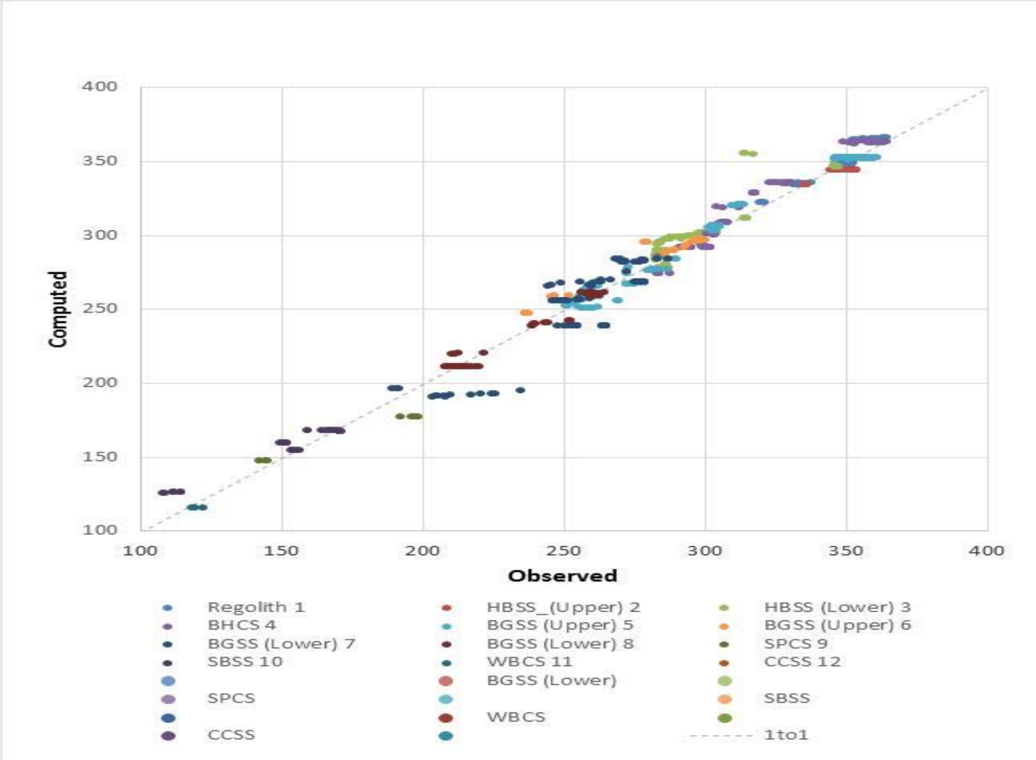



**Figure 29 Measured Vs Modelled Potentiometric Head Targets**

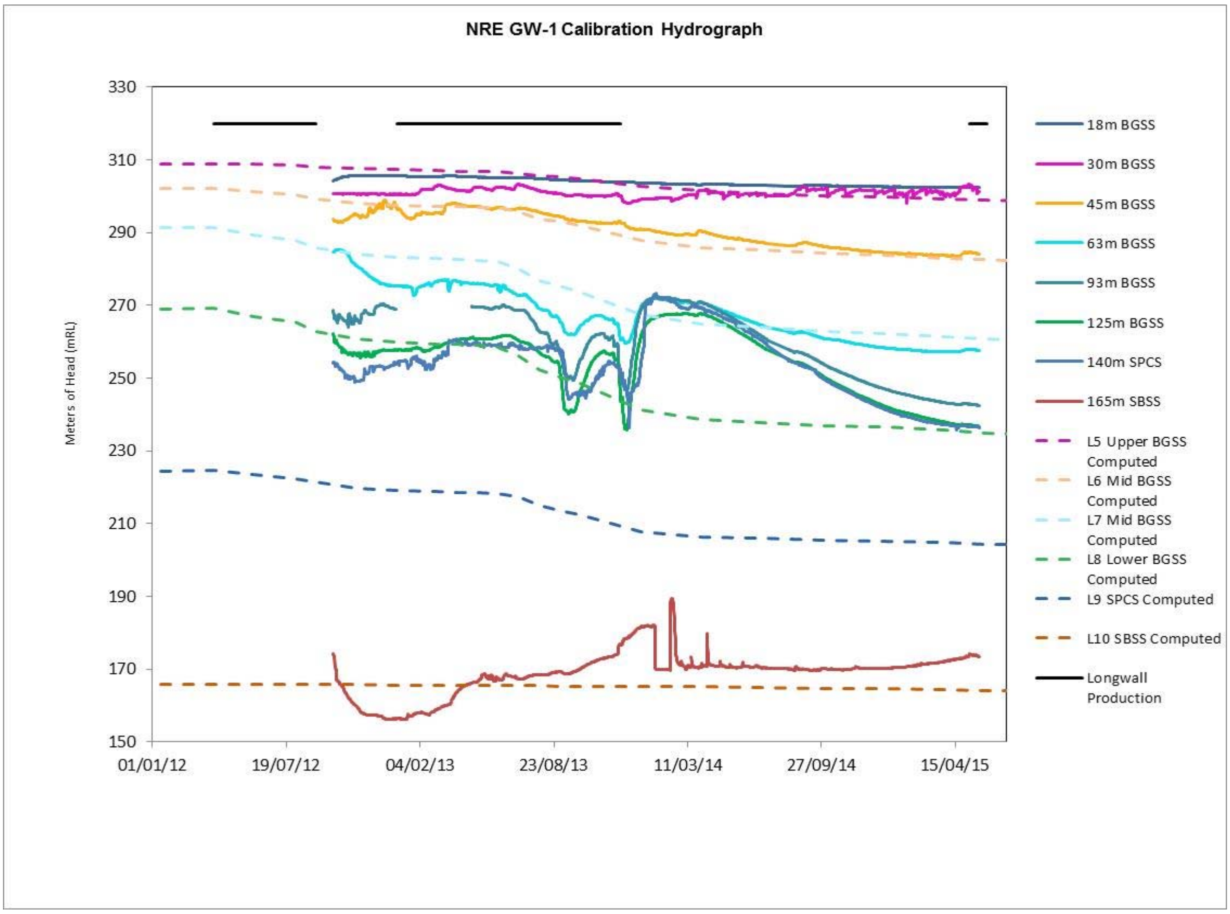



**Figure 30 Observed vs. Computed Groundwater Levels for NRE GW1**

### 9.13 Fracture and Depressurisation Zone Implementation

In previous groundwater model set ups, GeoTerra / GES (2014) utilised an analytical method (i.e. modified Tammetta equation) that is based on single seam extraction to provide a starting point for designing the height of potential depressurisation.

Ditton (2012) also developed a theoretical, single seam extraction, strata depressurisation assessment method, which expanded on the empirical database of observed heights of fracturing in Australian coalfields developed for ACARP (2003).

The Ditton (2012) method utilises a regression analysis to develop an analytical height of fracturing model to describe the height of connective cracking (A Zone) and disconnected cracking (B Zone) under a range of panel width (W), overburden height (H) and geological strata properties. The Ditton (2012) equations provide mean and 95% confidence limits of estimated height of fracturing for both the ‘A’ and ‘B’ zones.

Although these two methods were considered in the conceptual assessment, they were not used in the groundwater model set up as their predicted heights of depressurisation did not correlate to data from VWPs within the Russell Vale East double and triple seam mined areas.

In the current groundwater model set up, the fracture zone design and implementation within the triple seam mined, Russell Vale project area, focussed in the calibration process on matching heads to key piezometer data, primarily from GW1 and RV20. The approach utilised an empirical log-linear ramp function for the simulated height of fracturing in order to calibrate the observed vertical hydraulic head profiles. This was manually adjusted in order to match data from GW1 and RV20. 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 allowed primary mined coal seams to be represented individually and for the overburden to be subdivided into multiple layers. This allowed 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 could be adequately represented.

The fractured zone was simulated with horizontal hydraulic conductivity enhanced by a factor of two within all fractured zone components, and with vertical hydraulic conductivity enhanced by a function which varied the vertical hydraulic conductivity field within the deformation zone overlying extraction areas and “weighted” the permeability changes based on layer thickness. In the caved and mined zones, horizontal hydraulic conductivity was set to 10 m/day.

The height of the caved zone was assumed to be 5 times the mined seam thickness, although this was increased where zones of multi-seam mining occurred and where caved zone parameters were extended to the Bulli Seam, which limited an increase in Sy into the Balgownie Seam only.

For fractured zones, the strata hydraulic parameters were changed using the Time-Varying Material Properties (TMP) package of MODFLOW-SURFACT, which allows varying property values to be applied over time.

Fracturing was instigated by altering host rock calibrated hydraulic properties in accordance with mine progression.

Layer resolution within the model allowed the mined Wongawilli Seam to be represented in Layer 17, with the other layers above it available to simulate the collapsed or caved zone and connected and disconnected fractured zones to specific heights. This ensured that the impact of progressive caving and fracturing associated with mining was adequately represented in the model.

Vertical hydraulic conductivity was set to 1 m/day within the mined and caved zones.

The vertical hydraulic conductivity in the fractured zone was enhanced according to a log-linear monotonic (ramp) function which varied the vertical hydraulic conductivity field within the deformation zone overlying mining areas and weighted the hydraulic conductivity changes on layer thickness. However, a departure from the ramp function was used to calibrate the observed pressure variations in RV20 and GW1. Limits for the variability were governed by fracture height and assigned upper and lower bounds on hydraulic conductivity in the fractured zone. Assigned fractured zone properties are presented in **Table 5**.

The vertical hydraulic conductivity of the model strata directly beneath underground mined areas was also increased with a uniform increase in vertical hydraulic conductivity of 100 times the host values being applied. Similarly, horizontal hydraulic conductivity of the underlying layer was increased by a factor of 2 times the host (pre-mine calibrated) values.

Specific yields (Sy) were increased to simulate the highly disturbed nature within the caved zone and overlying variable fracture zone. Specific yield (Sy) was also increased in the Wongawilli Seam to 20% in the footprint of the Wongawilli Seam longwalls, which represents the increased storage occurring in the caved zone as overburden collapses. Above the mined coal seam Sy was increased, along with an increase in porosity to 10%. Within the Wongawilli – Balgownie Interburden, Sy was increased to 10% and the Balgownie to 5%.

Specific Storage (Ss) was increased by the same factors in the mined seam and within the overlying caved zone by applying an increase in the rock porosity component of the Ss parameter, in the same degree as for Sy.

#### 9.13.1 Calibrated Hydraulic Properties

**Table 5** summarises the calibrated hydraulic properties of the modelled layers and **Figure 31** shows a schematic of the stratigraphic profile of the vertical hydraulic conductivity of host vs. fractured zone showing the higher relative increase of vertical hydraulic conductivity (Kv) in the lower strata above mining levels.

It also shows the heights of predicted connective cracking / height of depressurisation of the two analytical methods discussed earlier.

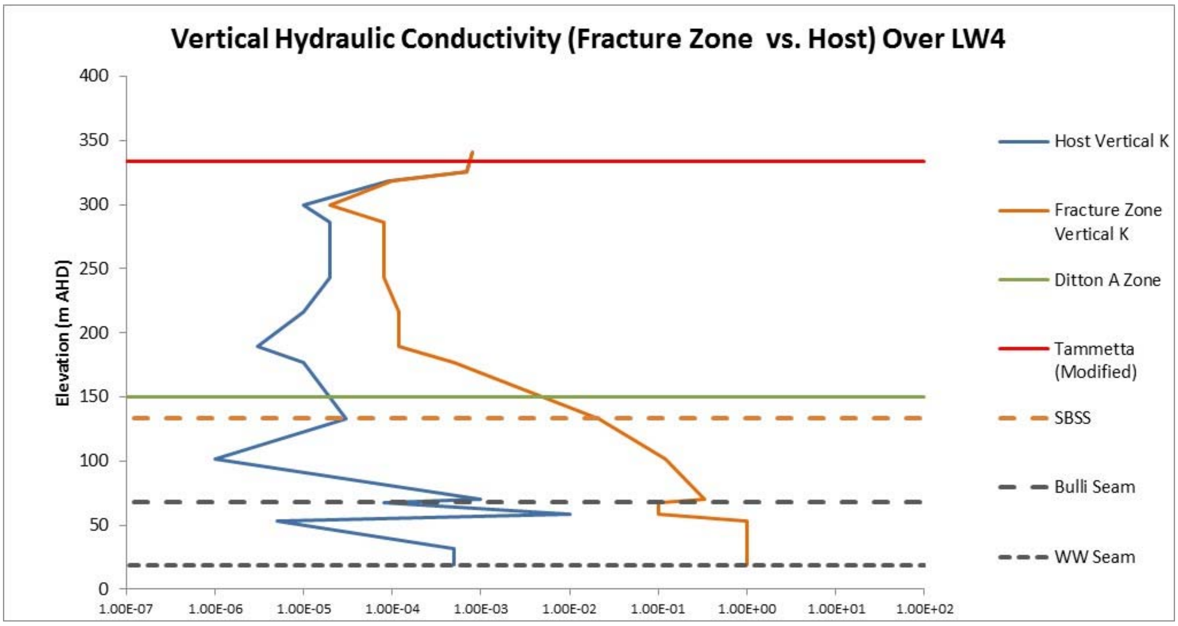



**Figure 31 Fracture Zone Vertical K vs. Host Kv**

**Table 5 Calibrated Hydraulic Properties**

| Layer | Stratigraphic Unit | Host (kx) | Ss [1/m] | Sy | Host (Kz) | Fracture Zone Wonga West (Kz) | Fracture Zone Russell Vale East Historic Workings Bulli Seam (Kz) | Fracture Zone Wongawilli Longwalls (Kz) |
|---|---|---|---|---|---|---|---|---|
| 1 | Upper Hawkesbury Sandstone | 3.00E-02 | 4.00E-04 | 1.00E-02 | 1.62E-02 | | | |
| 1 | Layer 1 (Coastal Plain) | 3.03E-01 | 8.00E-04 | 1.50E-01 | 9.58E-02 | | | |
| 2 | Mid Hawkesbury Sandstone | 5.00E-04 | 6.00E-06 | 1.10E-01 | 1.00E-05 | | | |
| 3 | Lower Hawkesbury Sandstone | 5.55E-04 | 6.00E-06 | 1.10E-01 | 9.00E-05 | | | 6.00E-04 |
| 4 | Bald Hill Claystone | 2.00E-05 | 6.00E-06 | 1.10E-01 | 9.88E-06 | | | 6.00E-05 |
| 5 | Mid Upper Bulgo Sandstone | 6.00E-04 | 6.00E-06 | 1.10E-01 | 2.00E-05 | | | 2.00E-04 |
| 6 | Mid Lower Bulgo Sandstone | 5.00E-04 | 6.00E-06 | 1.10E-01 | 2.00E-05 | | | 2.00E-04 |
| 7 | Lower Bulgo Sandstone | 9.00E-04 | 6.00E-06 | 1.10E-01 | 1.00E-05 | | | 2.00E-04 |
| 8 | Lower Bulgo Sandstone | 6.00E-06 | 6.00E-06 | 1.10E-01 | 1.00E-05 | | | 2.00E-04 |
| 9 | Stanwell Park Claystone | 7.00E-06 | 6.00E-06 | 1.10E-01 | 3.00E-06 | | | 5.00E-04 |
| 10 | Scarborough Sandstone | 7.00E-06 | 6.00E-06 | 1.10E-01 | 1.00E-05 | | | 2.16E-02 |
| 11 | Wombarra Claystone | 6.00E-06 | 6.00E-06 | 1.00E-02 | 3.00E-05 | 7.00E-04 | 2.00E-05 | 1.19E-01 |
| 12 | Coal Cliff Sandstone | 6.92E-06 | 2.50E-06 | 6.00E-03 | 1.00E-06 | 3.96E-04 | 3.00E-05 | 3.32E-01 |
| 13 | Bulli Seam | 9.50E-03 | 5.00E-06 | 2.00E-03 | 1.00E-03 | 1.00E-01 | 1.00E-03 | 1.00E-01 |
| 14 | Interburden | 2.10E-04 | 4.00E-06 | 8.00E-03 | 8.00E-05 | | | 1.00E-01 |
| 15 | Balgownie Seam | 1.20E-02 | 7.00E-06 | 3.00E-03 | 1.00E-02 | | | 1.00E+00 |
| 16 | Interburden | 8.20E-08 | 4.00E-06 | 5.00E-03 | 5.00E-06 | | | 1.00E+00 |
| 17 | Wongawilli Seam | 3.00E-02 | 4.00E-06 | 5.00E-03 | 5.00E-03 | | | 1.00E+00 |
| 18 | Kembla Sandstone | 5.00E-05 | 2.50E-06 | 5.00E-03 | 5.00E-06 | | | |
| | Basement | 5.32E-06 | 1.00E-06 | 1.00E-02 | 1.09E-06 | | | |

## 9.14 Mine Inflows

Based on available mine water balance records, the average daily groundwater inflow derived from strata leakage extracted from Russell Vale Colliery was 0.5 ML/day prior to extraction of LW4 and 1.5 – 2 ML/day during extraction of extraction of LW4 and LW5 as shown in **Figure 32**.

Records for mine inflows prior to the extraction of LW4 are considered to be uncertain and the lack of any reported inflow during the development stage is also considered to be implausible, however more accurate mine water pumping records have been obtained since the start of LW4.

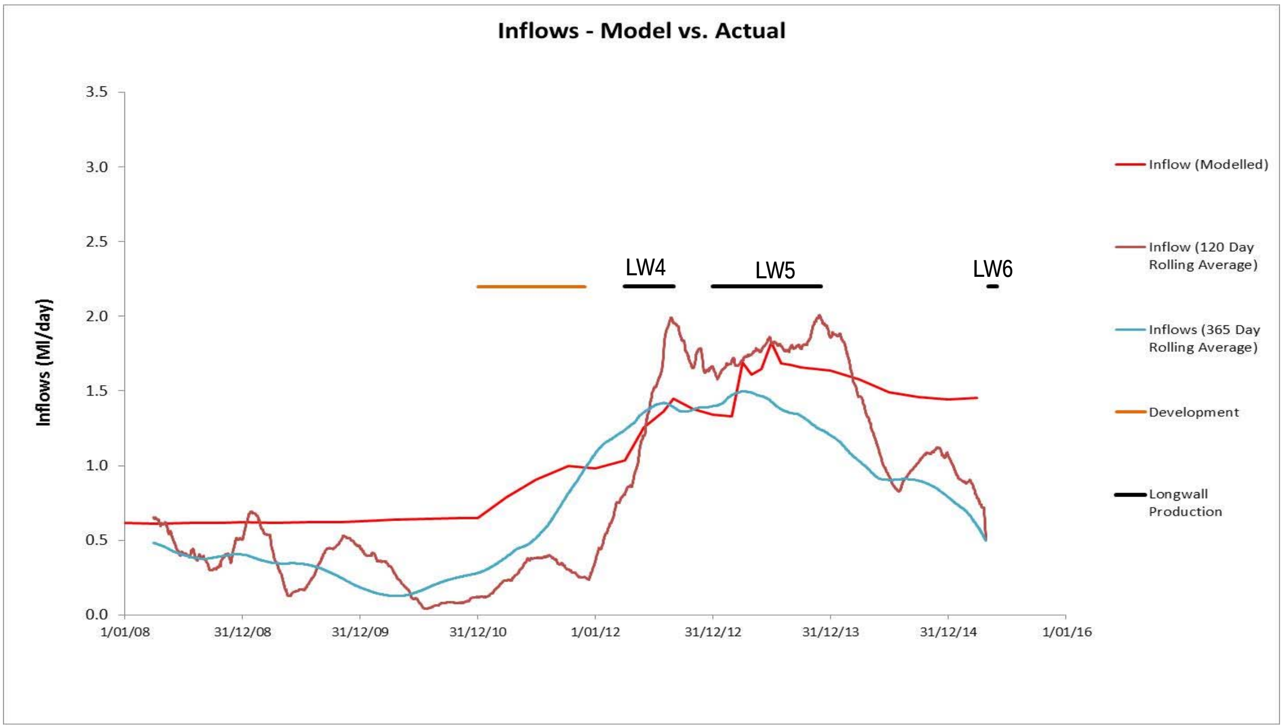



**Figure 32 Mine Inflows During the Calibration Period**

## 9.15 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 (as general heads in MODFLOW), and;
- water inflows to active mining areas and the sinks caused by historical mining areas.

The average water balance over 26 stress periods from 1991 to 2015 in the transient model run up until the end of the calibration period across the entire model area is summarised in **Table 6**, and includes continued mining in Russell Vale West.

The total inflow (recharge) to the aquifer system into the model domain is approximately 82ML/day, comprising rainfall recharge (approximately 71%), inflow from the head dependent boundaries on the margins (approximately 0.5%) and leakage from streams into the aquifer (approximately 22%).

The remaining 6% is accounted for with changes in storage within the overburden strata.

**Table 6 Simulated Water Balance at End of Transient Calibration**

| | Inflow (ML/d) | Outflow (ML/d) |
|---|---|---|
| **Storage** | 5.24 | 10.32 |
| **Constant Head** | 0.7 | 0.01 |
| **Drains (Outflow = Groundwater Entering Mine Workings)** | 0 | 2.57 |
| **Recharge (Direct Rainfall)** | 62.19 | 1.63 |
| **Et (Evapotranspiration)** | 0 | 58.07 |
| **River (Leakage/Baseflow)** | 18.9 | 14.43 |
| **Head Dependent Boundary (GHB)** | 0.24 | 0.27 |
| **Total** | 87.27 | 87.3 |
| **% Discrepancy** | -0.03% | |

### 9.16 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 Russell Vale lease area, these structures are not simulated in the model.

Observations of intersections of the Corrimal Fault and Dyke D8 within the three levels of extraction have not encountered any observable water make in the workings (SCT Operations, 2015).

As a result, and as outlined in SCT Operations (2015), neither the Corrimal Fault or Dyke D8 are assessed as being able to provide a credible risk of enablng hydraulic connection between Cataract Reservoir and the underground mine workings.

# 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 Russell Vale lease area.

The presence of alluvial sediments is limited to the upland swamps, which have been measured up to 1.8m 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 MODFLOW SURFACT and the regional scale model set up, the effect of subsidence on the thin (<2m) perched groundwater in upland swamps (within the 20m thick Layer 1) with their limited and variable spatial extent, was not assessed in the simulation. It was observed that Layer 1 could go dry in some areas.

Further discussion of the potential effects on swamps is contained in Biosis (2014).

## 10.3 Basement Groundwater Levels

**Figures 33** to **38** show north - south and east – west cross sections of the overall modelled hydraulic head (m) and groundwater levels 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 Russell Vale East.

**Figures 33** and **34** 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.

**Figures 35** and **36** 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 Sandstone is also evident.

**Figures 37** and **38** show these cross sections following completion of mining in the Wongawilli Seam where the fracture zone has fully developed and caused a further vertical propagation of the zero pressure contour. However, it has not broken through to surface.

Within the process of groundwater system recovery, the adits within the Illawarra Escarpment will spill well before full recovery of the groundwater system and adit sealing will be ineffective as the low lithostatic head pressure in the strata due to the low depth of cover on the escarpment will not be able to hold the water pressure (SCT Operations, 2015B). The lowest adit RL is at 117mAHD and that elevation is not reached within the 200 years of modelled recovery.

As a result, recovery of groundwater up to the adit RL is it is not modelled or anticipated to occur.

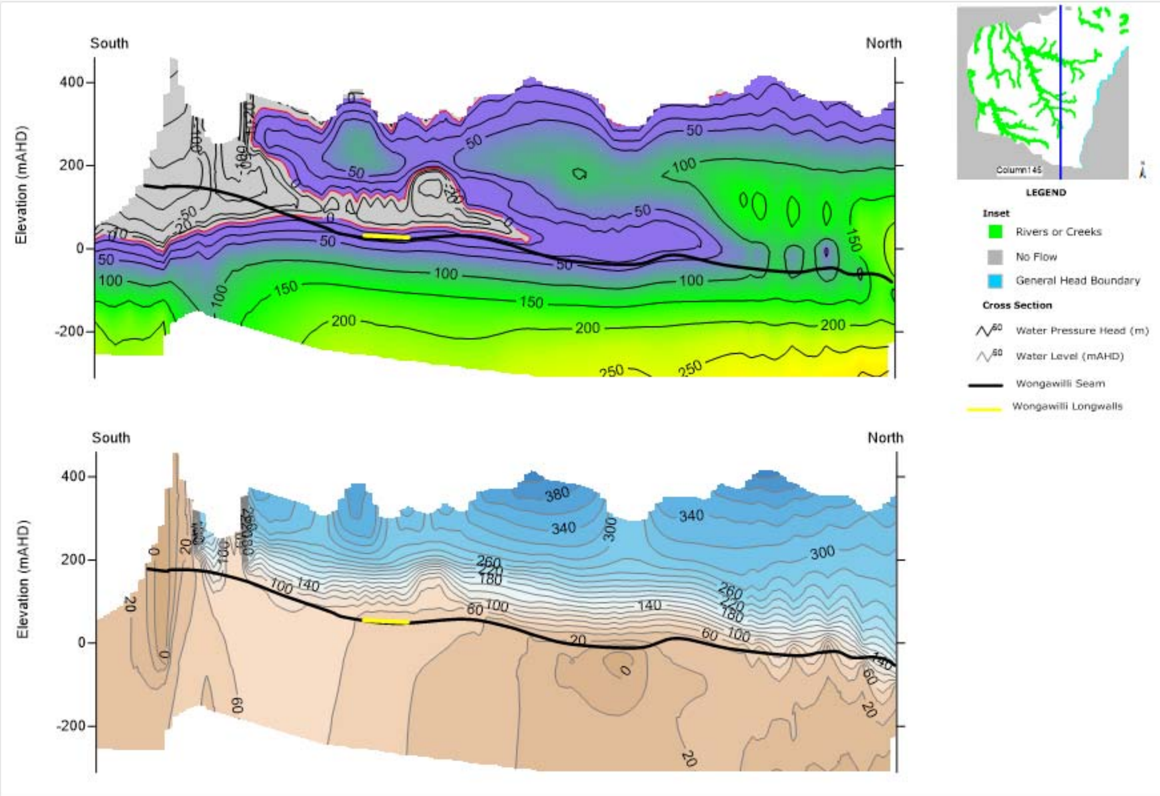



Figure 33 Predicted Pressure Head and Potentiometric Head Initial Conditions at Russell Vale East (North – South Cross Section on Easting 303000)

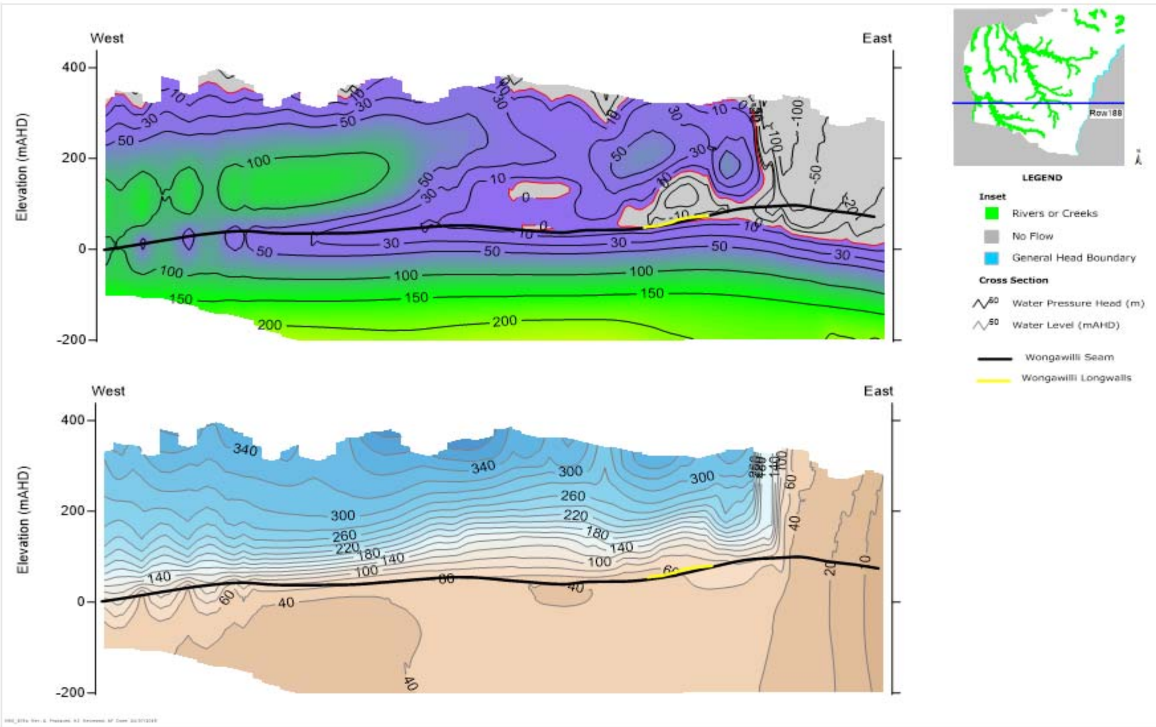



Figure 34 Predicted Pressure Head and Potentiometric Head Initial Conditions at Russell Vale East (East – West Cross Section on Northing 6196895)

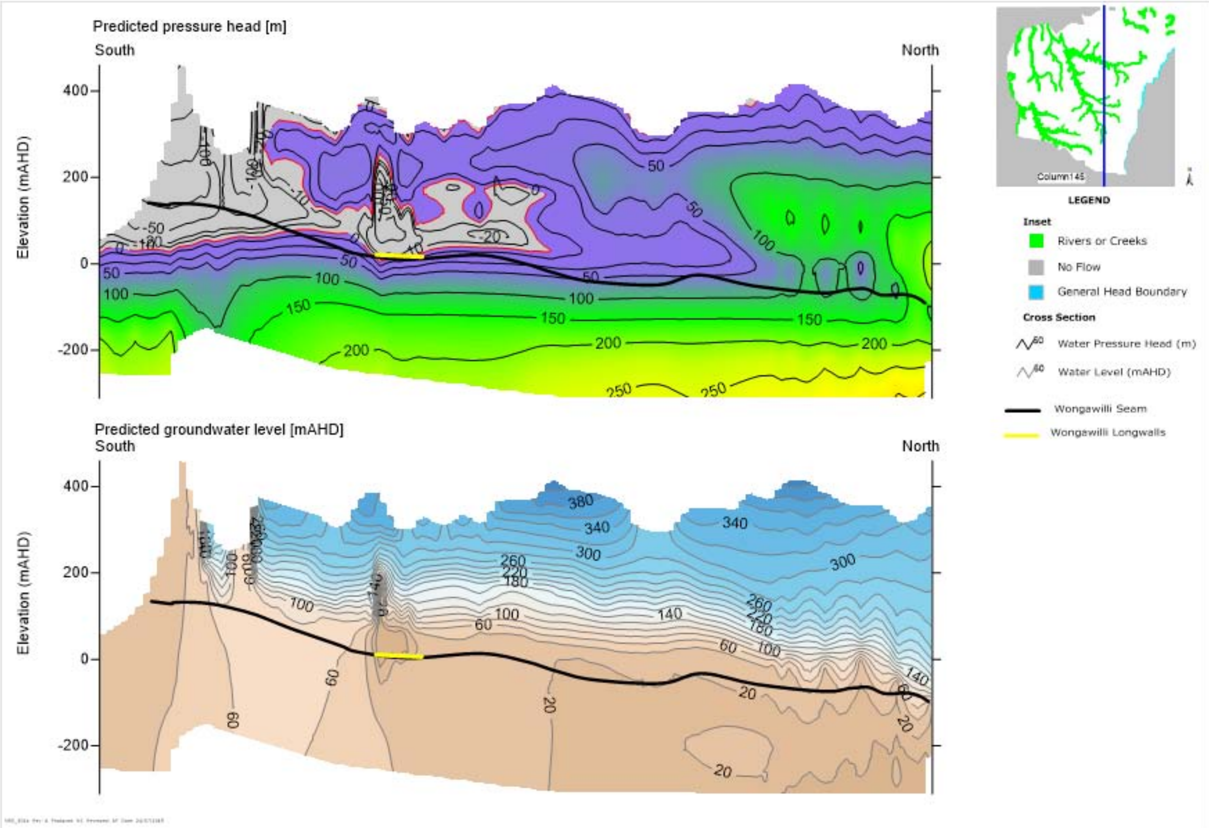



**Figure 35 Predicted Pressure Head and Potentiometric Head at Russell Vale East at the End of LW5 (North – South Cross Section on Easting 303000)**

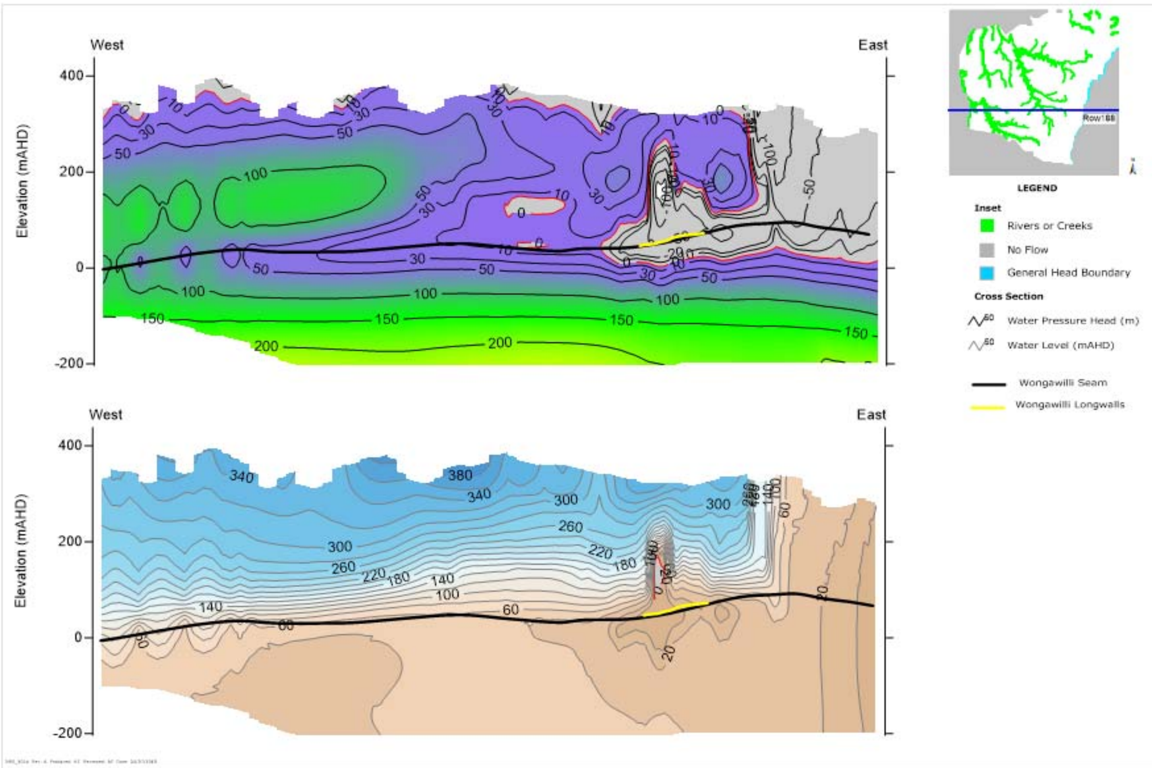



**Figure 36 Predicted Depressurisation at Wonga at the End of LW5 (East – West Cross Section on Northing 6196895)**

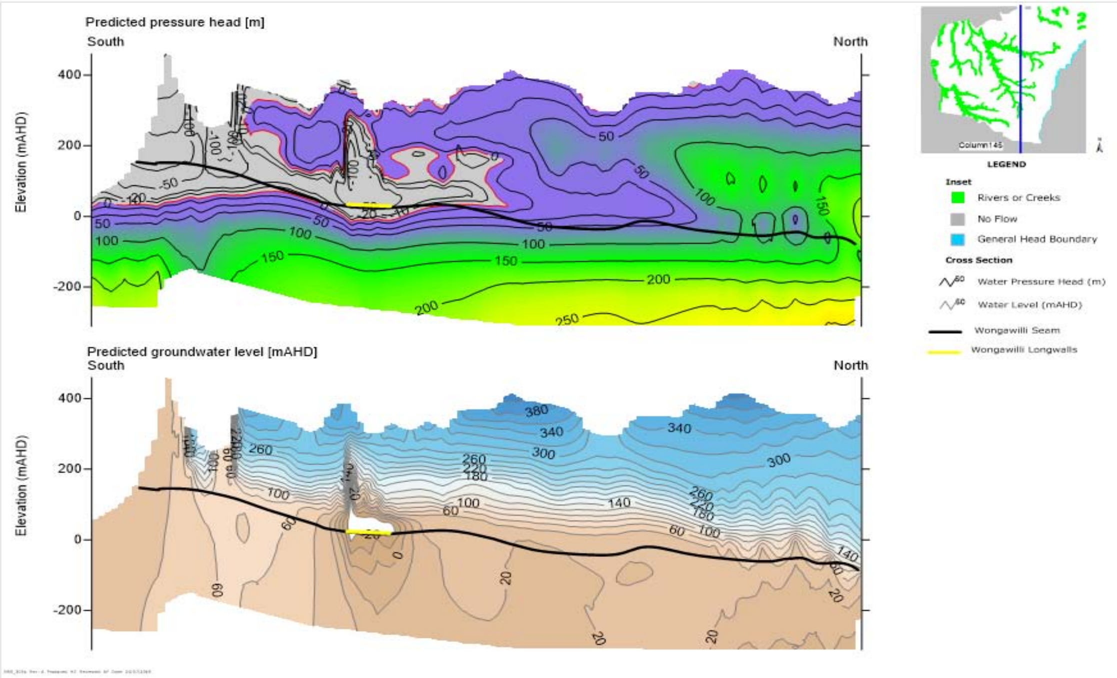



**Figure 37 Predicted Depressurisation at Russell Vale East at the End of Mining (North – South Cross Section on Easting 303000)**

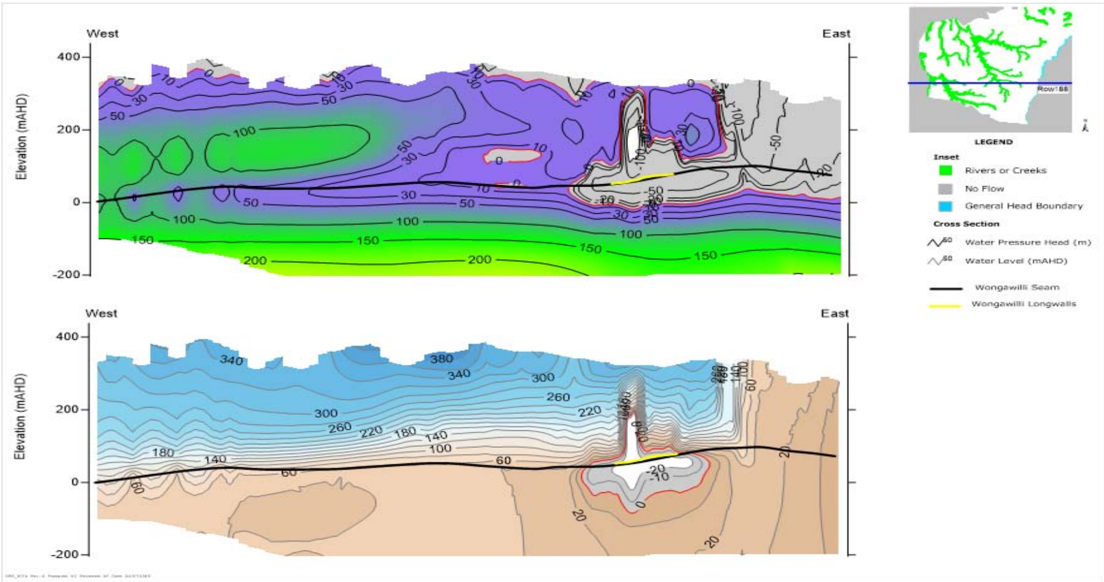



**Figure 38 Predicted Depressurisation at Russell Vale East at the End of Mining (East – West Cross Section on Northing 6196895)**

### 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 desiccate 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 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 / Regolith

The upper Hawkesbury Sandstone aquifer extends across the Study Area, with piezometer data indicating phreatic water levels ranging from 1 – 20m below surface within Russell Vale 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 at Russell Vale East.

After a piezometer is installed, the subsequent water level measurements indicate a combination of head pressure in the aquifer, variability of recharge and other associated 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 a water level reduction of up to 25m, with subsequent recovery by up to 31m due to the intermittent stop /start method by which Longwall 5 was mined.

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 (including the Hawkesbury Sandstone, Newport / Garie Formation, Bald Hill Claystone and upper Bulgo Sandstone in eroded creek bed locations) after the end of mining in Russell Vale East indicates up to 10m of drawdown as shown in **Figure 39** in comparison to pre Wongawilli Seam development.

**Figure 40** shows drawdown after mining is completed in comparison to post LW5 groundwater levels.

As shown in **Figures 41** and **42,** which represent 100 and 200 years respectively after mining, groundwater levels have continued to fall post-mining. However there is some recovery evident over LW4 through to LW10 with water levels recovering from a maximum of 10m drawdown to 5m after 100 years.

Drawdown over LWs 1-3 remains at approximately 50m at 50 years after mining. This is beyond the model layer with drawdown projected into deeper model layers. The plot shows drawdown in excess of the base of the model layer and therefore, in locations where water levels are below the base, the layer is dry in that location and the water levels shown reflect the next saturated active layer.

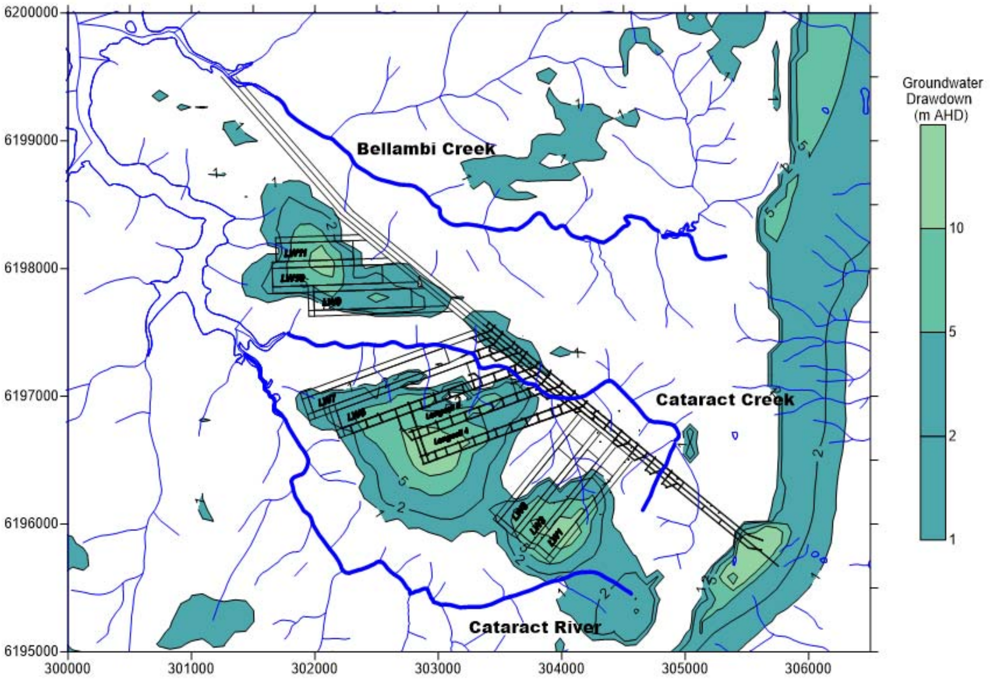



**Figure 39** Layer 1 Drawdown after Mining at Russell Vale East Relative to the Start of Mining in Wongawilli Seam.

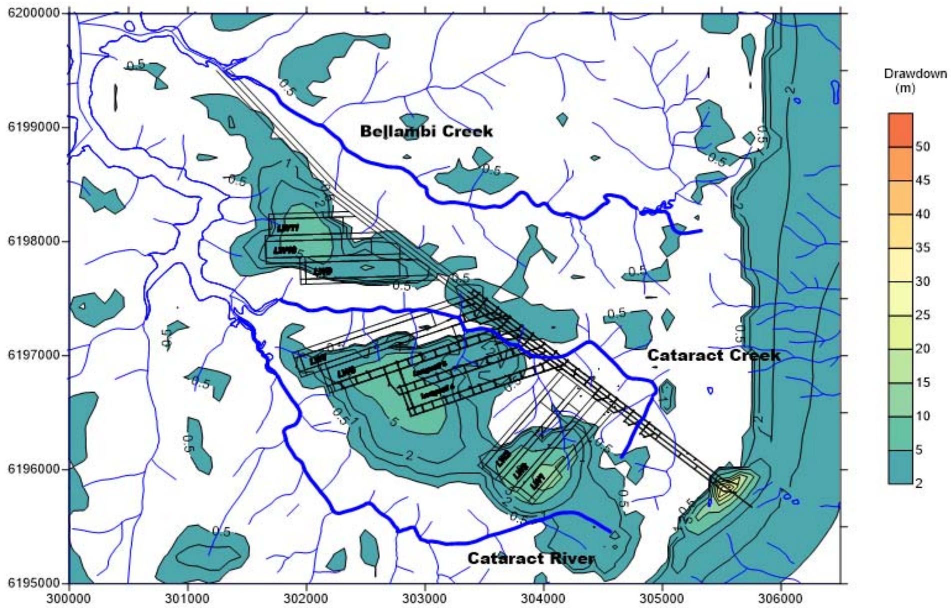



**Figure 40** Layer 1 Drawdown after Mining Longwalls 4 and 5 at Russell Vale East Relative to End of LW5

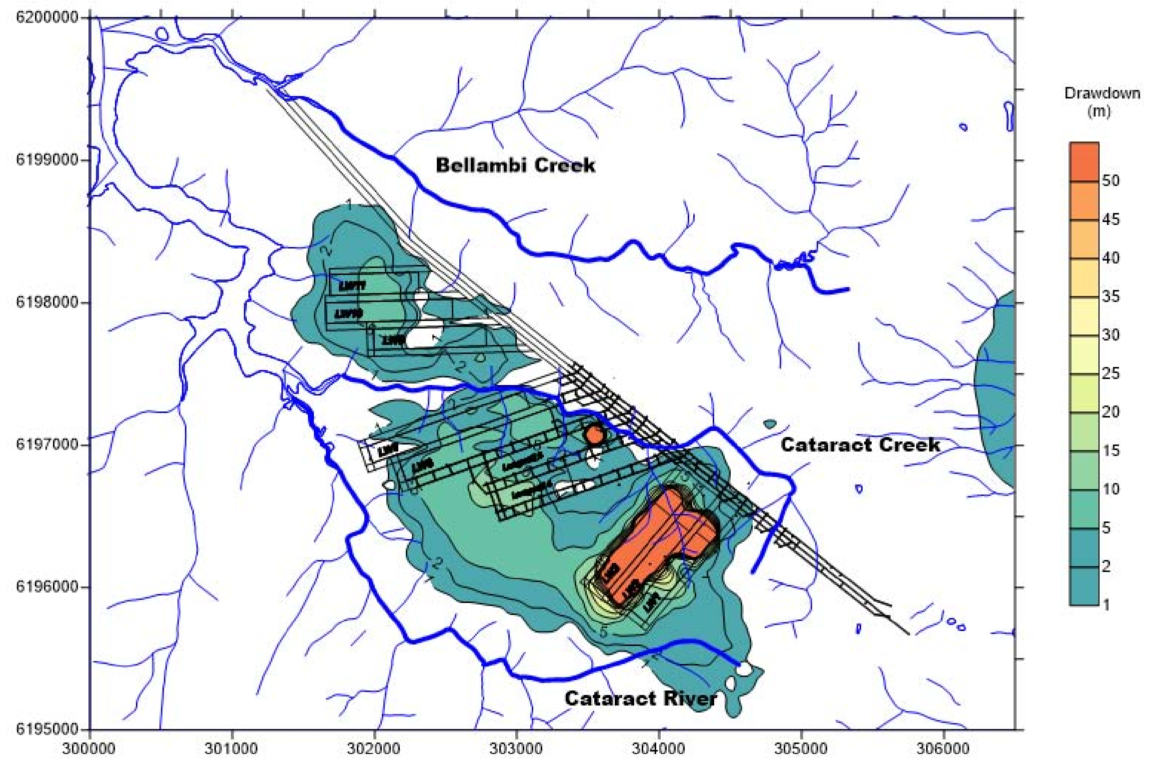



**Figure 41** Layer 1 Recovery 100 Years After Mining at Russell Vale East

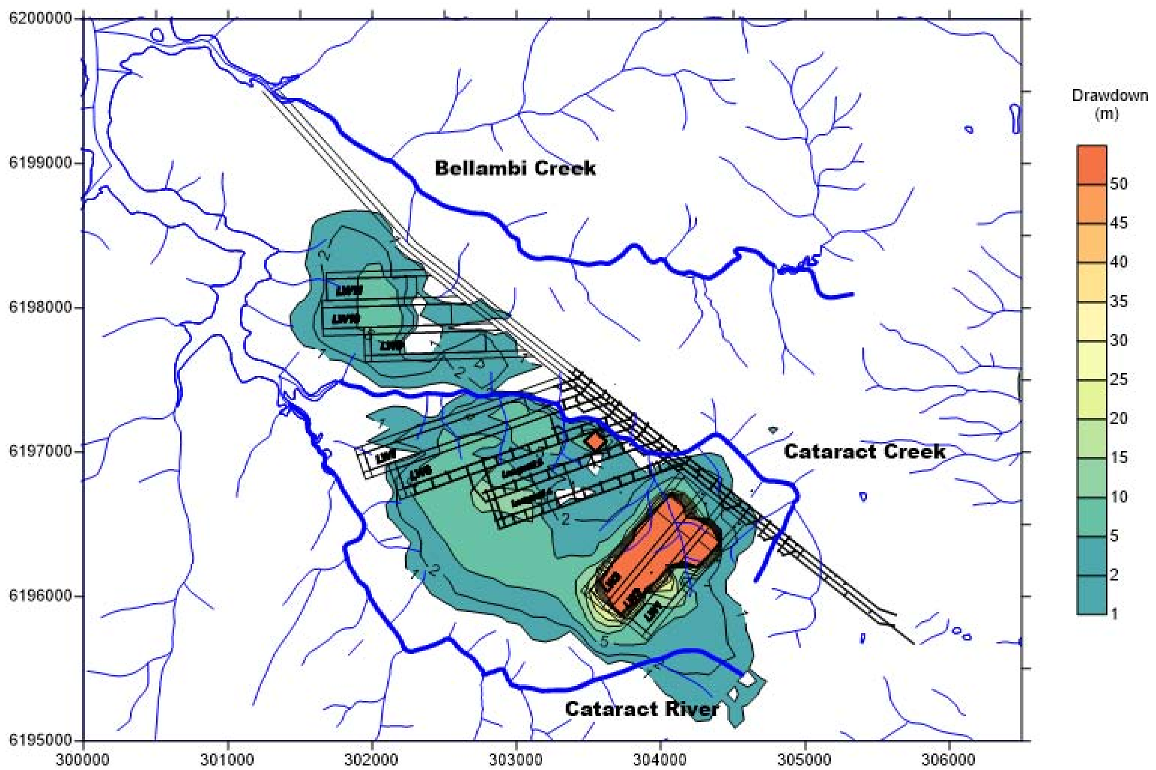



**Figure 42** Layer 1 Recovery 200 Years After Mining at Russell Vale East

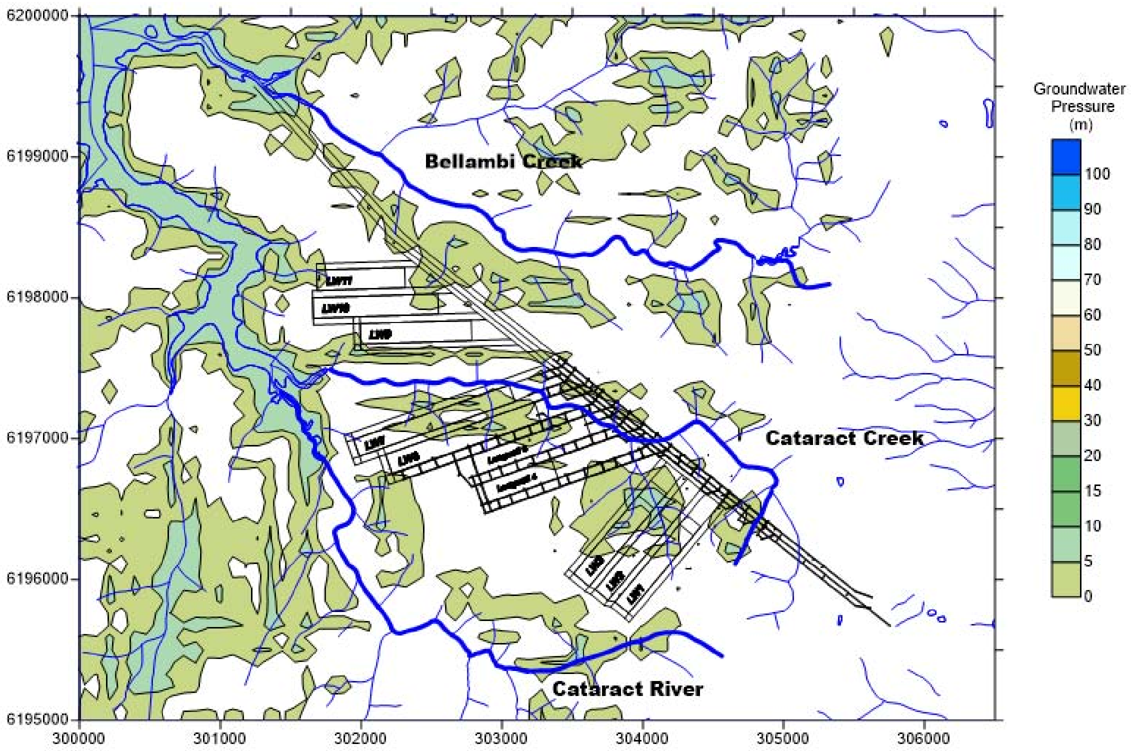



**Figure 43 Layer 1 Groundwater Pressure before the Start of Mining in Wongawilli Seam**

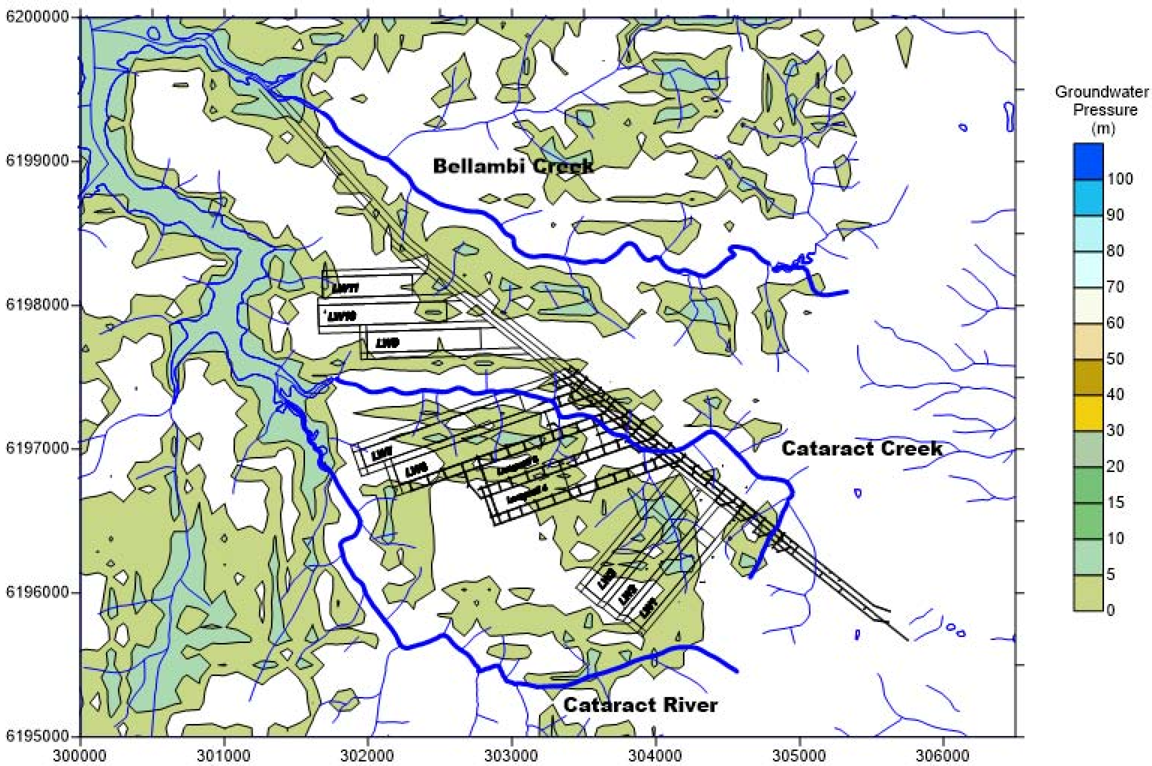



**Figure 44 Layer 1 Groundwater Pressure after the Completion of Mining in Wongawilli Seam**

After 200 years, the recovery scenario is almost identical with a very slight reduction in the drawdown footprint.

Differences are limited to area of the Wongawilli Seam panels. Pressures at 50 years **(Figure 45)**, 100 years **(Figure 46)**, and 200 years **(Figure 47)** after mining show little difference indicating static post mining pressures are achieved relatively quickly.

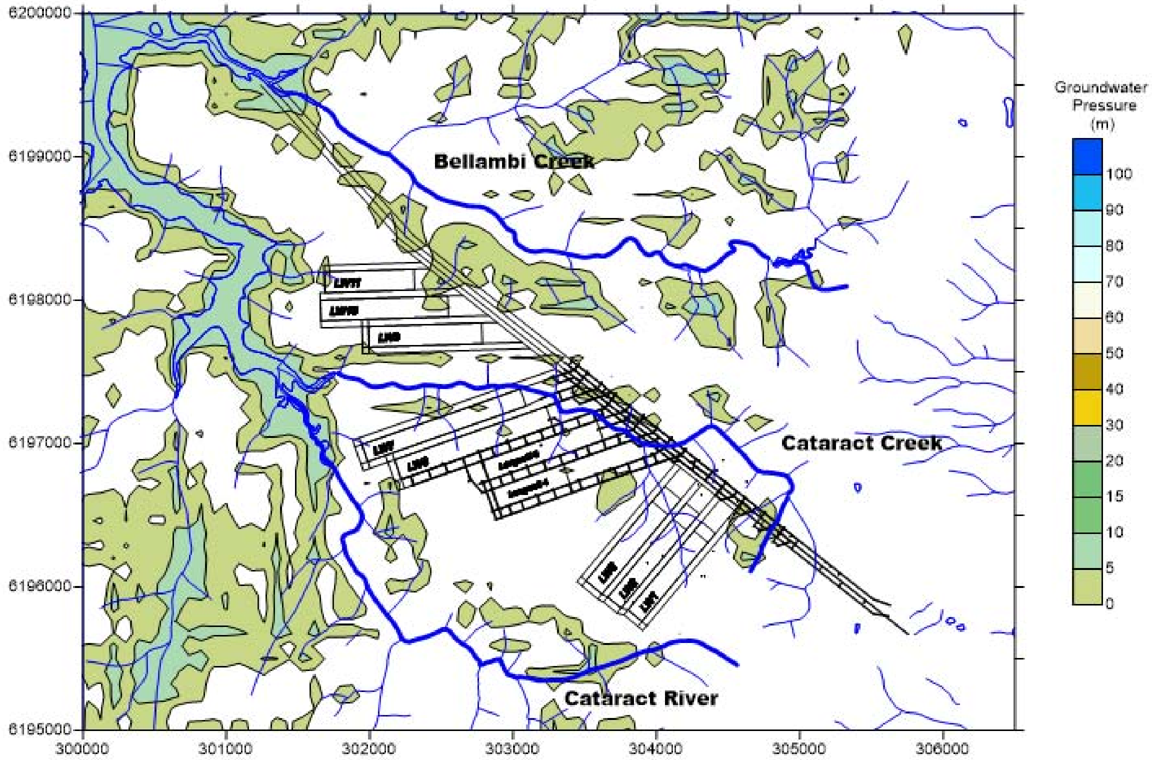



**Figure 45 Layer 1 Groundwater Pressure after 50 years Recovery**

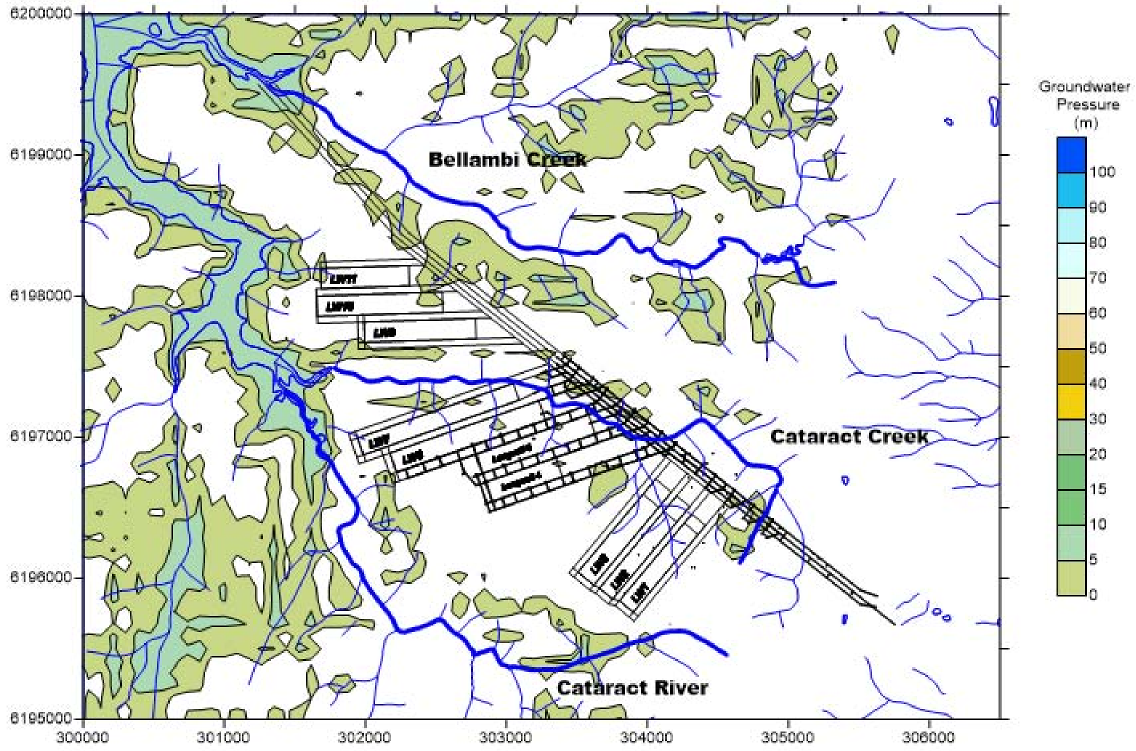



**Figure 46** Layer 1 Groundwater Pressure after 100 years Recovery

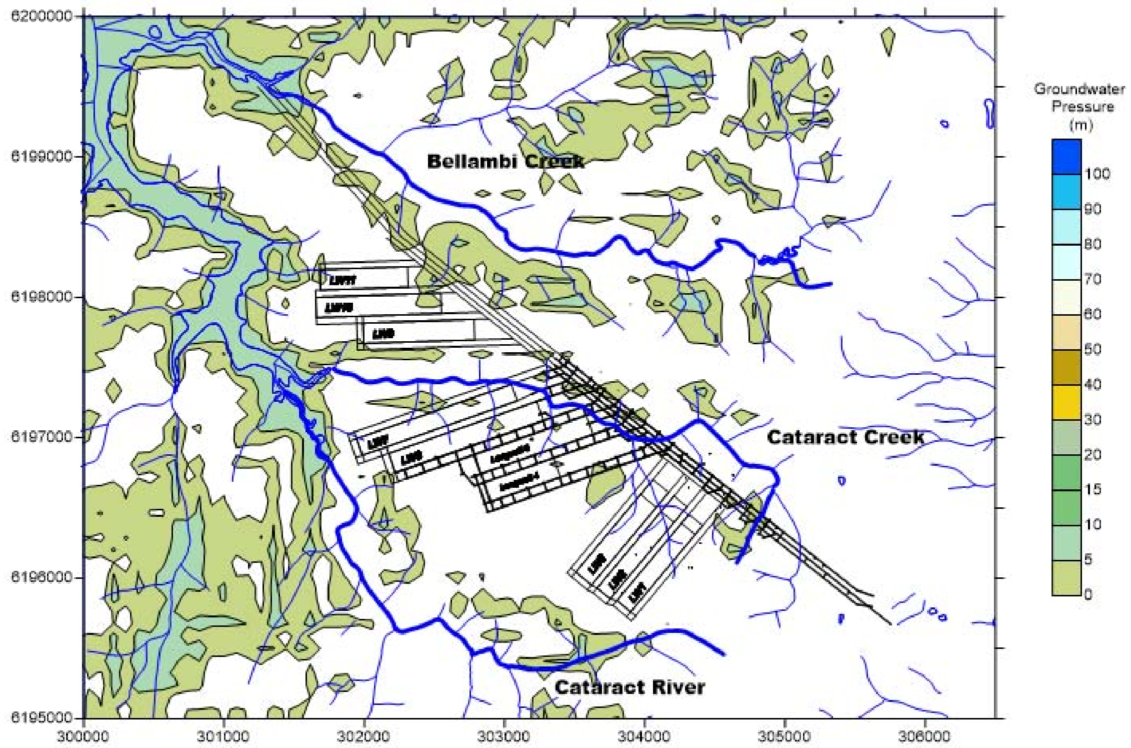



**Figure 47** Layer 1 Groundwater Pressure after 200 years Recovery

#### 10.3.3 Lower Hawkesbury Sandstone

Modelling of Layer 3 (Lower Hawkesbury Sandstone, Newport / Garie Formation, Bald Hill Claystone and upper Bulgo Sandstone) in eroded creek bed locations after the end of mining at Russell Vale East indicates up to 50m of drawdown occurs over LW1, LW2 and LW3, and a small area in LW6 as shown in **Figure 48** in comparison to pre Wongawilli Seam development. This suggests that the Hawkesbury Sandstone in this layer over LWs 1-3 will become unsaturated. **Figure 49** shows drawdown after mining is completed in comparison to post LW5 groundwater levels. The main difference between these two drawdown periods is the drawdown over LW4 and LW5.

**Figure 50** indicates that 100 years after mining, further reduction in groundwater pressures are expected to occur. However, although the drawdown footprint is larger, the deepest drawdown over LW4 and LW5 has reduced in magnitude compared to end of mining conditions. Similar to the base of the Hawkesbury Sandstone, water levels in strata over LW1 – LW3 have continued to fall such that drawdown exceeds the model base for this layer.

**Figure 51** indicates that 200 years after completion of mining, water pressures remain static in comparison to the previous 100 years. A very slight reduction in drawdown footprint is evident. This suggests that the peak impact is achieved prior to 100 years after mining, although no effective recovery is seen until after 200 years.

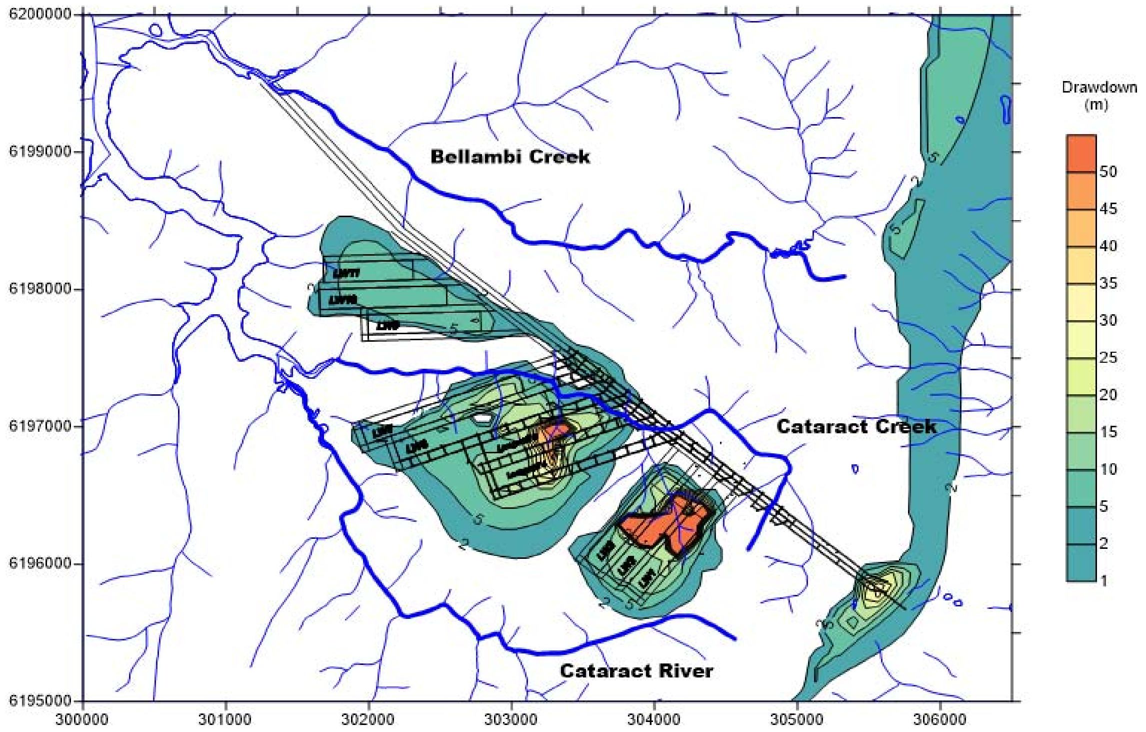



**Figure 48** Layer 3 Drawdown After Mining at Russell Vale East in Comparison to Pre Wongawilli Seam Development

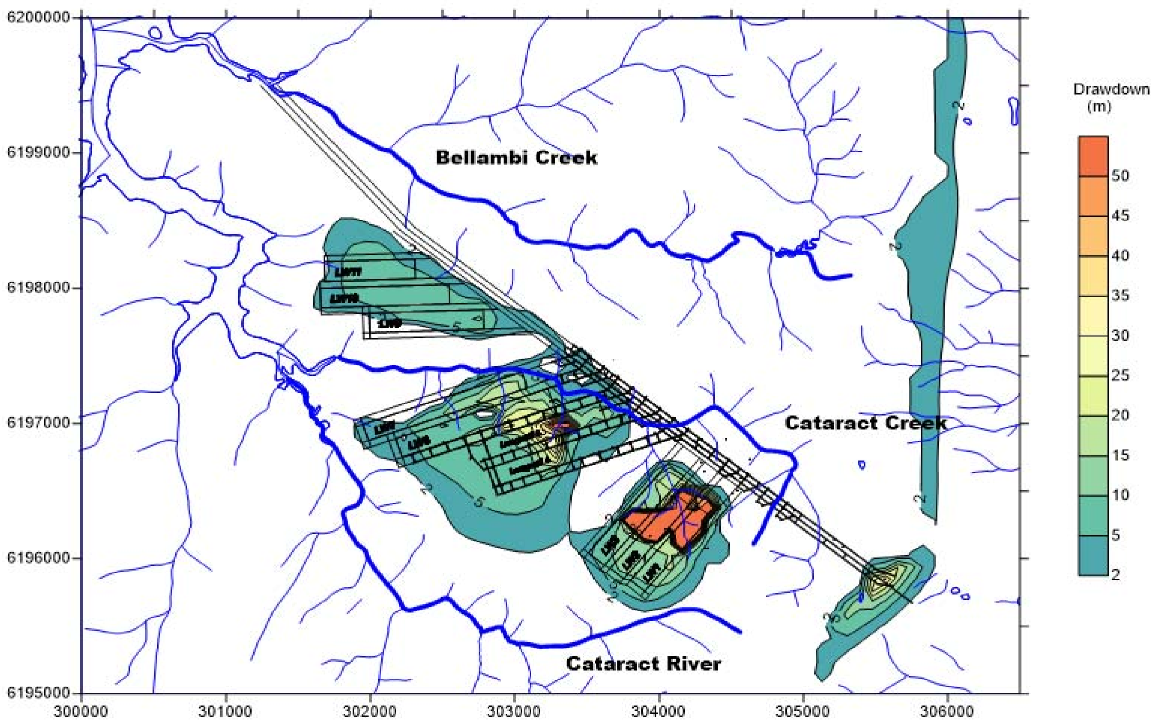



**Figure 49** Layer 3 Drawdown After Mining at Russell Vale East in Comparison to Post LW5 Development

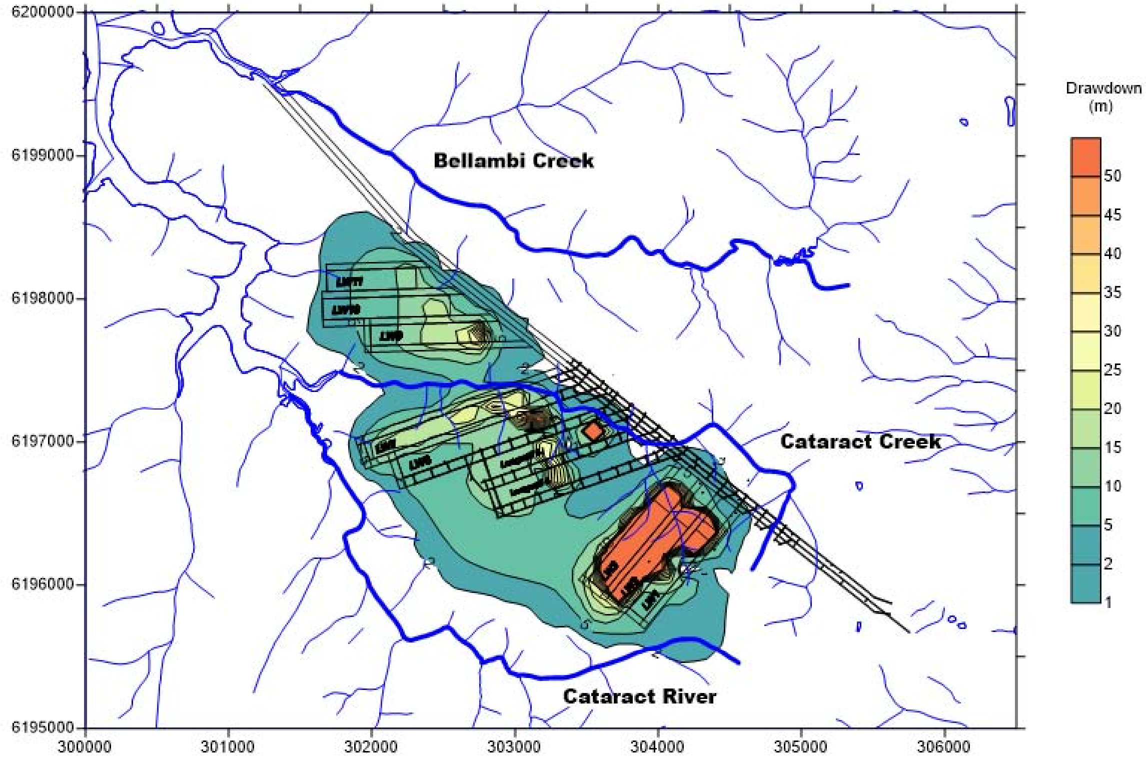



**Figure 50 Layer 3 Recovery 100 Years After Mining at Russell Vale East**

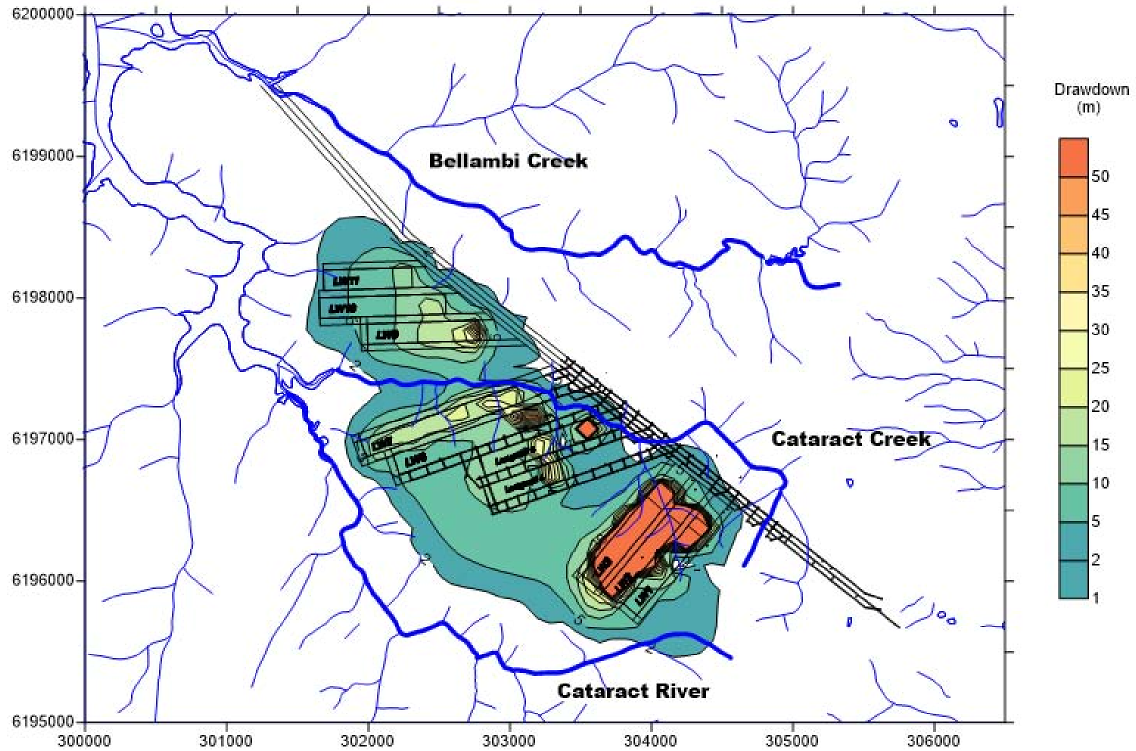



**Figure 51 Layer 3 Recovery 200 Years After Mining at Russell Vale East**

Groundwater pressures in the Lower Hawkesbury Sandstone (Layer 3) at the start and end of mining in the Wongawilli Seam are shown in **Figure 52** and **Figure 53**. Differences are limited to area of the Wongawilli Seam panels.

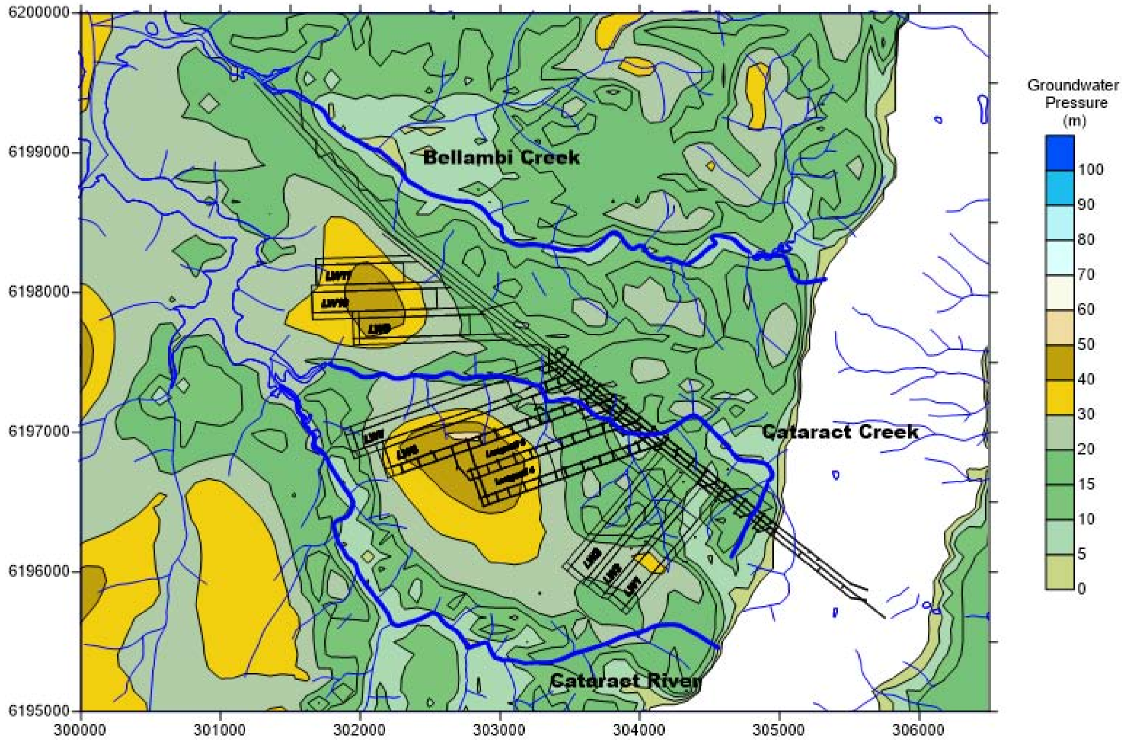



**Figure 52 Layer 3 Groundwater Pressure before the Start of Mining in Wongawilli Seam**

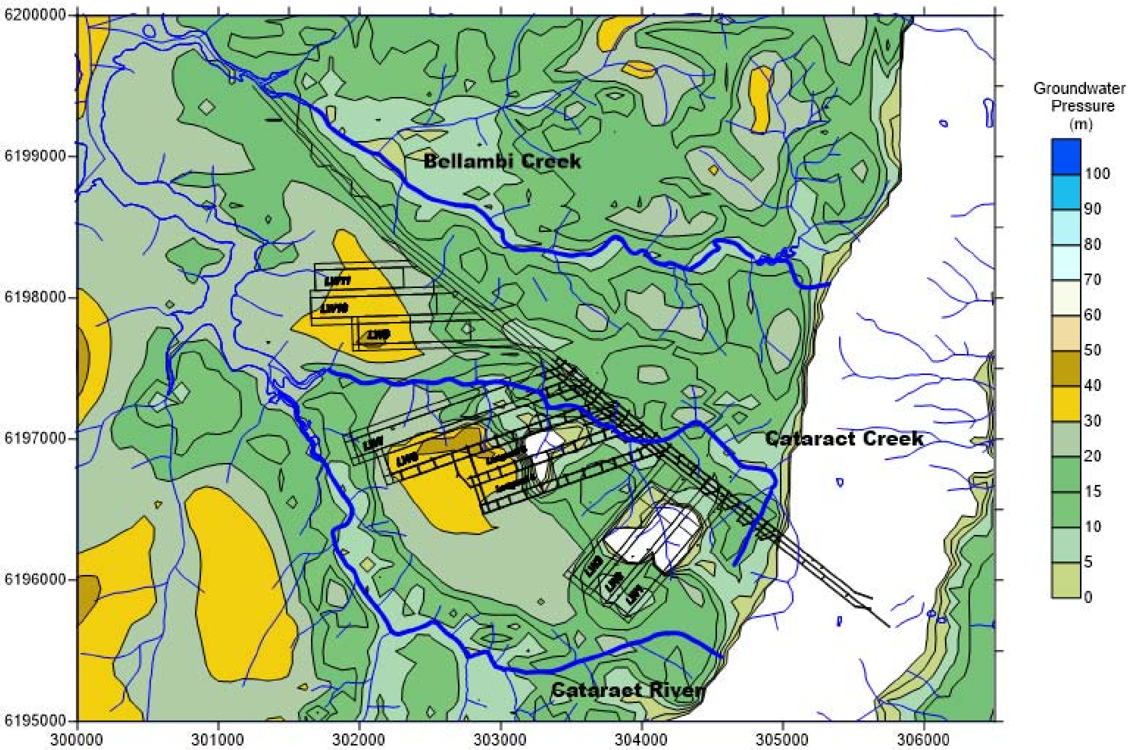



**Figure 53 Layer 3 Groundwater Pressure after the Completion of Mining in Wongawilli Seam**

Groundwater pressures during recovery are shown at 50 years **(Figure 54)**, 100 years **(Figure 55)**, and 200 years **(Figure 56)** after mining show little change in groundwater pressures through this period. However small recoveries are encroaching from down dip.

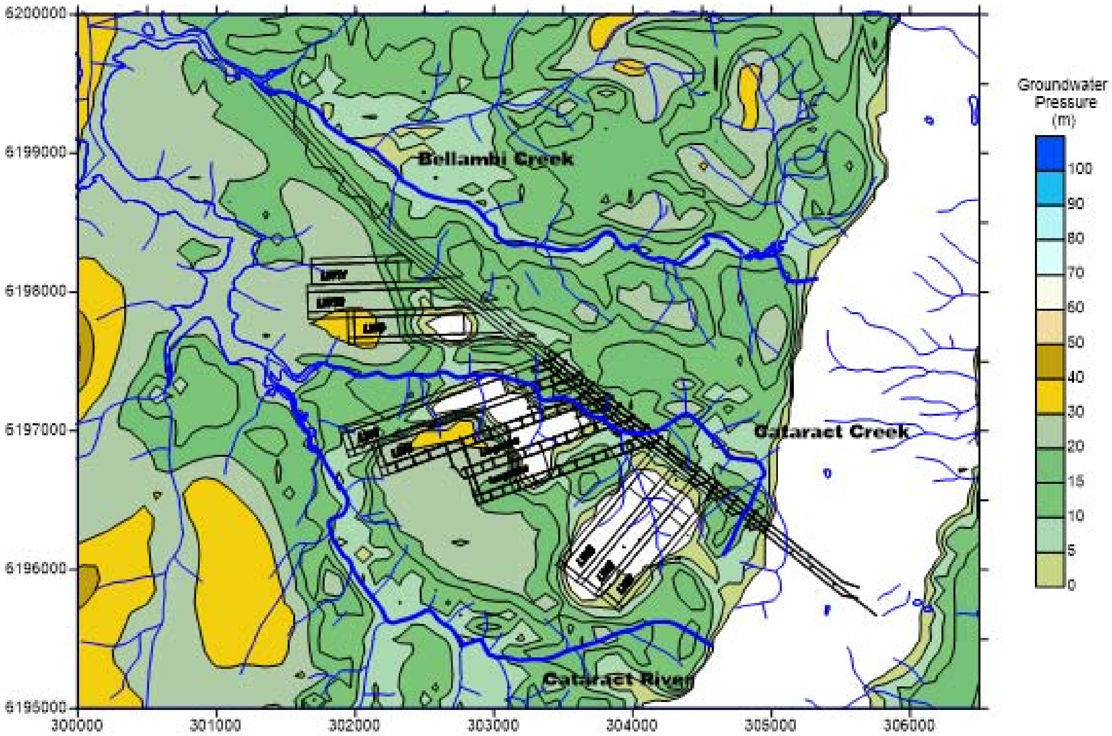



**Figure 54 Layer 3 Groundwater Pressure after 50 Years Recovery**

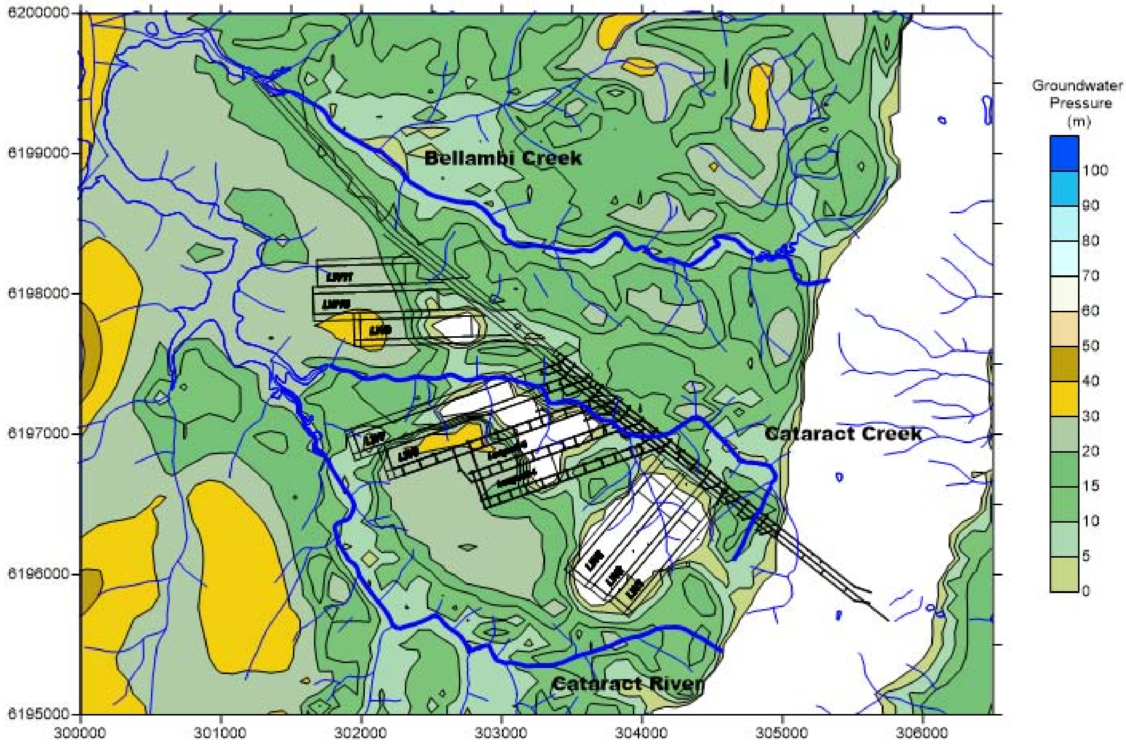



**Figure 55** Layer 3 Groundwater Pressure after 100 Years Recovery

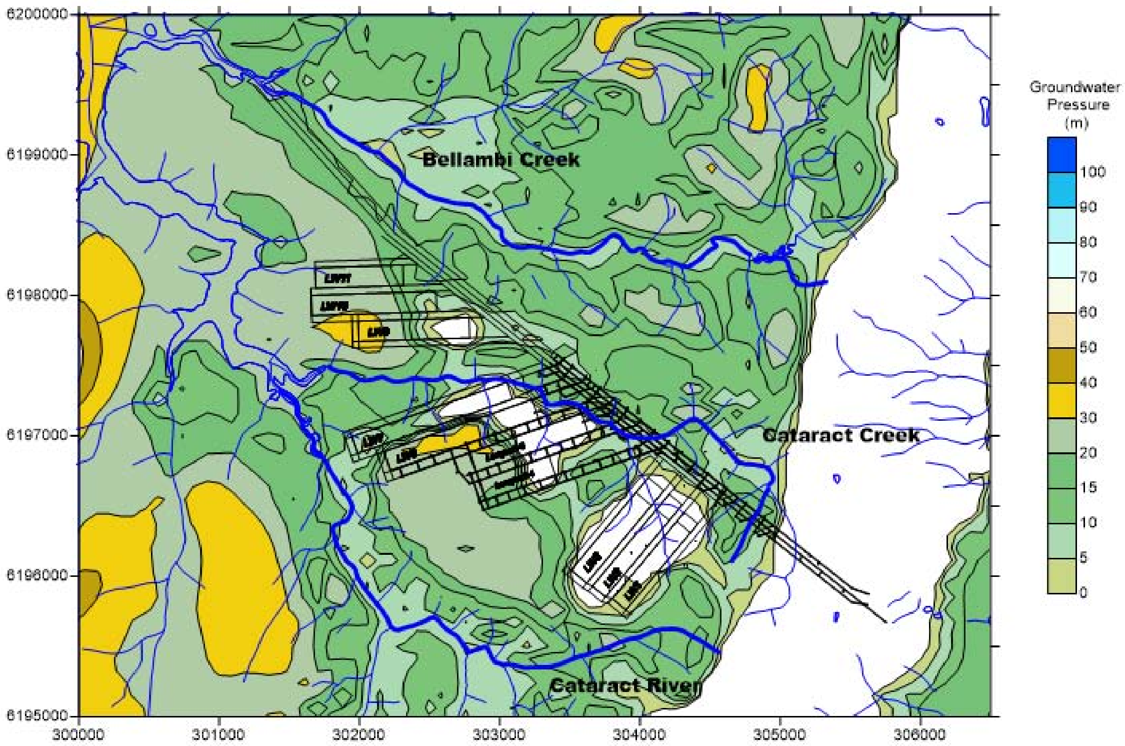



**Figure 56** Layer 3 Groundwater Pressure after 200 Years Recovery

#### 10.3.4 Upper Bulgo Sandstone

Modelling of Layer 5 (Bulgo Sandstone) after the end of mining, indicates up to 45m of drawdown over Russell Vale East, which occurs within the footprint of LWs 1-7 and part of LW9 in comparison to pre Wongawilli Seam development. **Figure 57** shows drawdown after mining is completed in comparison to post LW5 groundwater levels. As was the case for the 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 58.**

Modelling indicates that drawdown of up to 2m extends a maximum of 1km to the west of LW7 following completion of mining.

**Figures 59** and **60** indicate that 100 and 200 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 Russell Vale East, although deeper drawdown level within longwall footprint have reduced. As occurs in the overlying strata, pressures change little from 100 to 200 years after mining.

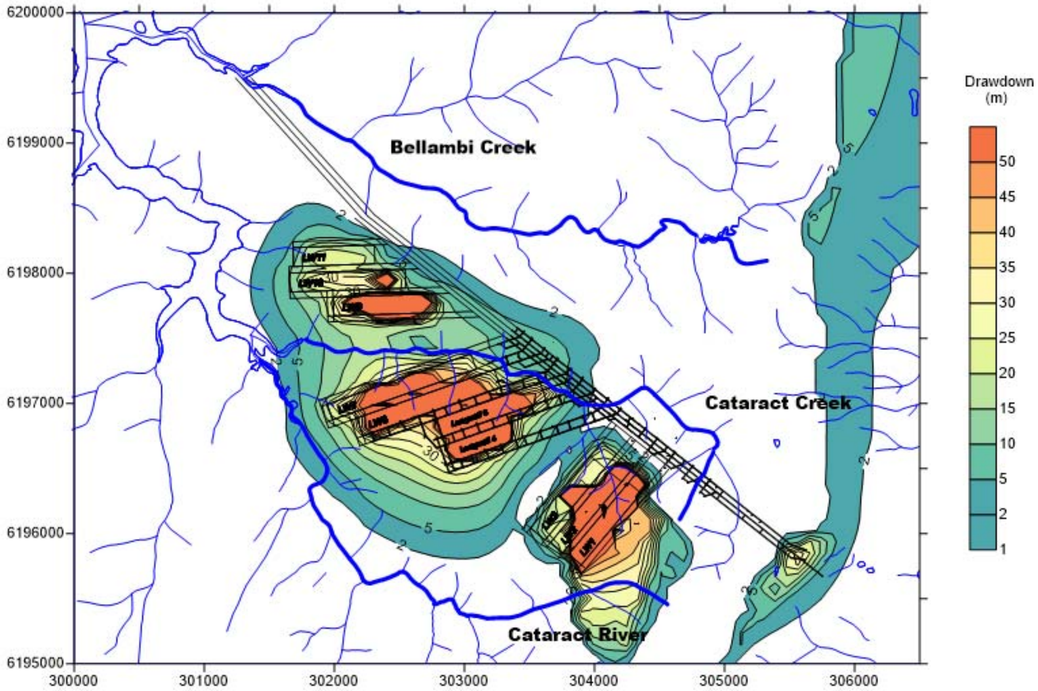



**Figure 57** Upper Bulgo Sandstone Drawdown After Mining Russell Vale East in Comparison to Pre Wongawilli Seam Development

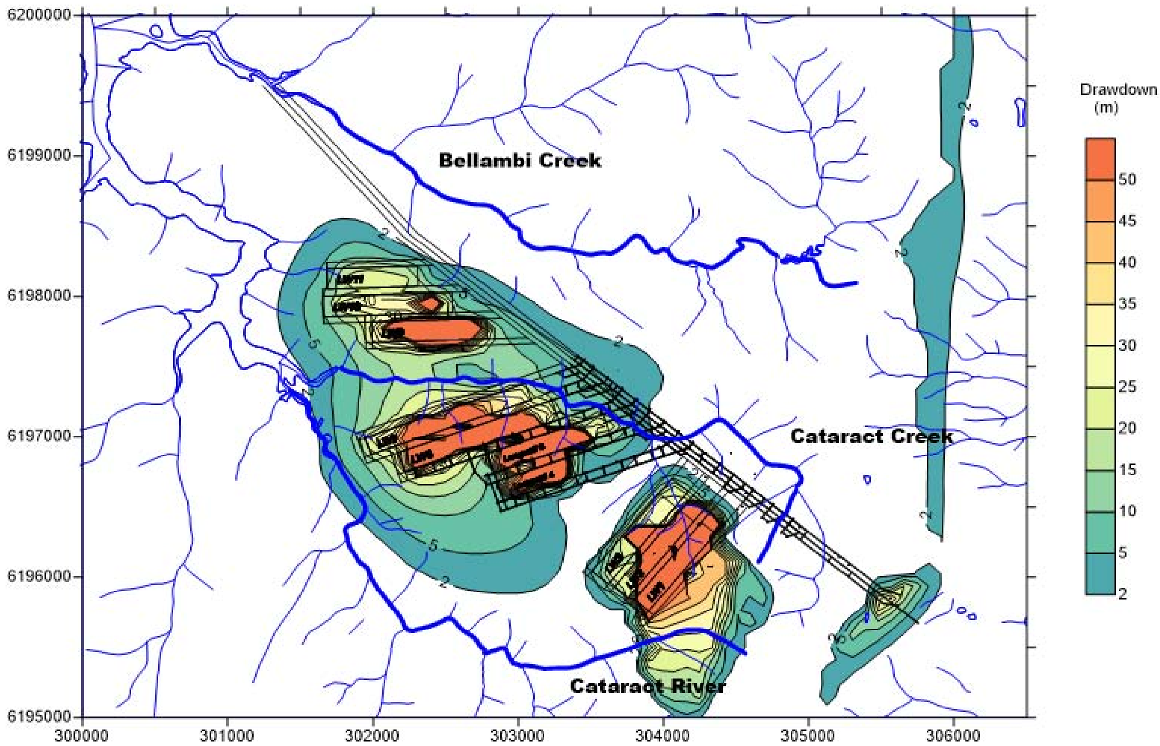



**Figure 58** Upper Bulgo Sandstone Drawdown After Mining at Russell Vale East in Comparison to Post LW5 Development

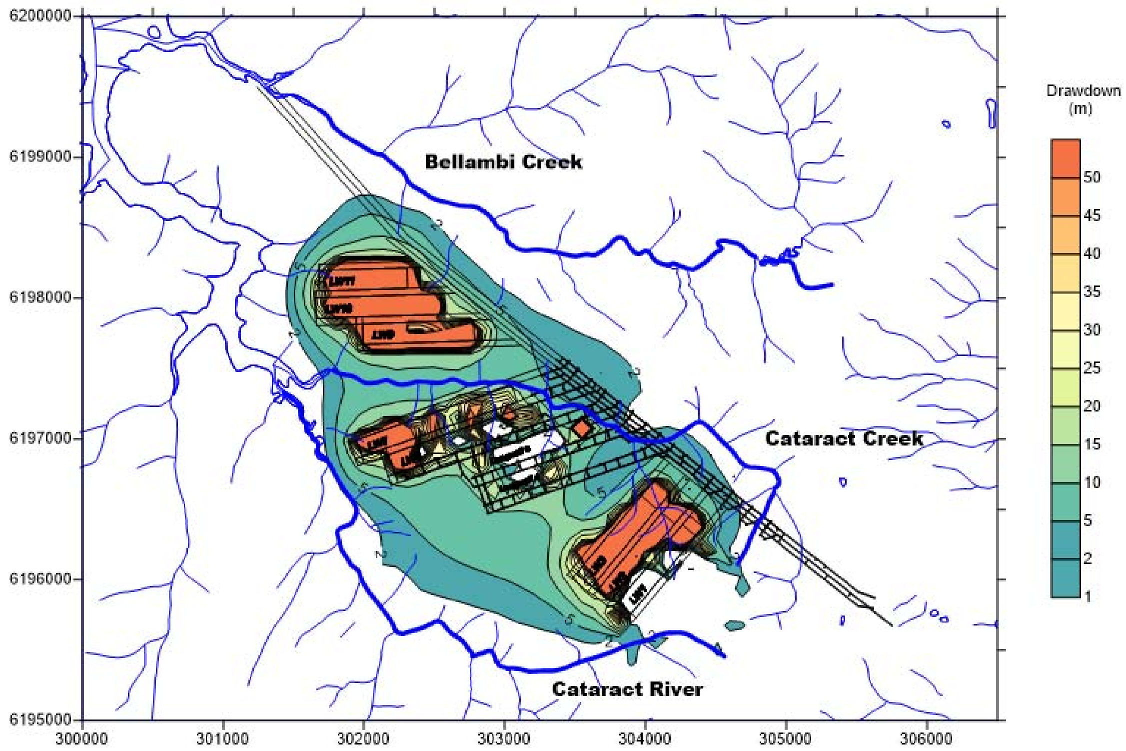



**Figure 59** Upper Bulgo Sandstone Recovery 100 Years After Mining at Russell Vale East

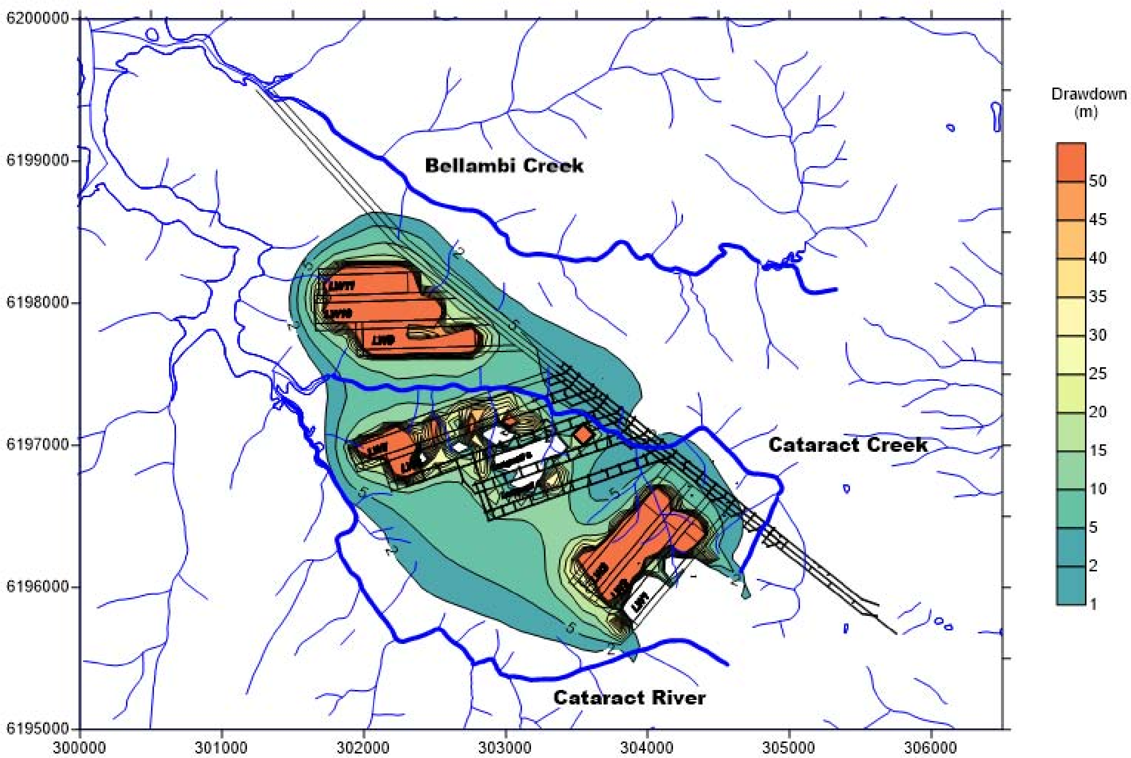



**Figure 60** Upper Bulgo Sandstone Recovery 200 Years After Mining at Russell Vale East

Groundwater pressures in the Upper Bulgo Sandstone (Layer 5) at the start and end of mining in the Wongawilli Seam are shown in **Figure 61** and **Figure 62**.

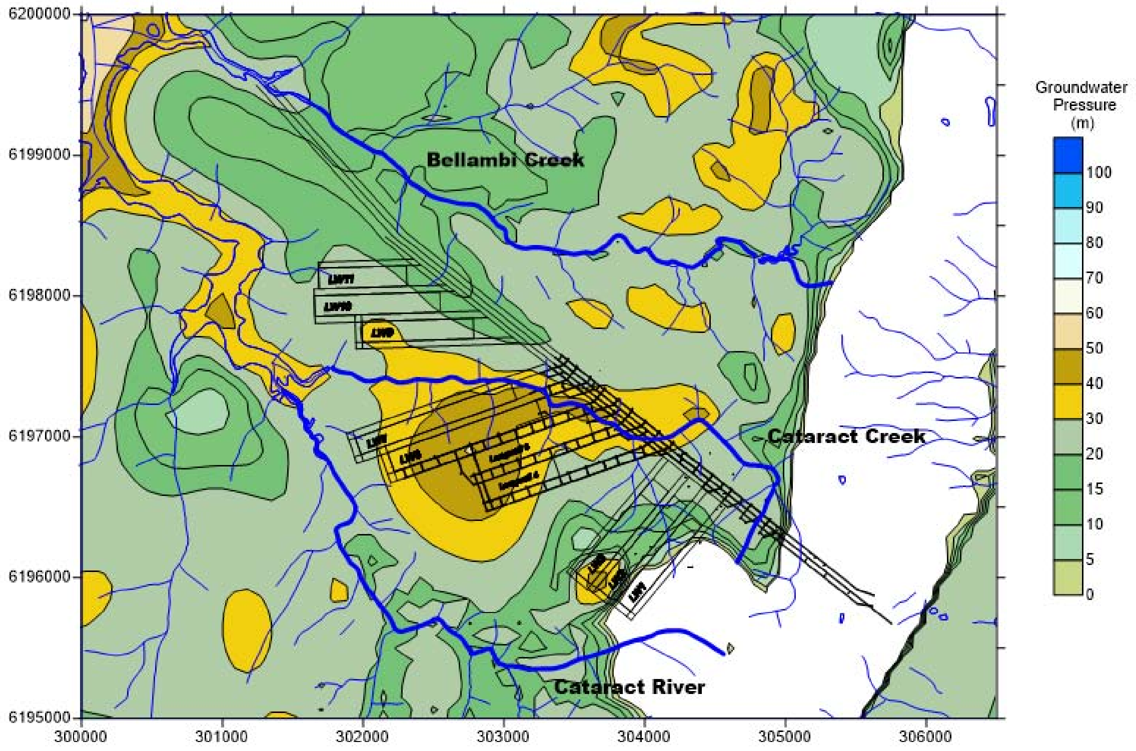



**Figure 61 Upper Bulgo Sandstone Groundwater Pressure before the Start of Mining in Wongawilli Seam**

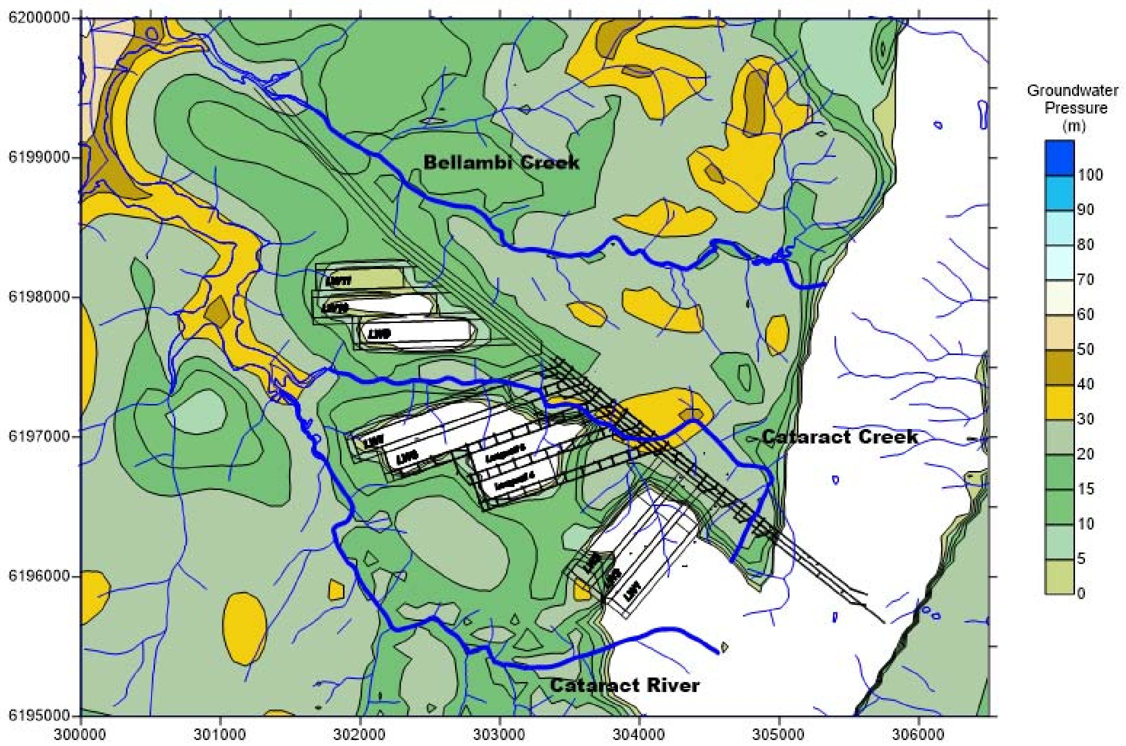



**Figure 62 Upper Bulgo Sandstone Groundwater Pressure after the Completion of Mining in Wongawilli Seam**

Groundwater pressures during recovery are shown at 50 years **(Figure 63)**, 100 years **(Figure 64)**, and 200 years **(Figure 65)** after mining show depressurisation continues to develop after 200 years.

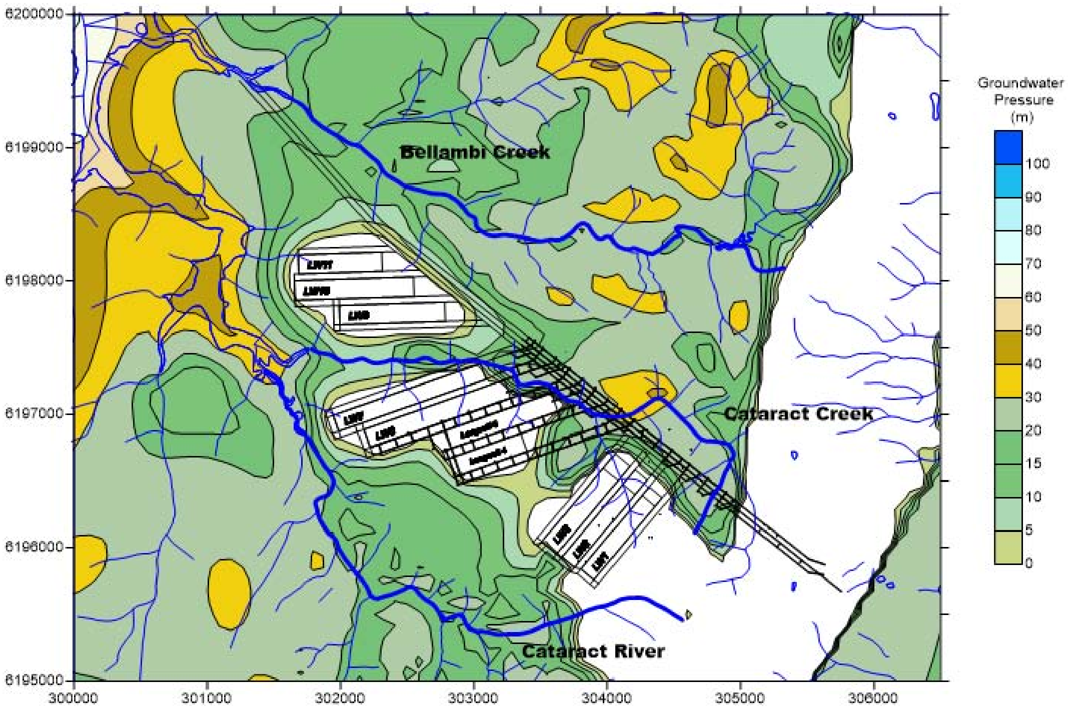



**Figure 63 Upper Bulgo Sandstone Groundwater Pressure after 50 Years Recovery**

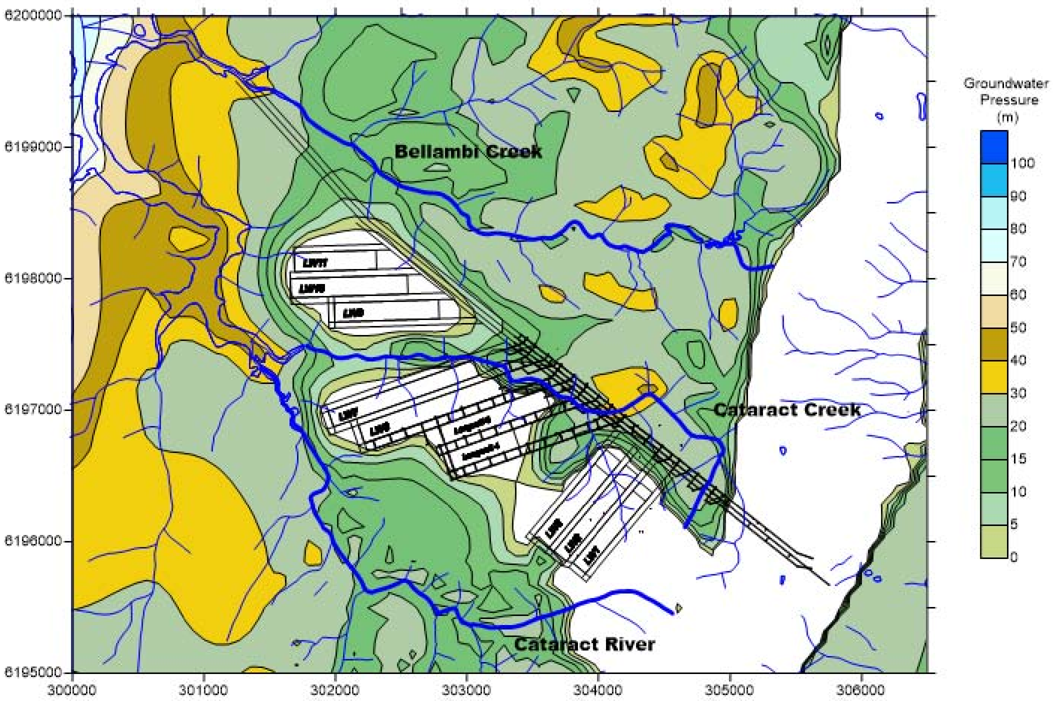



**Figure 64 Upper Bulgo Sandstone Groundwater Pressure after 100 Years Recovery**

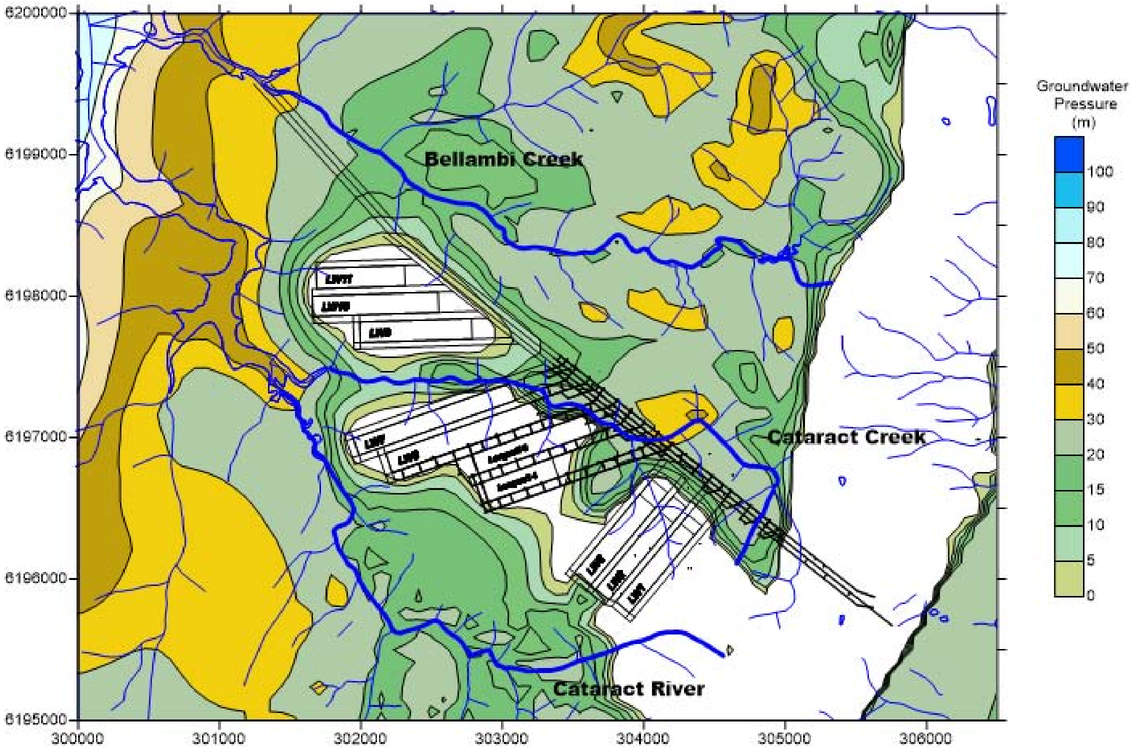



**Figure 65 Upper Bulgo Sandstone Groundwater Pressure after 200 Years Recovery**

### 10.3.5 Scarborough Sandstone

Modelling of Scarborough Sandstone (Layer 10) after the end of mining at Russell Vale East indicates drawdown below the base of the layer as shown in **Figure 66**, with the depressurisation after extraction of Longwall 5 shown in **Figure 67.** The predicted areal extent of drawdown at the end of mining shows 2m extending a maximum of 1km to the west of LW7

**Figure 68** indicates that 100 years after mining has been completed, water levels over the longwall footprint are still depressed in comparison to pre-mining levels with the 2m drawdown extent expanding slightly north and south. However the higher drawdown over the longwall panels have recovered to a large extent. After 200 years, drawdown continues to contract however, there is little change to that after 100 years as shown in **Figure 69**. However, as with overlying strata, maximum drawdown appears to have occurred by 100 years after cessation of mining.

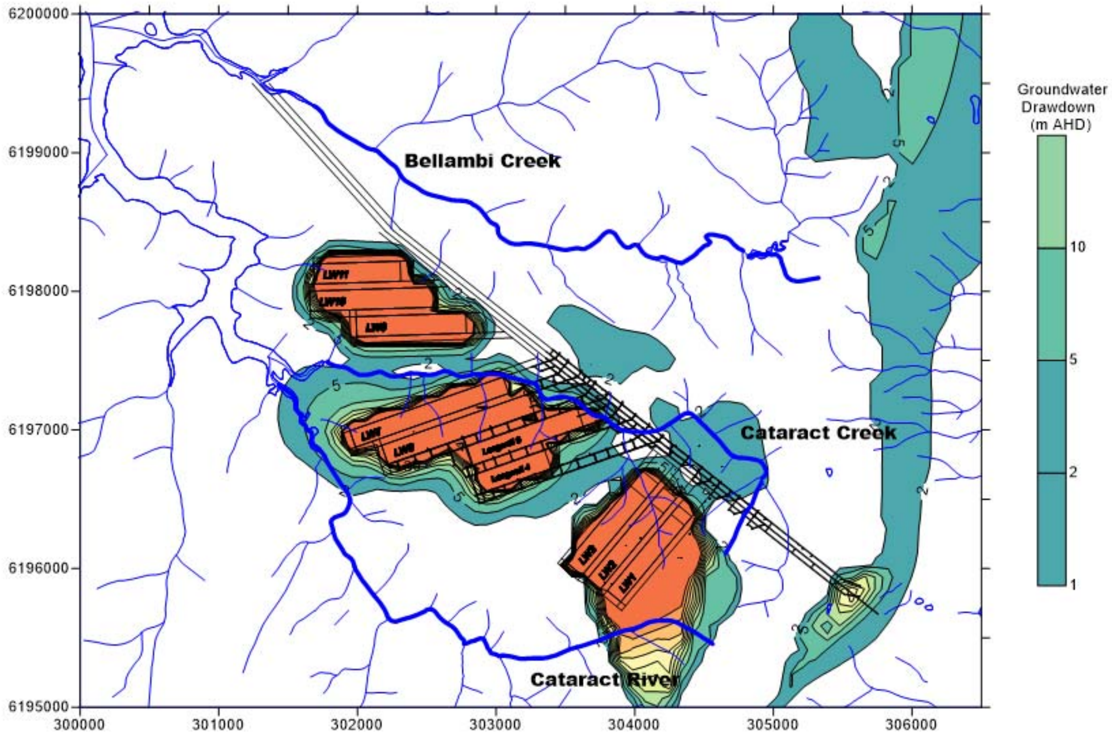



**Figure 66** Scarborough Sandstone Drawdown After Mining Russell Vale East in Comparison to Pre Wongawilli Seam Development

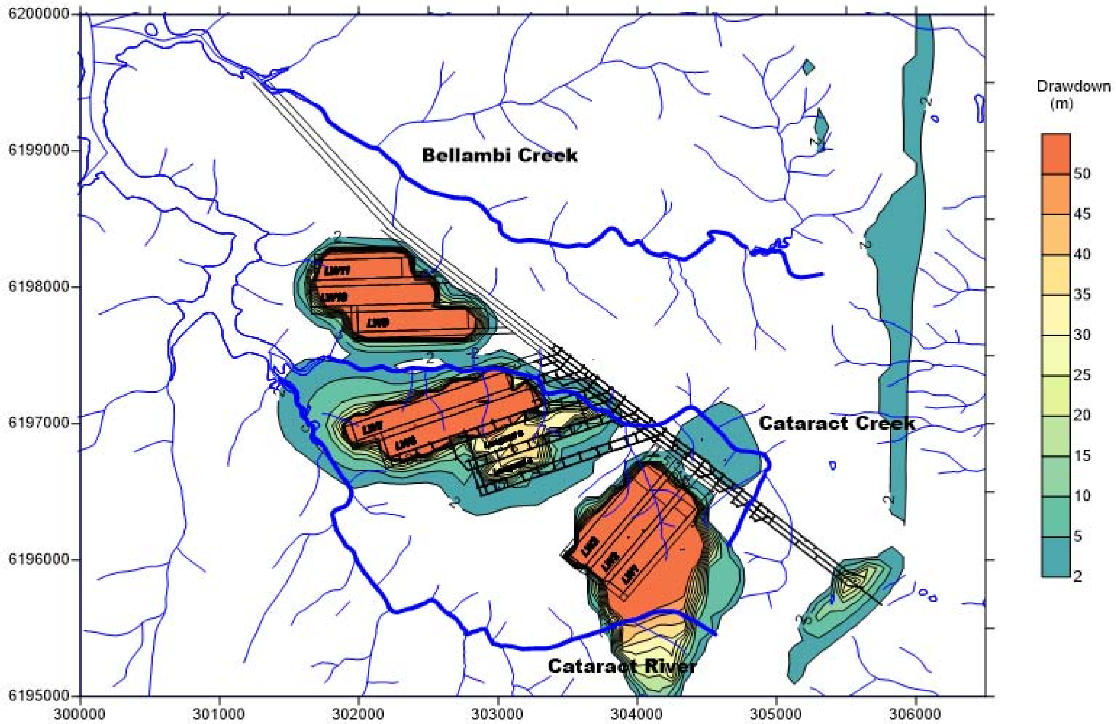



**Figure 67** Scarborough Sandstone Drawdown After Mining at Russell Vale East in Comparison to Post LW5 Development

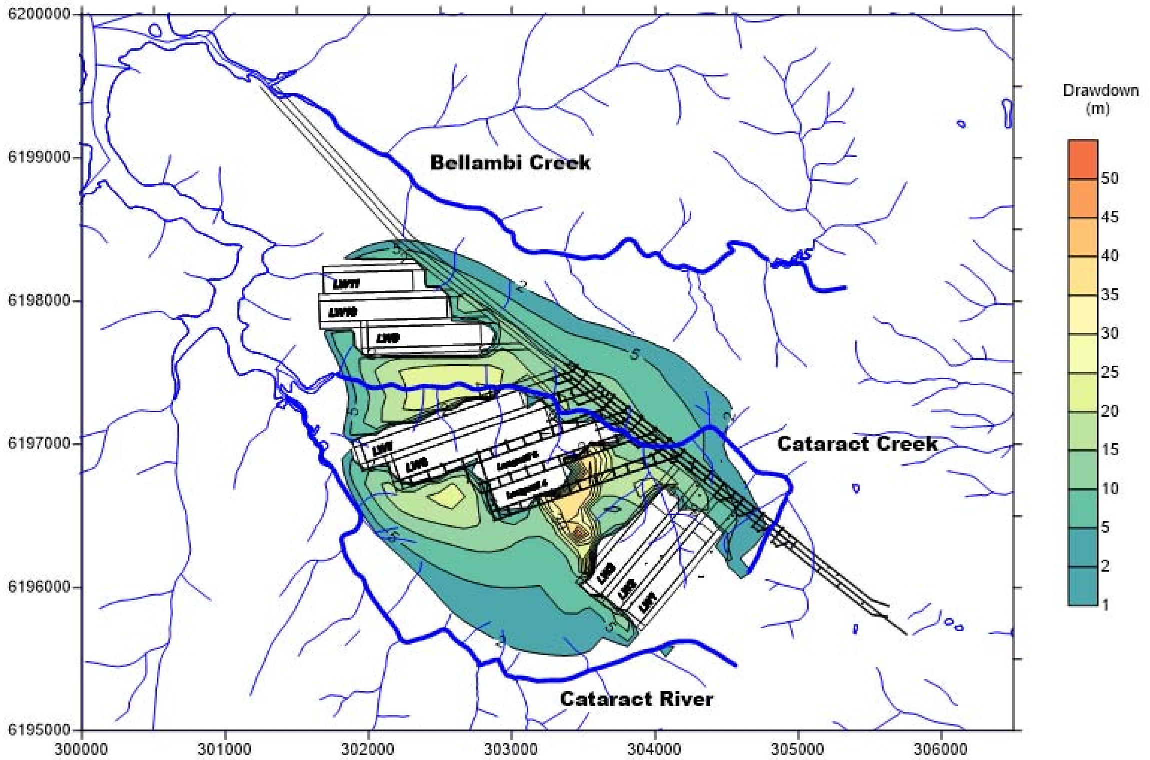



**Figure 68 Scarborough Sandstone Recovery 100 Years After Mining**

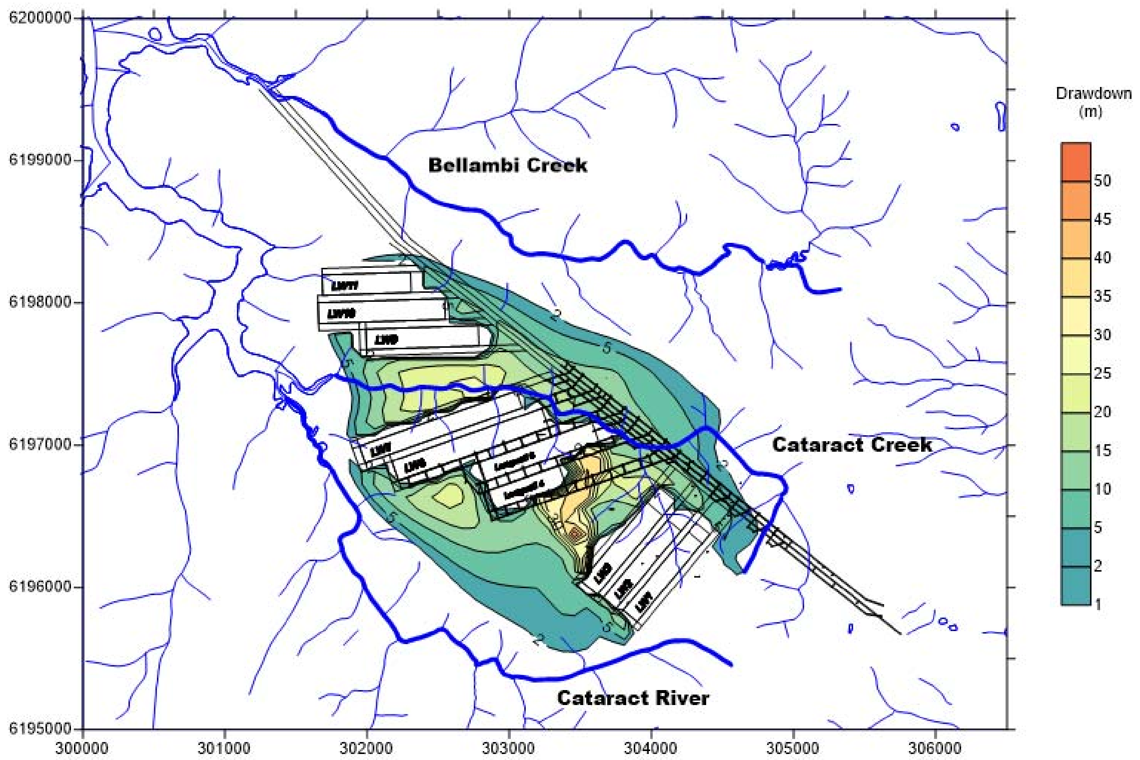



**Figure 69 Scarborough Sandstone Recovery 200 Years After Mining**

Groundwater pressures during recovery are shown at 50 years **(Figure 70)**, 100 years **(Figure 71)**, and 200 years **(Figure 72)** after mining shows that depressurisation continues to develop throughout the 200 year simulation in the Russel Vale area. However a recovery of groundwater pressures from western down dip areas occurs.

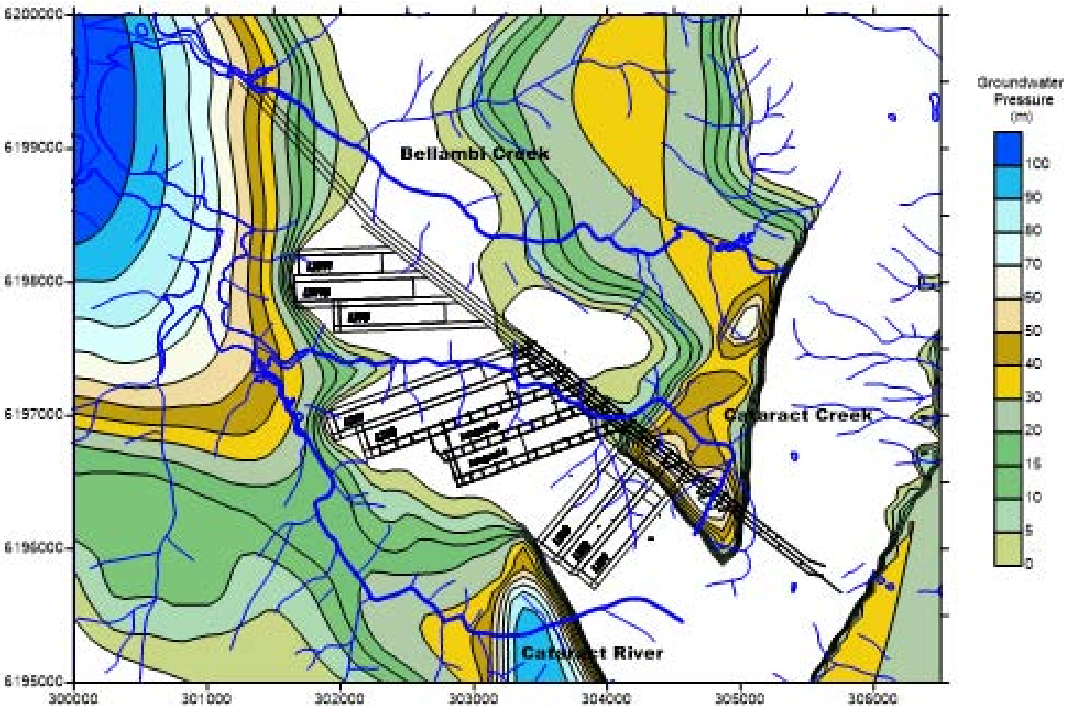



**Figure 70 Scarborough Sandstone Groundwater Pressure after 50 Years Recovery**

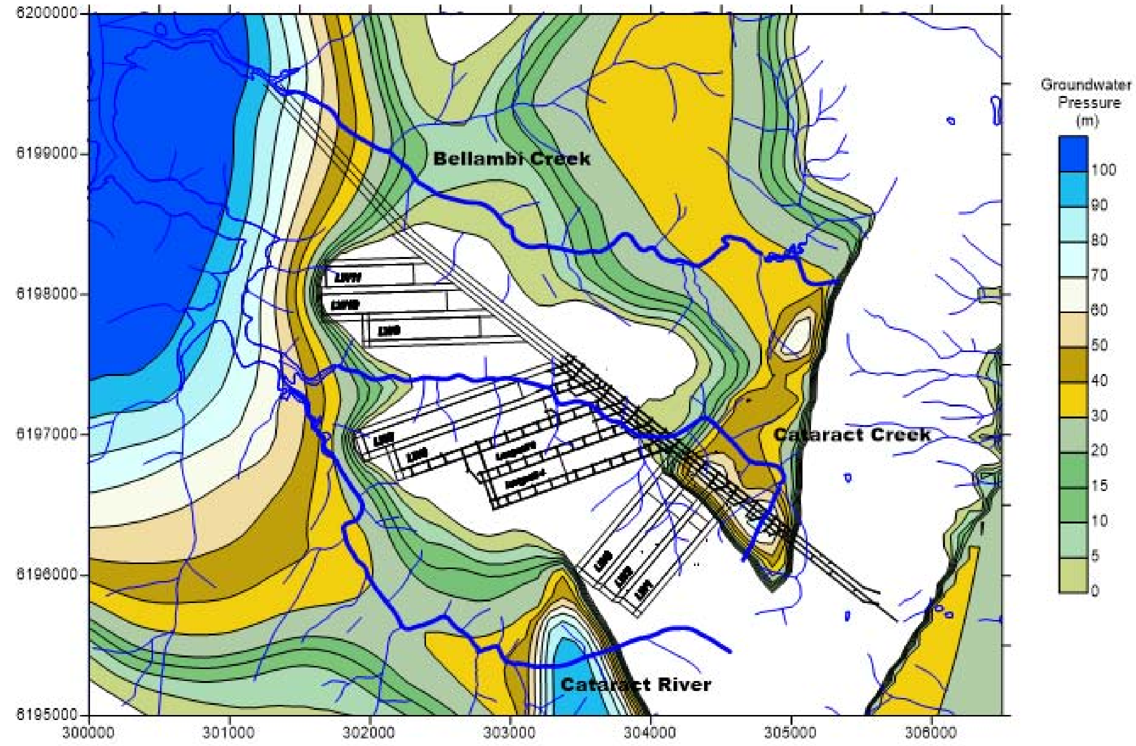



**Figure 71 Scarborough Sandstone Groundwater Pressure after 100 Years Recovery**

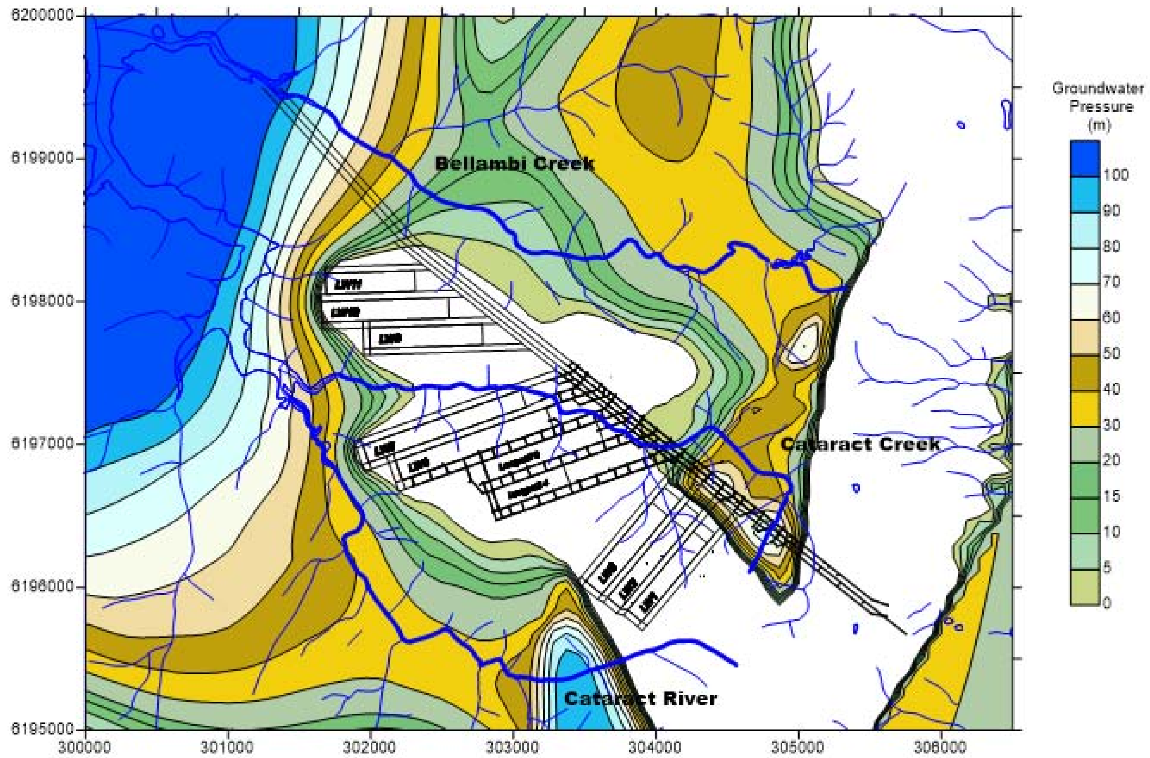



**Figure 72 Scarborough Sandstone Groundwater Pressure after 200 Years Recovery**

#### 10.3.6 Bulli Seam

No Bulli Seam drawdown figures are presented in this section as the seam is generally dry at Russell Vale East.

#### 10.3.7 Wongawilli Seam

Drawdown in the Wongawilli Seam at the end of mining in comparison to pre Wongawilli Seam development in Russell Vale East is modelled to reach up to 46m over the majority of the Wongawilli seam workings with drawdown extending north of the main headings by 3km and south of LW3 by 3km. The areal extent of the 2m drawdown contour at the end of mining at Russell Vale East extends a maximum of 4km to the north of the main headings as shown in **Figure 73**.

**Figure 74** 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.

At 100 years after completion of mining, the Wongawilli Seam is predicted to recover by up to 90m in comparison to initial conditions over Russell Vale East as shown in **Figure 75**.

Groundwater levels at the escarpment are at pre-mining levels after 100 years. However, the lowest Adit entry level of 117m AHD is not achieved within 200 years of recovery.

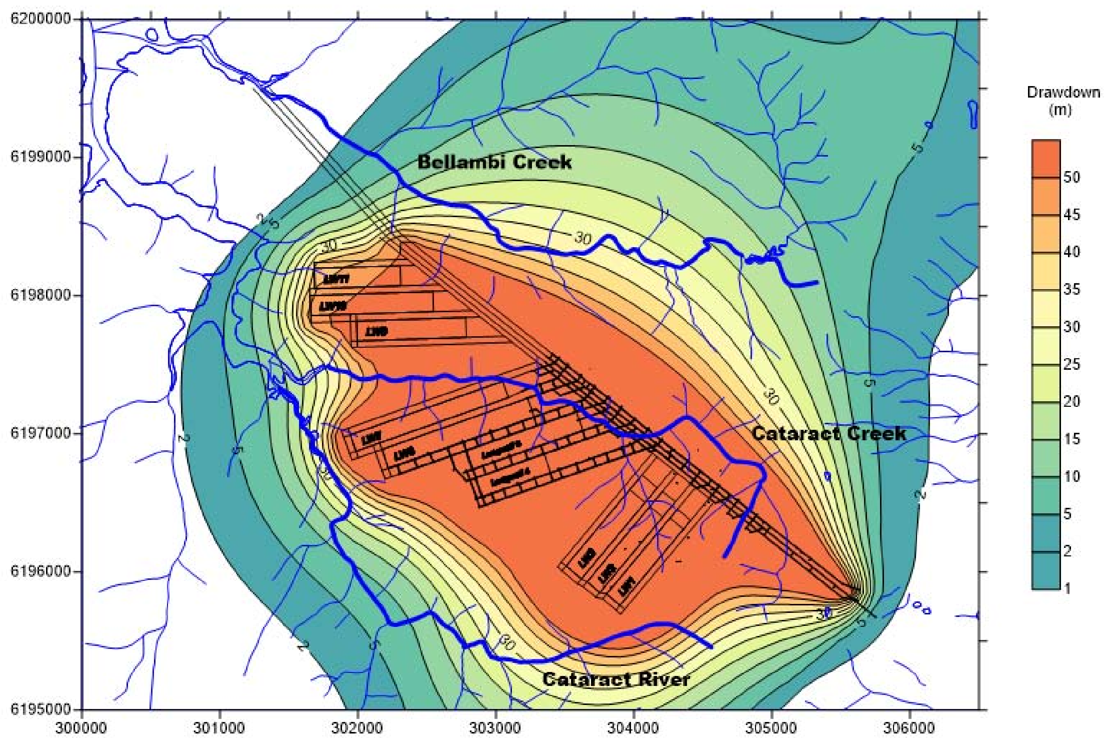



**Figure 73 Wongawilli Seam Drawdown After Mining Russell Vale East in Comparison to Pre Wongawilli Seam Development**

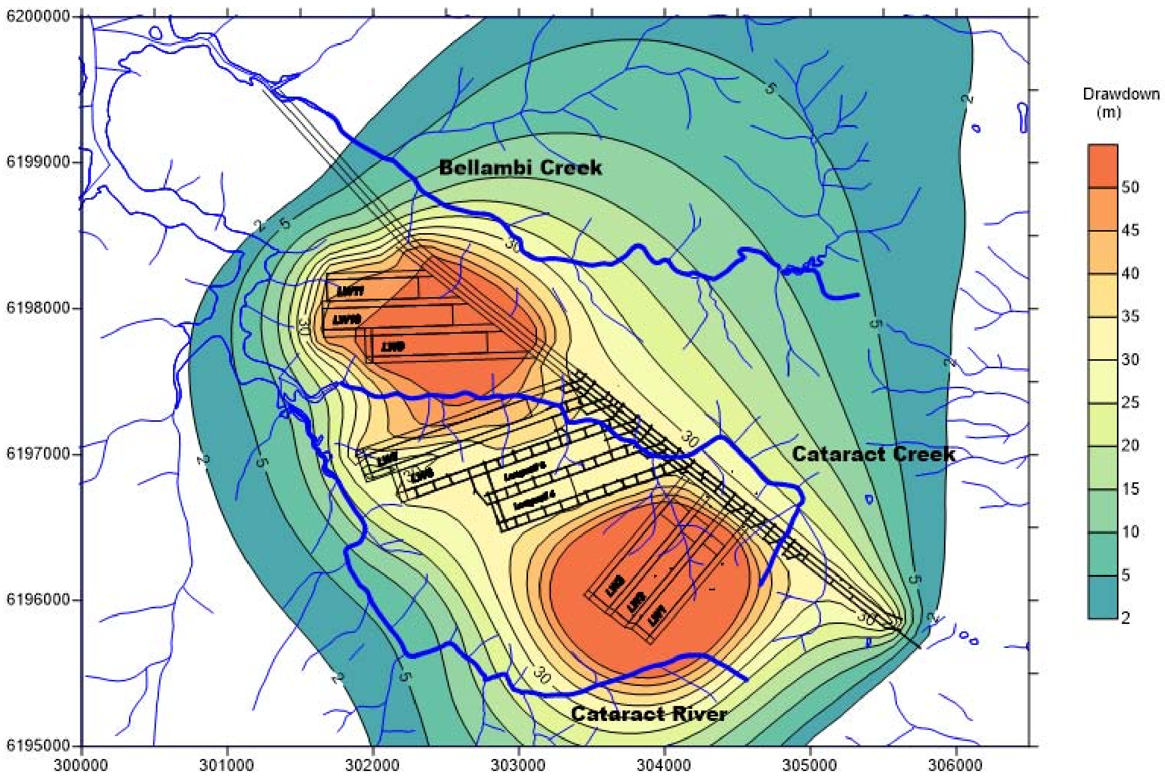



**Figure 74** **Wongawilli Seam Drawdown After Mining at Russell Vale East in Comparison to Post LW5 Development**

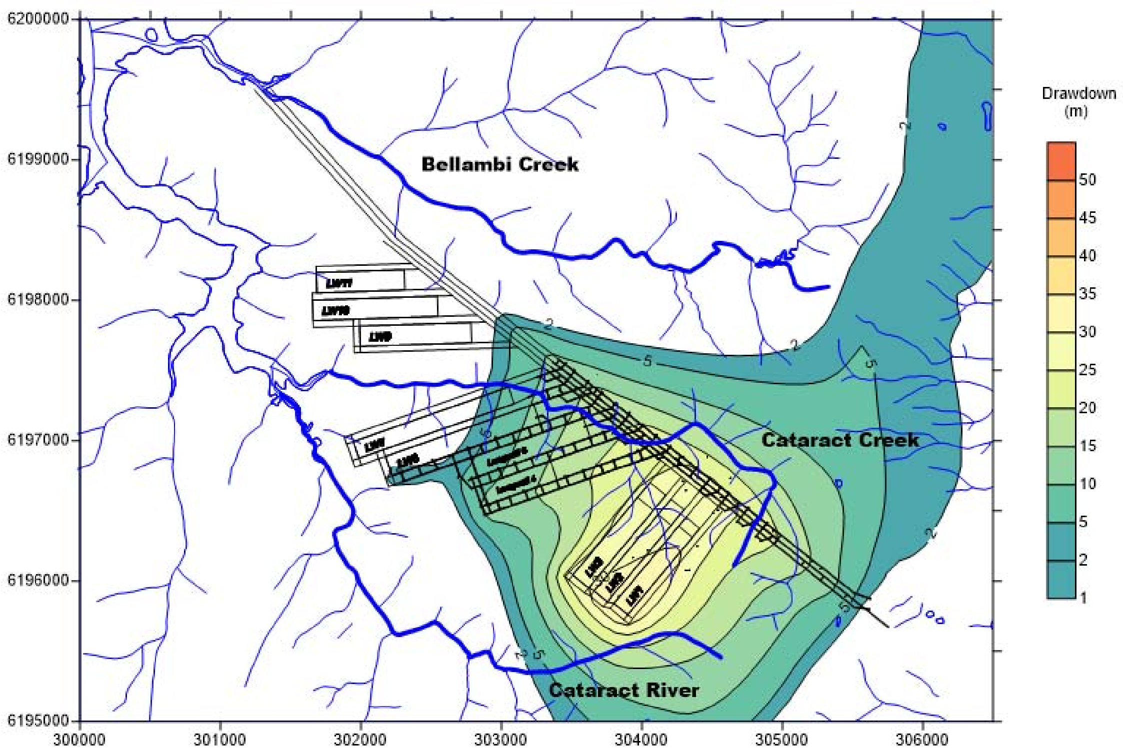



**Figure 75** **Wongawilli Seam Recovery 100 Years After Mining**

Groundwater pressures in the Wongawilli Seam (Layer 17) at the start and end of mining in the Wongawilli Seam are shown in **Figures 76** and **77.**

Groundwater pressures during recovery are shown at 50 years **(Figure 78)**, 100 years **(Figure 79)**, and 200 years **(Figure 80)** after mining shows that a recovery of groundwater pressures occurs throughout this simulated period although levels do not recover to that of pre-mining levels.

The Wongawilli Seam shows a greater propensity to recover in comparison to overlying strata mainly due to the fact that it is less impacted by previous mining activities. However, recovery levels do not achieve pre-mining levels within the 200 year recovery simulation.

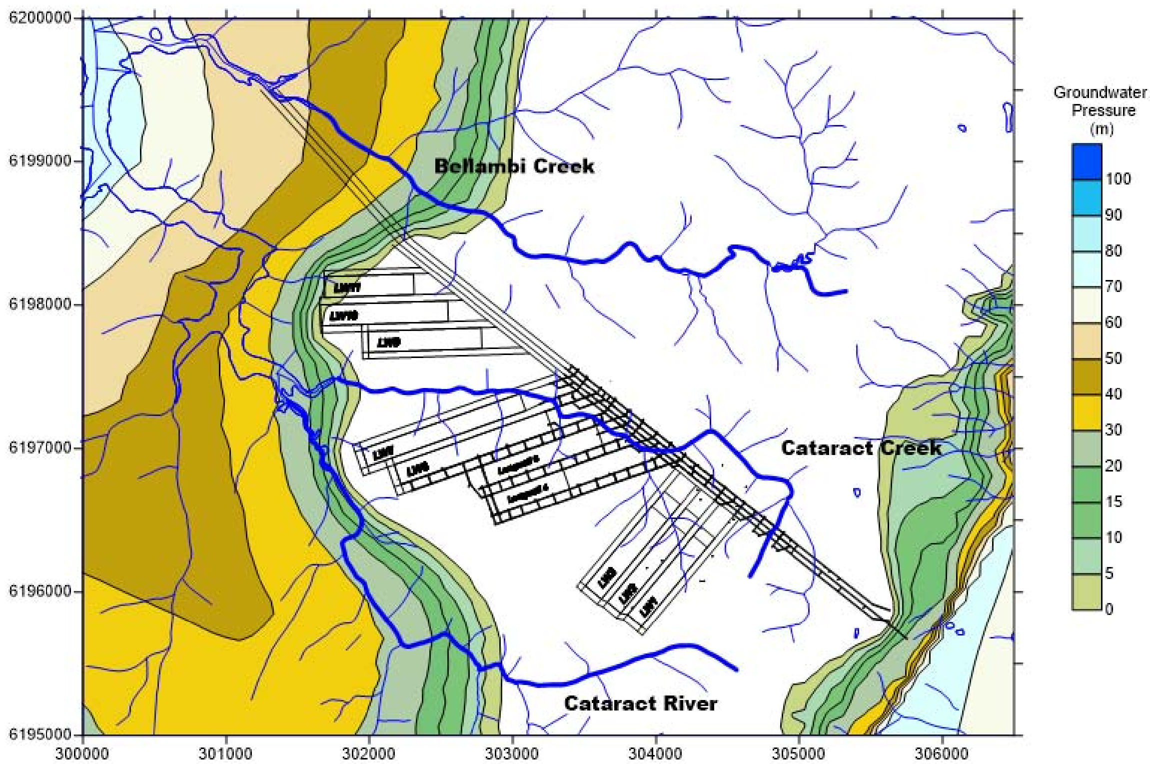



**Figure 76 Wongawilli Seam Groundwater Pressure before the Start of Mining in Wongawilli Seam**

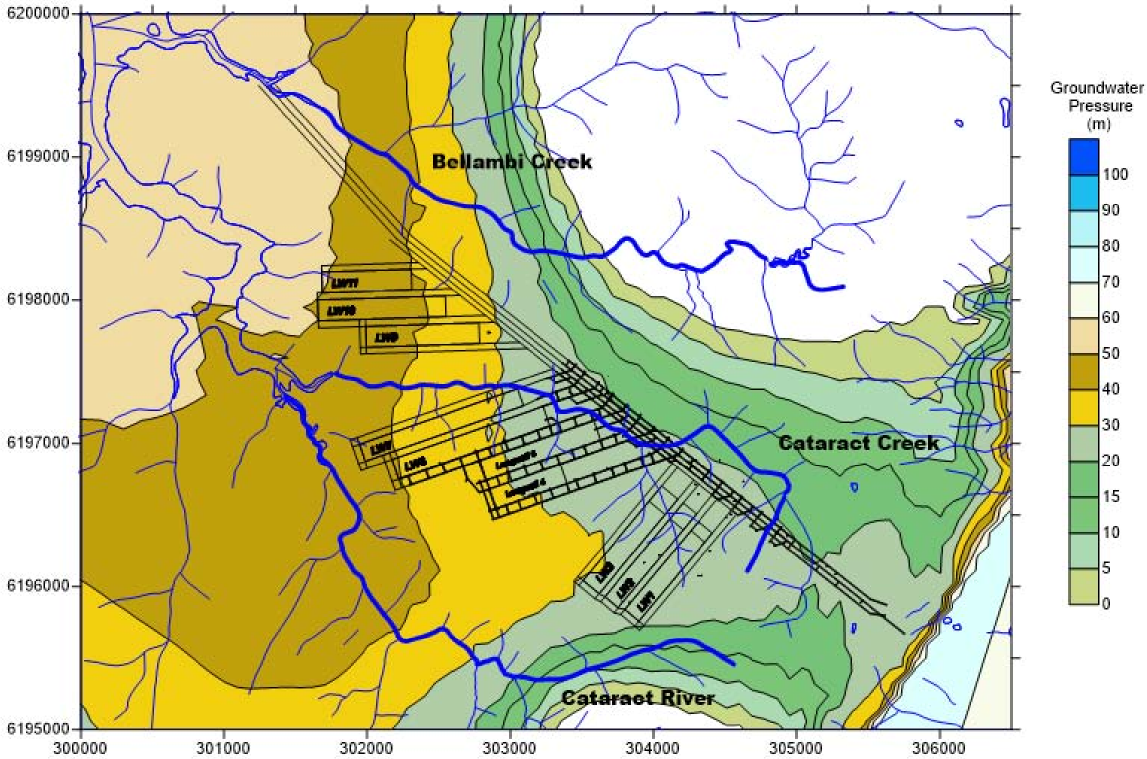



**Figure 77 Wongawilli Seam Groundwater Pressure after the Completion of Mining in Wongawilli Seam**

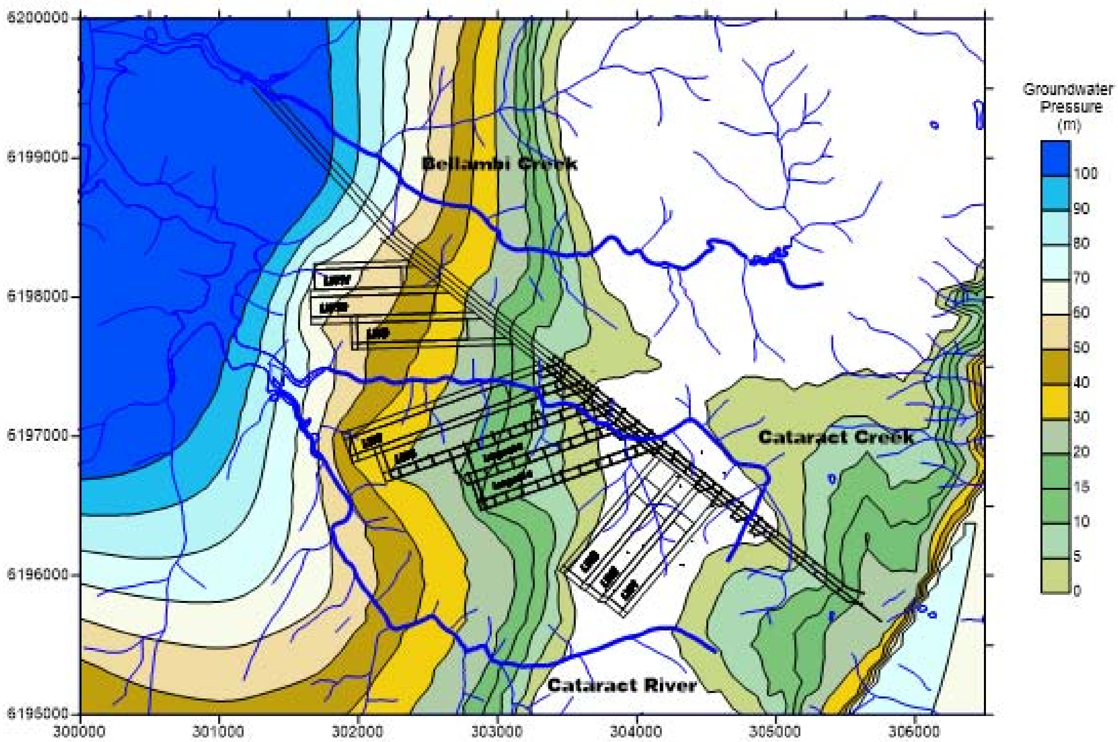



**Figure 78 Wongawilli Seam Groundwater Pressure after 50 Years Recovery**

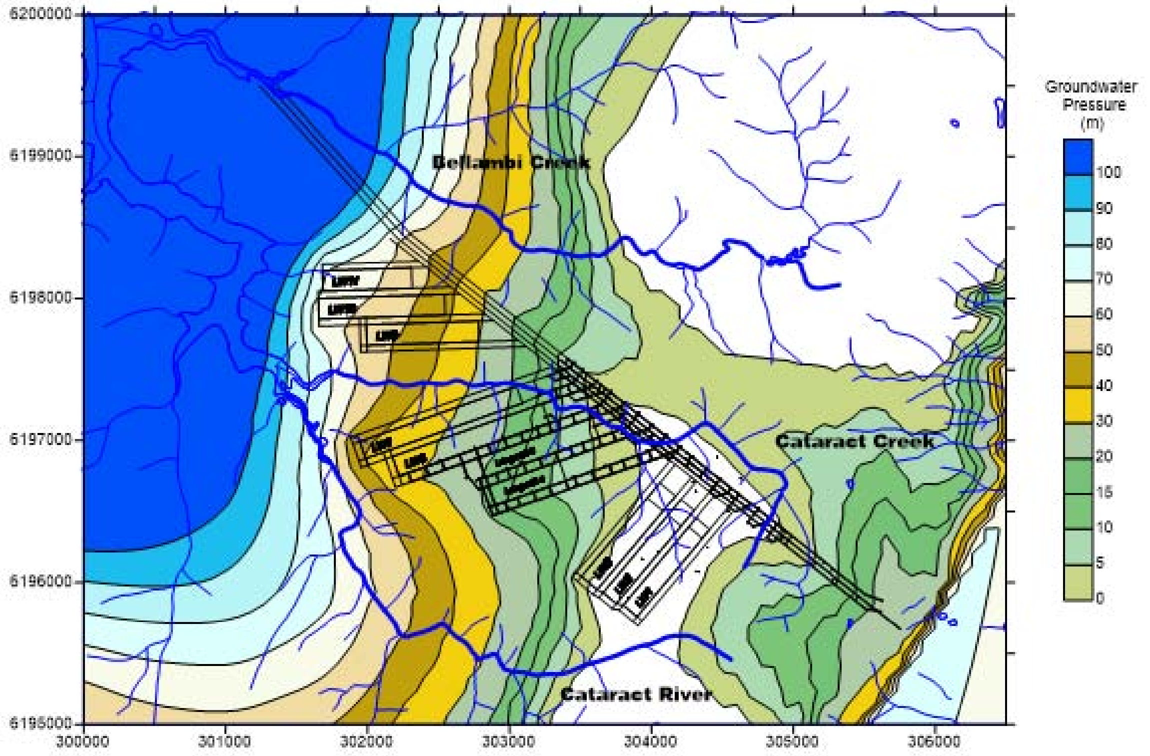



**Figure 79** **Wongawilli Seam Groundwater Pressure after 100 Years Recovery**

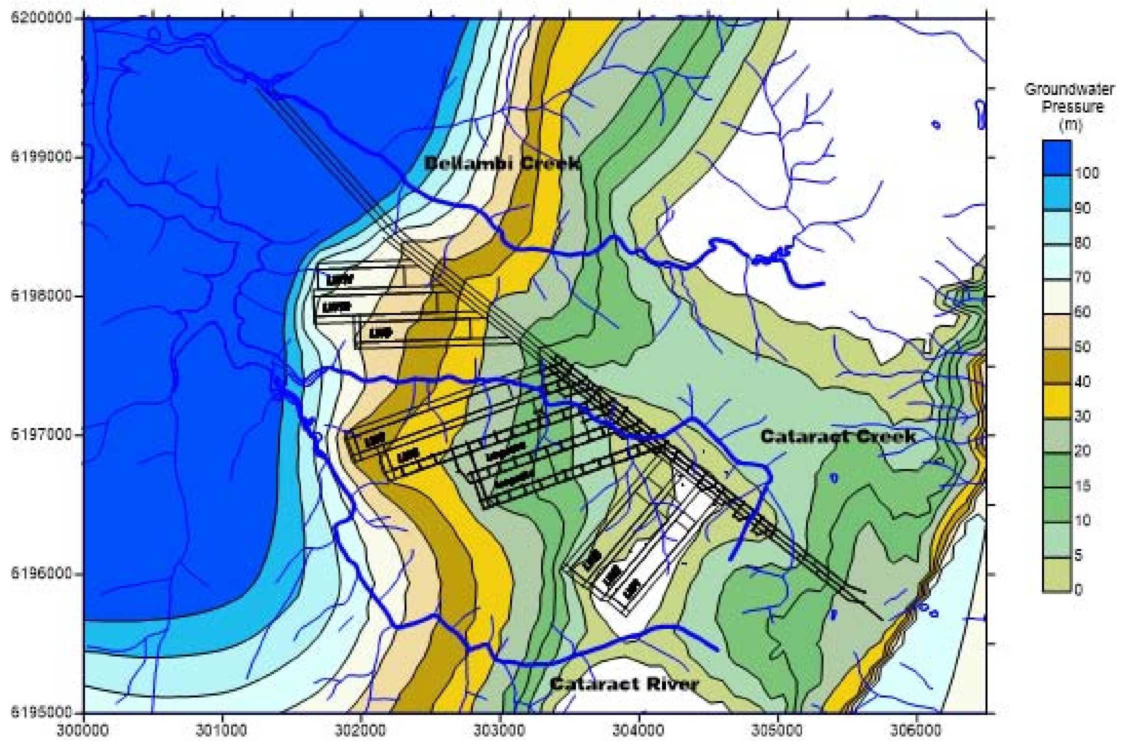



**Figure 80** **Wongawilli Seam Groundwater Pressure after 200 Years Recovery**

**Figure 81** shows a simulated recovery hydrograph at the location of vibrating wire monitoring bore GW1. It demonstrates the permanent dewatering evident within the Wongawilli Seam and the overlying strata up and including the Bulgo Sandstone.

**Figure 82** shows a simulated recovery hydrograph at the location of mine entry Adit for the Wongawilli Seam. It shows that groundwater levels recover to pre-mining levels and do not reach the elevation of the 117.5m AHD adit RL.

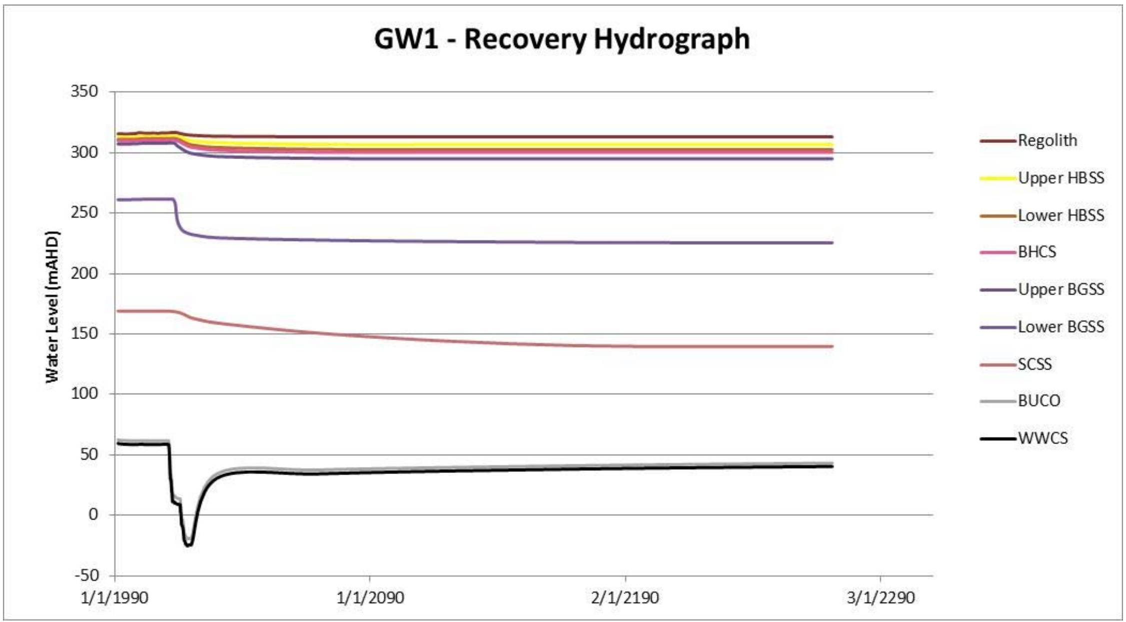



**Figure 81 Modeled Recovery Hydrograph for GW1**

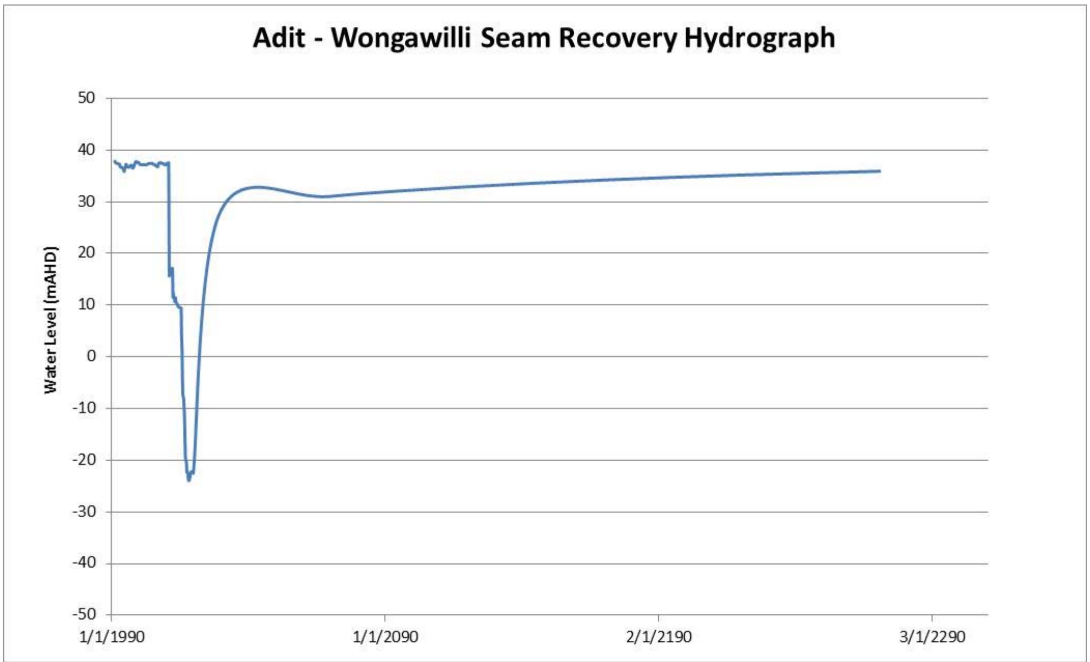



**Figure 82 Modeled Recovery Hydrograph for Wongawilli Seam Near Access Adit**

## 10.4 Stream and Groundwater System Connectivity

A number of mechanisms can potentially occur to 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 “losing” streams into the shallow groundwater system migrates along the local hydraulic gradient and re-emerges further downstream, 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 “gaining” streams during periods of high recharge, or;
- reduction of the perched and highly variable shallow groundwater contribution to swamps, and, subsequently, the local streams.

### 10.4.1 Cataract Creek

The geotechnical subsidence assessment (SCT Operations 2014) concluded the multi-seam mined Bulli and Balgownie Seam workings at Russell Vale 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, 2014).

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 Russell Vale East workings following significant rain in the catchments over the Russell Vale 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 10m of depressurisation in Layer 1 at the end of mining Russell Vale 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, as well as after the Balgownie Seam Longwalls and Longwalls 4, 5 and 6 (340m) in the Wongawilli Seam. It is not anticipated that the incremental effect due to extraction of the remaining length of Longwall 6 and Longwalls 1, 2, 3, 7, 9, 10 and 11 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 to 6 (340m) 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 13ML/d of which 4.1ML/d is baseflow, with a median baseflow of 2.9ML/d (WRM Water & Environment, 2015).

The groundwater modelling predicts a 0.041ML/day (14.9ML/year) transfer of stream flow from the stream beds to the underlying strata in the Cataract Creek, Cataract River and Bellambi Creek catchments at the end of the proposed mining as shown in **Table 7** and **Figure 64**.

It should be noted, however, that this does not mean that all of the 14.9ML water volume is "lost" as flow into the reservoir, as a portion of the 14.9ML will migrate to the reservoir via lower elevation, down-gradient, groundwater seeps into the lower catchments and reservoir. It is beyond the capacity of the groundwater or surface water models to specify how much of the 14.9ML will enter the reservoir via groundwater seepage from stream flows that were transferred from the stream bed into the underlying strata.

The modelled (0.32%) 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 Russell Vale 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 7** and **Figure 64**.

The modelling predicts a reduction in baseflow of 0.00035ML/day (0.14ML/yr) in the Cataract River (upstream of Cataract Reservoir) and a gain in baseflow of 0.00064ML/day (0.23ML/yr) in Bellambi Creek at the of the proposed mining. The modelled annual changes for the Cataract River (0.003%) and Bellambi Creek (0000000.1%) flows are therefore relatively minor compared to the average annual stream flow into Cataract Reservoir.

**Table 7 Modelled Cataract Creek, Cataract River and Bellambi Creek Stream Flow Changes**

| | Current Baseflow Loss (ML/day) / (ML/year) | Baseflow Loss Due to Proposed Mining Compared to Current Flows (ML/day) / (ML/year) |
|---|---|---|
| **Cataract Creek (Upstream of Cataract Reservoir)** | | |
| **Current** | 0.001 / 0.37 | - |
| **End of Mining** | 0.042 / 15.33 | 0.041 / 15.0 |
| **Cataract River (Upstream of Cataract Reservoir)** | | |
| **Current** | 0.00065 / 0.23 | - |
| **End of Mining** | 0.001 / 0.37 | 0.00035 / 0.14 |
| **Bellambi Creek** | | |
| **Current** | 0.00065 / 0.23 | - |
| **End of Mining** | 0.00001 / 0.004 | -0.00064 / -0.23 (gain) |
| **TOTAL** | | **0.041 / 14.9** |

### 10.4.3 Shallow Groundwater Contribution to Swamps

The volumetric contribution of shallow perched aquifer groundwater to swamps, and subsequently, as outflow drainage to the local streams is addressed in Biosis (2014A) and WRM Water and Environment (2015).

Although no direct installation and monitoring of shallow ephemeral groundwater systems and their contribution to swamp water levels has been conducted to date, monitoring of piezometer water levels within previously (and potentially) undermined swamps has been assessed by Biosis (2014A), whilst their discharge outflow rates have been determined by WRM Water and Environment (2015), who ascertained that the swamps are not, as is widely assumed, significant, long term contributors of baseflow to stream flow at Russell Vale East.

Swamp CCUS4, which overlies Wongawilli Seam Longwall 6, is predicted by Biosis (2014A) to be the most likely swamp that may undergo reductions in swamp groundwater levels and outflow discharge to Cataract Creek.

Monitoring to date (WRM Water and Environment, 2015), indicates that flow sites CT3A and CT3, which lie downgradient of the as yet not undermined swamp CCUS4, and CT1, CT1A and CT2, which lie downgradient of previously undermined swamps over Longwalls 4 and 5, do not have a significant and sustained baseflow discharge into Cataract Creek.

Peak flows of up to 20ML/day were monitored after the April 2015 storm at CT2 and CT3 / 3A which lasted for a day or slightly more after the storm, dropping off rapidly to a background outflow of 2-5ML/day after less than a week, then to very low to no outflow (<1ML/day) after that.

## 10.5 Cataract Reservoir

Cataract Reservoir has a full operating storage of 97,190ML. The lowest level of the storage as advised by Water-NSW 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 14.9ML/year from the Cataract Creek, Cataract River and Bellambi Creek catchments at the end of the proposed mining at Russell Vale East is less than 0.05% of the low level storage, or 0.015% of its full storage capacity.

The potential 14.9ML/yr loss of stream flow discharge into Cataract Reservoir is also very small compared to the potential evaporation off the surface of the full reservoir of 120,700ML/year.

It should be recognised that the potential loss of stream flow addressed by WRM Water and Environment (2015) relates to the very highly unlikely, potential worst case impact of 7.3ML/day (2,665ML/year) in the situation where all surface runoff catchments upgradient of and overlying the proposed secondary extraction areas are cracked and all affected catchment runoff is diverted away from the streams and does not re-emerge further downstream as groundwater seeps.

The mechanism addressed by the groundwater model is the impact relating to regional depressurisation of the underlying aquifers, with associated groundwater level reduction, and as a result, reduction in groundwater baseflow to the streams and the reservoir which is predicted at 14.9ML/year.

It is important to note that the two different predicted values of potential stream flow loss address different mechanisms and that the two approaches do not “contradict” each other, as they address the issue from different angles.

As a result, the potential theoretical worst case stream flow loss, which WRM Water and Environment (2015) point out, is very highly unlikely to occur, would be WRM’s value of 7.3ML/day (2,665ML/yr), of which the groundwater modelled prediction of 15ML/yr is a component.

#### 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 reservoir is 0.00024ML/day (0.1ML/year) at the end of mining. The modelled sub-surface transfer of 0.1ML /year from the stored waters at the end of the proposed mining is less than 0.0003% of the low level, or 0.0001% of its full storage capacity.

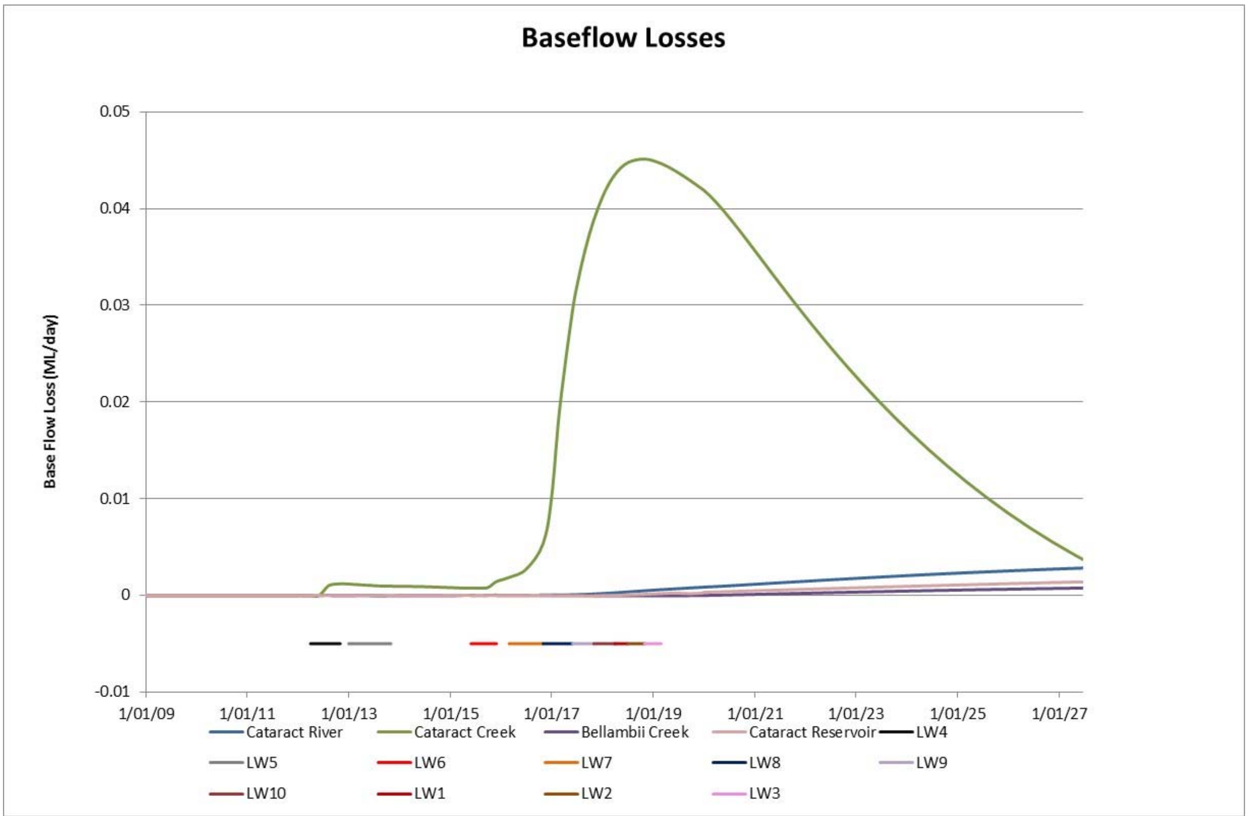



**Figure 83 Russell Vale East Stream and Cataract Reservoir Depressurisation Related Base Flow Losses**

### 10.6 Subsidence Interaction with Faults and Dykes

The Corrimal Fault is mapped as crossing over the proposed Russell Vale 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 or LW7 (SCT Operations, 2015). 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 is predicted to reduce to no displacement at Longwall 7.

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 underlies the reservoir. This observation indicates that 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, or significant drainage from the reservoir to the mine, is not considered likely.

The thin (<1m wide) highly weathered dyke D8 is located over the Russell Vale 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).

Although SCT Operations (2015) has discounted the possibility of it occurring, if inflow monitoring in the mine indicates 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, 2015), 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 groundwater inflows to the proposed Russell Vale East and the old Bulli Seam workings at Russell Vale West workings for each stage of mining are shown in **Table 8** and **Figure 84**.

The proposed extraction at Russell Vale East 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 and also up dip of initial extraction in the Wongawilli Seam.

A background groundwater inflow of 0.6ML/day is currently measured from the dormant Bulli Seam workings including that from the western side of Cataract Reservoir. These inflow rates are variable in the recorded flow data however the average rate for the period from 1/1/2013 – 31/12/2014 is 0.6ML/day (219ML/year). These rates decrease in eastern areas as groundwater makes its way vertically into Wongawilli Seam workings as mining progresses.

However, it should be noted that approximately 0.6ML/day is pumped out at Russell Vale portal from the Bulli seam workings at Russell Vale West. It is assumed that this includes 0.2ML/day (73ML/year) of inflow that is thought to be generated in the up-gradient Cordeaux Colliery lease area as this area is partially flooded and there is a potential head gradient across the barrier with the western Bulli Seam workings in the order of 40m.

In addition, 0.2ML/day (73ML/year) of groundwater seepage inflow from Russell Vale East is also thought to be generated from the up-gradient Bulli Colliery.

**Table 8 Predicted Groundwater Mine Inflows**

| Stage | Bulli Seam Inflow (ML/day) and (ML/year) | Predicted Russell Vale East Inflow (ML/day) and (ML/year) | Total Mine Inflow (ML/day) and (ML/year) | Total Licensable Inflow (ML/year) (excluding up gradient inflow of 146ML/year) |
|---|---|---|---|---|
| **Pre Longwall 4** | 0.40 / 146 | 0.20 / 73 | 219 | 73 |
| **Post Longwall 5** | 0.49 / 179 | 1.04 / 383 | 1.54 / 562 | 416 |
| **Post Longwalls 6 and 7** | 0.48 / 178 | 2.27 / 826 | 2.75 / 1004 | 858 |
| **Post Longwalls 9 to 11** | 0.49 / 179 | 2.73 / 996 | 3.22 / 1175 | 1029 |
| **Post Longwalls 1 to 3** | 0.50 / 183 | 2.82 / 1029 | 3.32 / 1212 | 1066 |

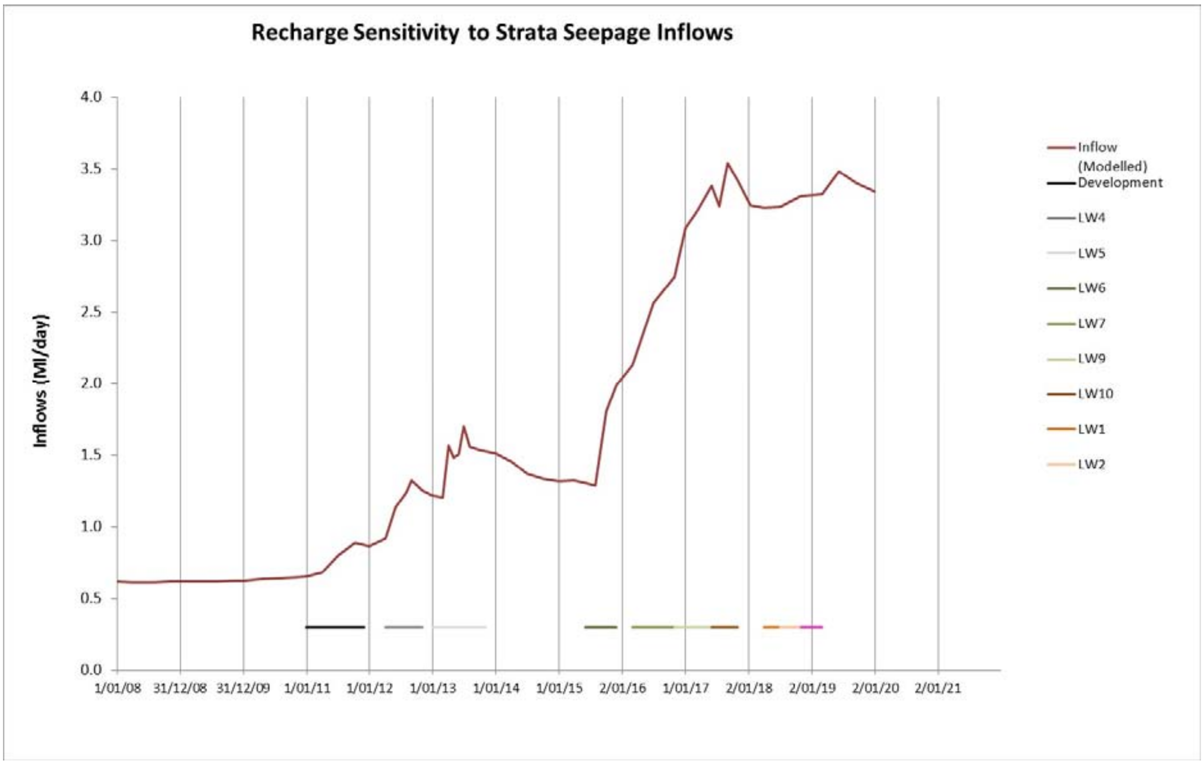



**Figure 84 Predicted Total Groundwater Seepage Inflows**

The groundwater inflow rate levels off after completion of extraction of Longwall 11 in 2018 because this marks the end of mining activities in the down dip region of the mining proposal. After this period, mining activities relocate up dip to LW1 – LW3 where dewatering of the Wongawilli seam and some depressurisation of overlying strata has already occurred.

### 10.8 Groundwater Chemistry

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 groundwater of adverse quality is anticipated to discharge into the reservoir 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 Russell Vale lease 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, and no swamps are present downstream of, the Wollongong Coal Russell Vale 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 Colliery (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

## 12.1 Recharge Sensitivity

An analysis has also been carried out to assess the sensitivity to the assumed input parameters for recharge.

The sensitivity analysis was carried out on a steady state model using the stress period from the end of the calibration period and groundwater level data from a range of dates not necessarily active in that period.

This model was not part of the original calibration and was utilised only for the purpose of a sensitivity run. Given that the model is not in steady state during this period, calibration with groundwater level data is not as accurate as that indicated in Section 9.12.

While the model is not under steady state conditions, steady state calibration statistics do not deteriorate dramatically from the base case model calibration statistics with an RMS of 16.7, and a SRMS of 6.9%. Although this is not a satisfactory calibration point, it serves as a baseline to make the comparisons.

The sensitivity analysis was undertaken by first decreasing and then increasing recharge and evaluating the impacts of the changes on the target heads from monitoring data by comparing to the “base” case.

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. Three recharge zones within the base case model were included. However, note that in the base case model, zone 3 is identical to zone 2 and was used to investigate potential downward leakage of rainfall recharge over LW4 and LW5 in the base case calibration model. It is useful here to again investigate this potential. Zone 2 occupies the higher ridgeline areas where higher vertical conductivities were included.

**Figure 85** shows the recharge zonation within the base case model.

**Figure 86** shows the results of the sensitivity analysis whereby calibration performance is measured in terms of the sum of residuals of targets heads. It shows that increasing and decreasing recharge over the model domain in zones 1 and 3 does not improve calibration performance. Decreasing slightly in zone 2 does improve the calibration statistics slightly however this deteriorates rapidly as recharge levels drop.

As the model was built with elevated hydraulic conductivities in the ridgelines extending to the Bald Hill Claystone in zone 2 into which the upper part of the fracture zone extends, there is the potential for variability of groundwater strata seepage into mine workings.

**Figure 87** shows the mine inflow for the base case and with recharge across the transient base case model with multipliers of 0.5 and 2. It shows that under the current model construction set up, variability in mine inflow can be induced with variable rainfall. Most of this being derived through Bulli Seam workings in the Russell Vale East area, hence the variation seen within the pre Wongawilli development.

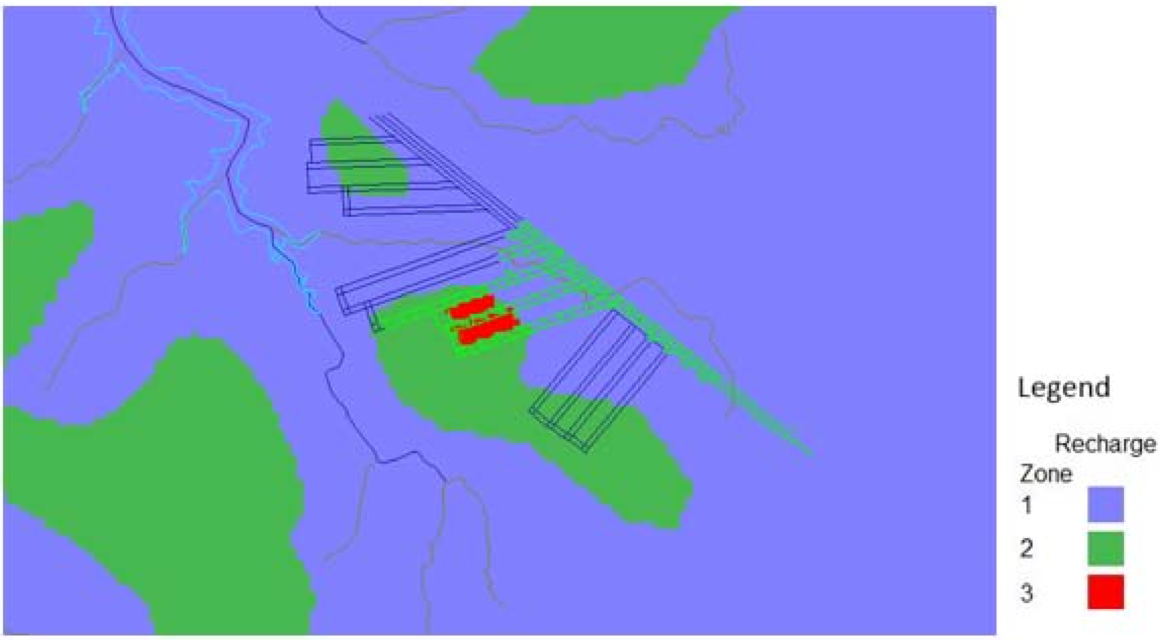



**Figure 85 Recharge Sensitivity Analysis Results**

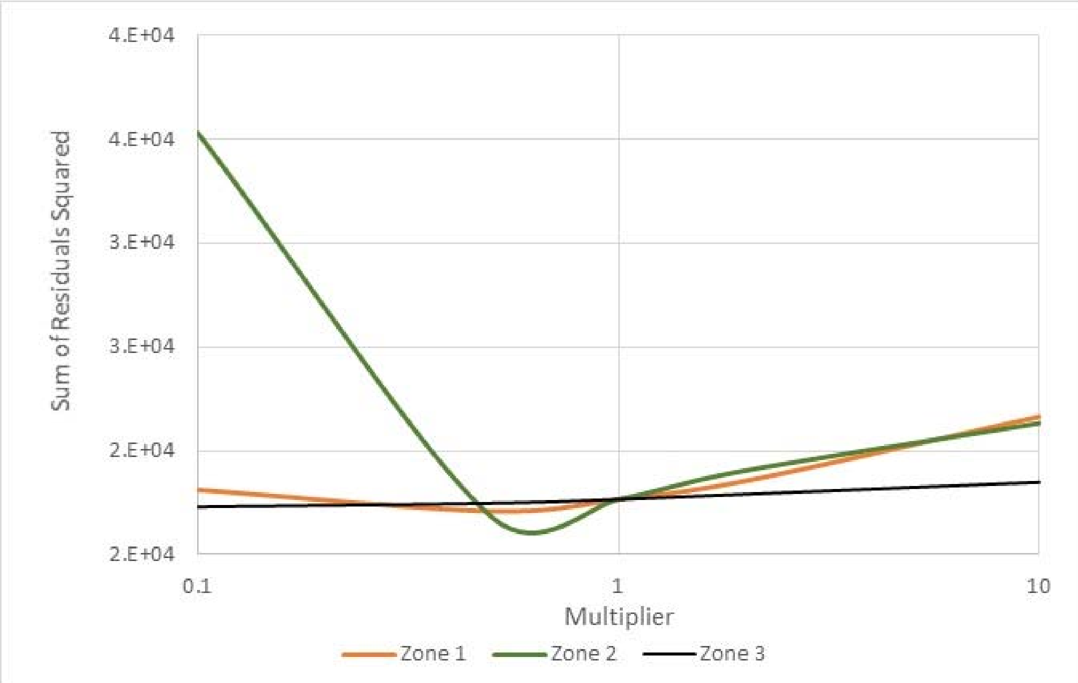



**Figure 86 Recharge Sensitivity Analysis – Sum of Residuals**

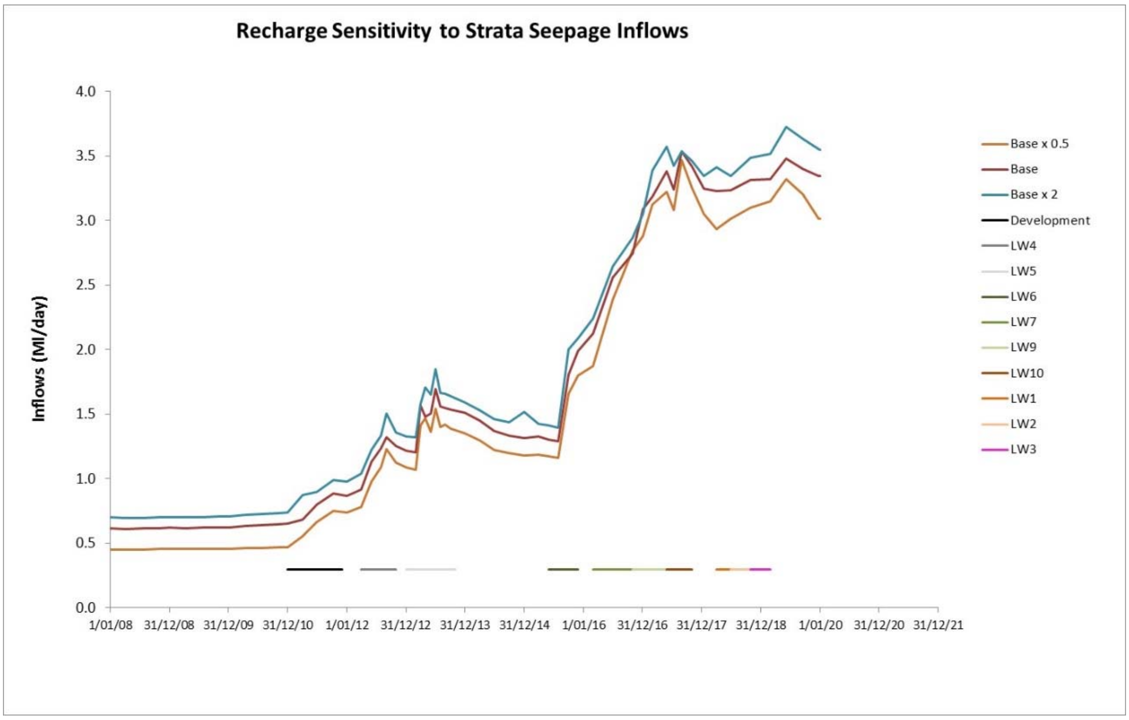



**Figure 87 Recharge Sensitivity to Strata Seepage Inflows**

### 12.2 Storage Sensitivity

Storage coefficient [S] is the parameter that controls the rate of recovery of groundwater head.

Sensitivity analysis was performed on this parameter by increasing it from the base case by a factor of 10. Therefore, the specific yield increased to 0.05 and storage coefficient increased to 0.0001 for the sandstone and the coal seam layers, and the specific yield and storage coefficient increased to 0.01 and 0.00001 respectively in claystone, shale and in the deepest formation.

### 12.3 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 Russell Vale east mining domain within the overall Study Area at a sufficiently detailed scale.

The previous modelling, undertaken as part of the original PPR assessment, looked at the possible connection of surface water features to a potential subsidence generated depressurisation field and subsequent depletion of stream flow. Depletion of stream flow within overlying drainage pathways was recognised as 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 was undertaken where hydraulic conductivity fields were randomly generated with variability based on statistics were derived from the packer test database. This stochastic approach was used to explore the uncertainty in the model predictions arising from hydraulic property heterogeneity and in this case, specifically lateral or horizontal hydraulic conductivity.

Variation of the conductivity field was limited to the horizontal plane only because the base case predictions indicated that depressurisation to surface was 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 model predicted 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.

Changes to baseflow losses in Cataract Creek showed a variability of up to +/- 100% on the Base Case scenario. Mine seepage inflow rates varied +/- 20% from Base Case results.

Although this model has had changes made to the hydraulic conductivity fields and the model code has been changed, it is fundamentally very similar to the earlier work and is assumed to perform in a similar manner to this stochastic modelling approach. Therefore it has not been repeated.

# 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 localised effects of near-surface tensile stream bed cracking due to valley closure and valley uplift effects on stream flow, nor has it been designed to assess subsidence effects on swamp water levels or discharge volumes.

The model does not include specific assessment of 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, hydraulic parameters and their resultant attributes as post subsidence barriers or transmissive conduits.

The model has been designed with the main objectives being to simulate water level variability to mining stresses, to assess groundwater seepage to underground mining areas and to assess the potential impact with surface water features.

Outcomes from the model heavily relied on calibration against targets such as groundwater levels and mine water pumping rates which were supplied by the proponent and were recently reviewed and updated, but still have a degree of uncertainty due to their short (<2 year) reliable data records.

# 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 groundwater inflow make into the WCL workings of 1066ML/year, Wollongong Coal will require a WAL for at least 701ML/year in addition to their current licence. This is the maximum predicted inflow (1066ML/year) minus the existing licensing entitlement (365ML/yr).

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 14.9ML/yr at the end of mining as shown in **Table 9**.

**Table 9 Surface Water Licensing Requirements**

| Surface Water Source | Predicted Surface Water "Take" (ML/year) |
|---|---|
| **Russell Vale East Stream Baseflow** | 14.9 |
| **Cataract Reservoir Leakage** | 0.1 |
| **(TOTAL)** | **15.0** |

Volumetric assessment of potential annual stream flow changes due to valley closure related cracking and transfer to sub-surface flow cannot 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 variable 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 overall 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 15.0 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 10** and for the perched, ephemeral aquifers in **Table 11**.

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 10 NSW Minimal Impact Considerations for Less Productive Porous Rock Water Sources**

| Minimal Impact Consideration | Proponent Response |
|---|---|
| Water Table – Level 1<br><br>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:<br><br>a) high priority groundwater dependent ecosystem, or<br>b) high priority culturally significant site listed in the schedule of the relevant water sharing plan, or<br><br>A maximum of a 2 m decline cumulatively at any water supply work unless make good provisions should apply. | There are no:<br><br>• high priority groundwater dependent ecosystems, or;<br>• high priority culturally significant sites<br><br>listed under Schedule 4 of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011.<br><br>The swamps above the mine plan are not classified as Temperate Highland Peat Swamps on Sandstone (which is high priority GDE).<br><br>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<br><br>If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any:<br><br>a) high priority groundwater dependent ecosystem; or<br>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.<br><br>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<br><br>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<br><br>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<br><br>a) Any change in the groundwater quality should not lower the beneficial use category of the | The beneficial use category of the groundwater source will not be changed beyond 40m from the Wonga East proposal area. |

| | |
|---|---|
| groundwater source beyond 40m from the activity, and<br><br>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.<br><br>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.<br><br>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”. | There are no highly connected surface water sources (alluvial aquifers) in the Wonga East proposal area<br><br>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><br><br>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.<br><br>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.<br><br>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 11 NSW Minimal Impact Considerations for Perched Ephemeral Aquifer Water Sources**

| Minimal Impact Consideration | Proponent Response |
|---|---|
| Water Table – Level 1<br><br>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:<br><br>c) high priority groundwater dependent ecosystem, or<br>d) high priority culturally significant site listed in the schedule of the relevant water sharing plan, or<br><br>A maximum of a 2 m decline cumulatively at any water supply work unless make good provisions should apply. | There are no:<br><br>• high priority groundwater dependent ecosystems, or;<br>• high priority culturally significant sites<br><br>listed under Schedule 4 of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011.<br><br>The swamps above the mine plan are not classified as Temperate Highland Peat Swamps on Sandstone (which is high priority GDE).<br><br>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<br><br>If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any:<br><br>c) high priority groundwater dependent ecosystem, or<br>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.<br><br>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<br><br>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<br><br>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<br><br>d) Any change in the groundwater quality should not lower the beneficial use category of the | The beneficial use category of the groundwater source will not be changed beyond 40m from the Wonga East proposal area. |

| | |
|---|---|
| groundwater source beyond 40m from the activity; and<br><br>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.<br><br>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.<br><br>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". | There are no highly connected surface water sources (alluvial aquifers) in the Wonga East proposal area<br><br>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><br><br>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.<br><br>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.<br><br>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 12**.

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 12 Groundwater Level Monitoring Suite**

| | **Piezometer Type** |
|---|---|
| **Basement** | |
| NREA, C, D, E, G, NRE3, GW1A, RV18, 19, 21, 22A, 23A | Open Standpipe |
| NREA, B, D, NRE3, GW1, RV16, 17, 20, 22, 23 | 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 13**.

**Table 13 Standing Water Level Monitoring Method and Frequency**

| Monitoring Site | Sampling Method | Frequency / Download | Units |
|---|---|---|---|
| Open standpipe piezometers | Water level logger / dip meter | twice daily / bi-monthly | mbgl |
| Vibrating wire piezometer arrays | Vibrating wire piezometer | twice daily / quarterly | m head pressure |

**NOTE**: mbgl = meters below ground level

## 16.2 Groundwater Quality

**Tables 14** and **15** 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 14 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 15 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 (2014A) 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 Cataract Reservoir Water Storage

Water stored within Cataract Reservoir and any potential adverse effects from the proposed mining will be managed through monitoring of the mine inflow volumes and piezometer water levels / heads between the proposed workings and the reservoir.

Any potential changes to the water quality of the reservoir will be monitored through assessment of the discharging stream water quality in Cataract Creek (Site CC8 and / or CC9) and in Cataract River at Site CR3 or CR4, depending on the height of the reservoir at the time of monitoring, along with at Site CD1 within the reservoir.

Specific details of the reservoir monitoring and management will be provided in a detailed monitoring and management plan that will be prepared and approved prior to commencement of the proposed mining.

### 16.6 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).

### 16.7 Rainfall

Daily rainfall data will be obtained from a local weather station for the duration of mining in the proposal catchment area.

### 16.8 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.

### 16.9 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.

## 16.10 Impact Assessment Criteria

### 16.10.1 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.

### 16.10.2 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 16.**

**Table 16 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.

### 16.11 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.

### 16.12 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.

### 16.13 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.

### 16.14 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 LWs 4, 5 and 6 (340m). 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 the remainder of Longwall 6, Longwall 7 and Longwalls 9-11 are planned to be mined first, and as they do not underlie 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
# Regulatory Review Summary

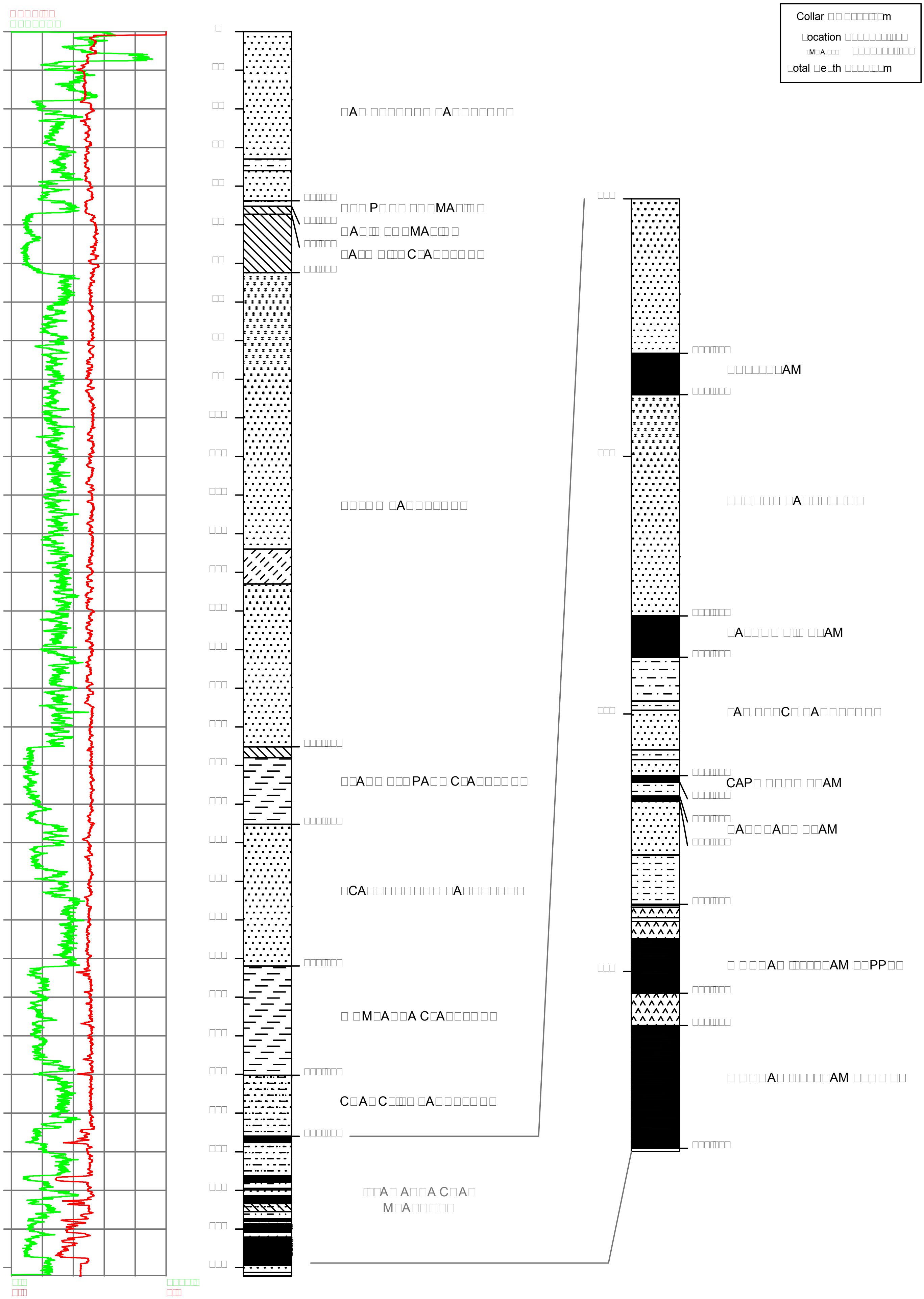
| Comment | Where Addressed |
|---|---|
| Reasoning behind the use of the same value of drainable porosity for all strata in the groundwater model since this parameter significantly influences the evolution of the phreatic surface and mine inflows; | Sections 9.13 / 12.2 |
| Discussion of revised model calibrations including presentation of hydrographs showing measured and predicted pressure heads using the ‘pseudo soil’ option; | Sections 9.12 / 9.13 and Appendix C |
| Illustration of model pressure heads (in plan) in the coal seams, Bulgo Sandstone and Hawkesbury Sandstone prior to, during and post mining (50 and 100 years); | Section 10.3 |
| Assessment of the long term steady state groundwater flow systems post mining and identification of shallow and surficial areas that are likely to be dewatered; | Section 10.3 |
| Assessment of potential leakage via the adit and assessment of the role played by the abandoned overlying workings (and their adits) in constraining the recovery of pore pressures; | Section 10.3 |
| Risk assessment associated with potential leakage from Cataract Dam via the proposed panel extractions and adit (see also Galvin & Associates report to the PAC dated 05/03/2015); | Risk assessment meetings have been conducted and provided to IRAP |
| Mitigation measures that might be invoked to minimise impacts. | Section 16.13 |
| Recommendation In view of the Proponent’s decision to discard the PPR-RM model in favour of an alternated mode, I suggest the PPR-RM be amended to include the revised modelling and any additional assessments that might be directed towards resolving the above noted issues. | See above |

# Appendix B
# Piezometer Installation Details

## RUSSELL VALE COLLIERY PIEZOMETERS

| HOLE NAME | CO-ORDINATES (MGA 56) E / N | | RL (M) | END DATE | TOTAL DEPTH (M) | INSTRUMENTATION | DOMAIN | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| NRE A | 303692.00 | 6196033.00 | 376.18 | 21/11/2009 | 47.2 | Open Standpipe | Russell Vale East | |
| NRE A VWP | 303680.00 | 6196034.00 | 376.18 | 01/12/2009 | 153.0 | VWP borehole | Russell Vale East | |
| NRE B | 303938.69 | 6197566.59 | 372.69 | 03/04/2009 | 173.1 | 4 VWP borehole | Russell Vale East | |
| NRE C | 303233.00 | 6198797.00 | 362.89 | 03/12/2009 | 24.0 | Open Standpipe | Russell Vale East | |
| NRE D | 301870.50 | 6198509.23 | 348.83 | 02/12/2009 | 52.0 | Open Standpipe | Russell Vale East | |
| NRE D VWP | 301875.00 | 6198493.00 | 348.83 | 01/12/2009 | 176.0 | 4 VWP borehole | Russell Vale East | |
| NRE1 GW1 | 303693.30 | 6196913.30 | 318.20 | 14/09/2012 | 170.1 | 8 VWP borehole | Russell Vale East | |
| NRE1 GW1a | 303741.80 | 6196983.10 | 311.70 | 22/08/2012 | 27.0 | Open Standpipe | Russell Vale East | |
| RV16 VWP | 303567.40 | 616288.10 | 362.30 | 01/07/2014 | 322.2 | 8 VWP borehole | Russell Vale East | |
| RV17 VWP | 301979.90 | 6196818.40 | 333.40 | 01/09/2014 | 79.9 | 4 VWP borehole | Russell Vale East | |
| RV18 OS | 302041.30 | 6196884.80 | 339.60 | 10/09/2014 | 20.5 | Open Standpipe | Russell Vale East | |
| RV19 OS | 301867.70 | 6196787.10 | 312.10 | 17/09/2014 | 18.4 | Open Standpipe | Russell Vale East | |
| RV20 VWP | 302934.50 | 6196629.20 | 373.50 | 19/12/2014 | 134.7 | 5 VWP borehole | Russell Vale East | collar not yet surveyed |
| RV21 OS | 302657.90 | 6197892.80 | 349.20 | 28/11/2014 | 22.9 | Open Standpipe | Russell Vale East | collar not yet surveyed |
| RV22 VWP | 303031.40 | 6197636.20 | 344.00 | 23/10/2014 | 234.3 | 8 VWP borehole | Russell Vale East | collar not yet surveyed |
| RV22a OS | 303033.70 | 6197630.70 | 343.80 | 28/10/2014 | 37.4 | Open Standpipe | Russell Vale East | collar not yet surveyed |
| RV23 VWP | 301373.40 | 6198236.30 | 297.80 | 21/11/014 | 222.4 | 8 VWP borehole | Russell Vale East | collar not yet surveyed |
| RV23a OS | 301374.70 | 6198231.50 | 297.60 | 26/11/2014 | 26.6 | Open Standpipe | Russell Vale East | collar not yet surveyed |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NRE E | 296727.00 | 6202286.00 | 329.30 | 23/10/2009 | 29.0 | Open Standpipe | Russell Vale West | |
| NRE F | 294803.00 | 6201954.00 | 359.27 | 05/12/2009 | 60.0 | Open Standpipe | Russell Vale West | |
| NRE G | 296949.00 | 6205678.00 | 363.00 | 20/10/2009 | 53.0 | Open Standpipe | Russell Vale West | |
| P501 | 298771.09 | 6201855.95 | 328.16 | 01/12/1992 | 338.0 | 5 VWP borehole | Russell Vale West | not drilled by NRE |
| P502 | 298597.95 | 6202049.05 | 319.33 | 01/08/1993 | 375.0 | 5 VWP borehole | Russell Vale West | not drilled by NRE |
| P514 | 297917.00 | 6204280.00 | | 01/01/1998 | 191.0 | Open Standpipe | Russell Vale West | not drilled by NRE |
| NRE3 | 294803.00 | 6201954.00 | 359.27 | 20/11/2009 | 60.0 | Open Standpipe | Russell Vale West | |
| NRE3 VWP | 294802.60 | 6201953.62 | 359.27 | 05/12/2009 | 282.4 | 4 VWP borehole | Russell Vale West | |




| | Name | Date |
|---|---|---|
| DRN | C | |
| CKD | | |
| APP | | |
| SCALE | | |

Title

DRAWING NUMBER

REV

Wo o Coa Ltd.

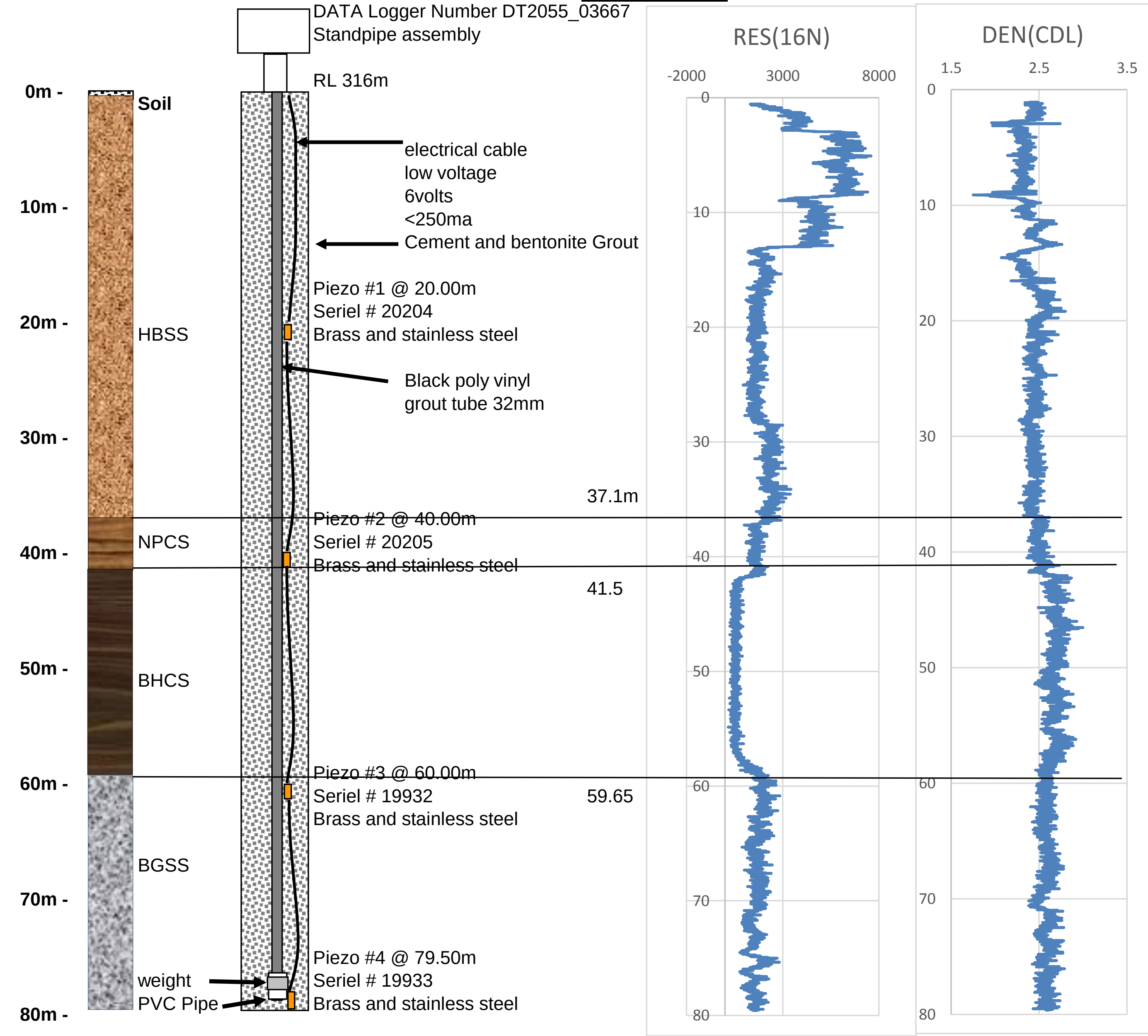
NSW 2518

ABN 28 111 244 896

# Wollongong Coal VW PIEZO INSTALLATION
# WELL CONSTRUCTION hole RV17

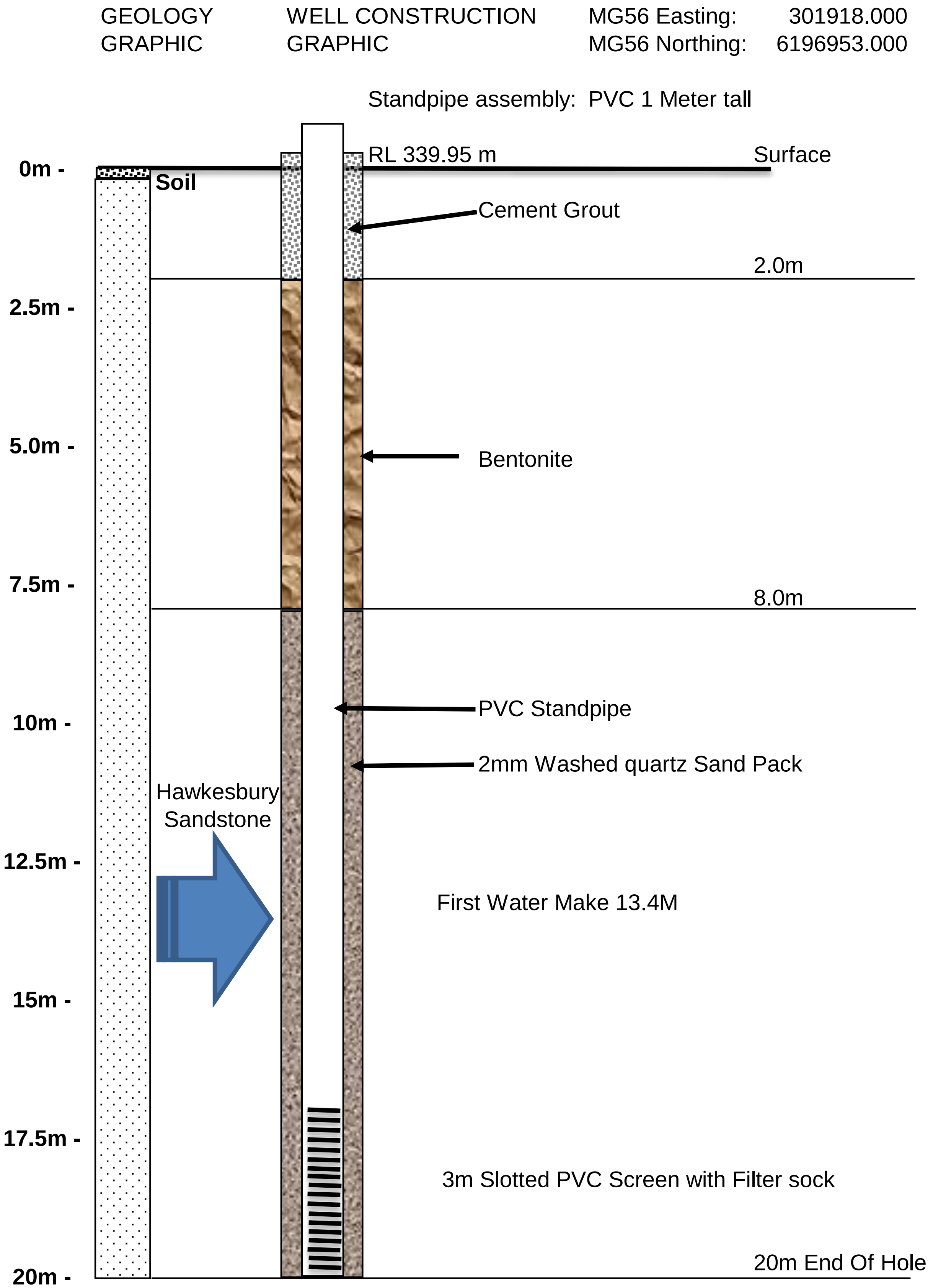
**Hole RV17** **Monday, 1 September 2014**

| | |
|---|---|
| Easting: | 301797.00 |
| Northing: | 6196927.00 |




**Total Depth 79.75m**

# Wollongong Coal Standpipe Piezometer
# RV18 WELL CONSTRUCTION
## Wednesday, 10 September 2014



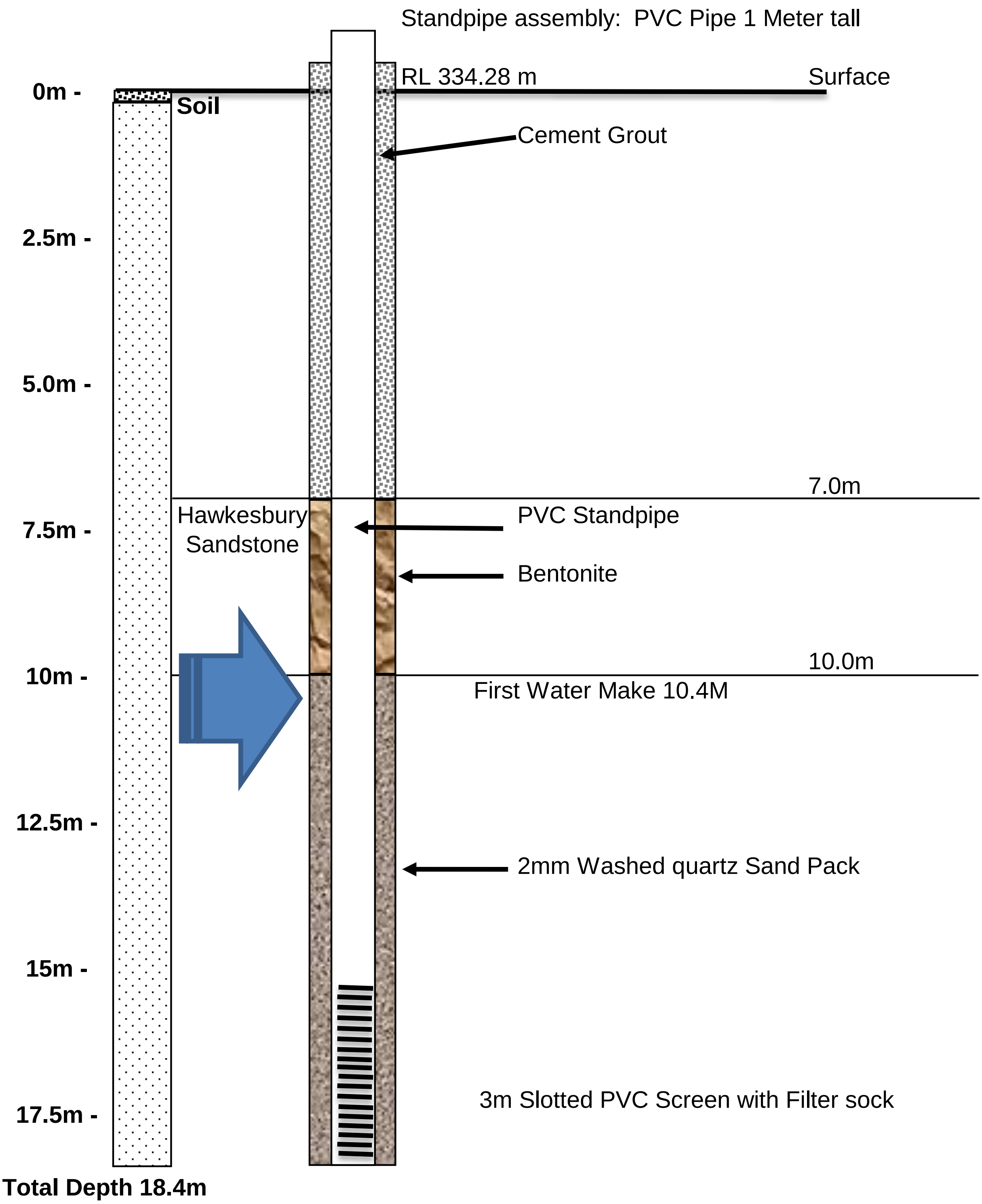

**Total Depth 20.0m**

# SCT Operations Pty Ltd

September 2014

# Wollongong Coal Standpipe Piezometer
# RV19 WELL CONSTRUCTION
## Wednesday, 17 September 2014

| GEOLOGY GRAPHIC | WELL CONSTRUCTION GRAPHIC | MG56 Easting: | 301862.000 |
| --- | --- | --- | --- |
| | | MG56 Northing: | 6196944.000 |

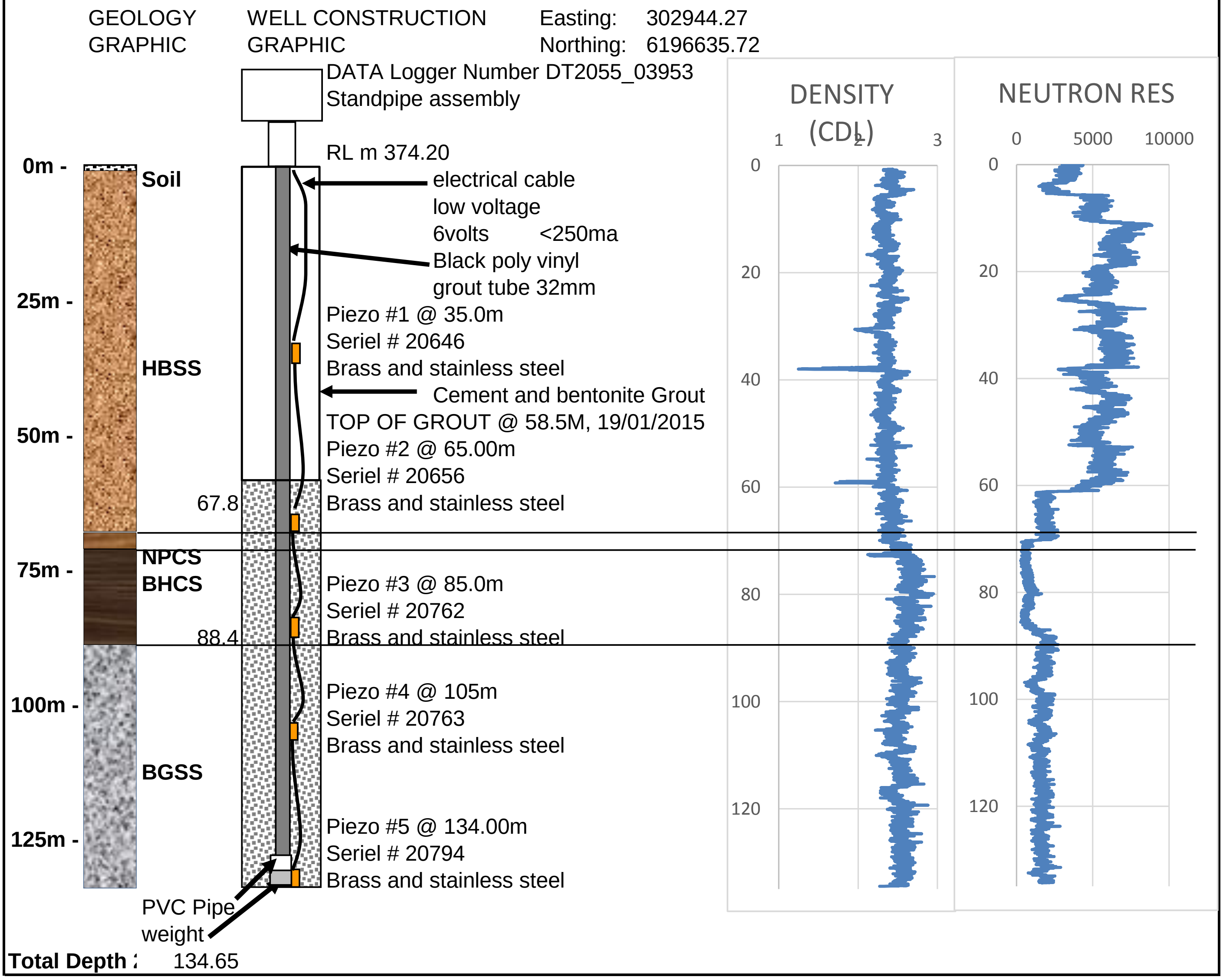



SCT Operations Pty Ltd

September 2014

# Wollongong Coal VW PIEZO INSTALLATION
# WELL CONSTRUCTION hole RV20

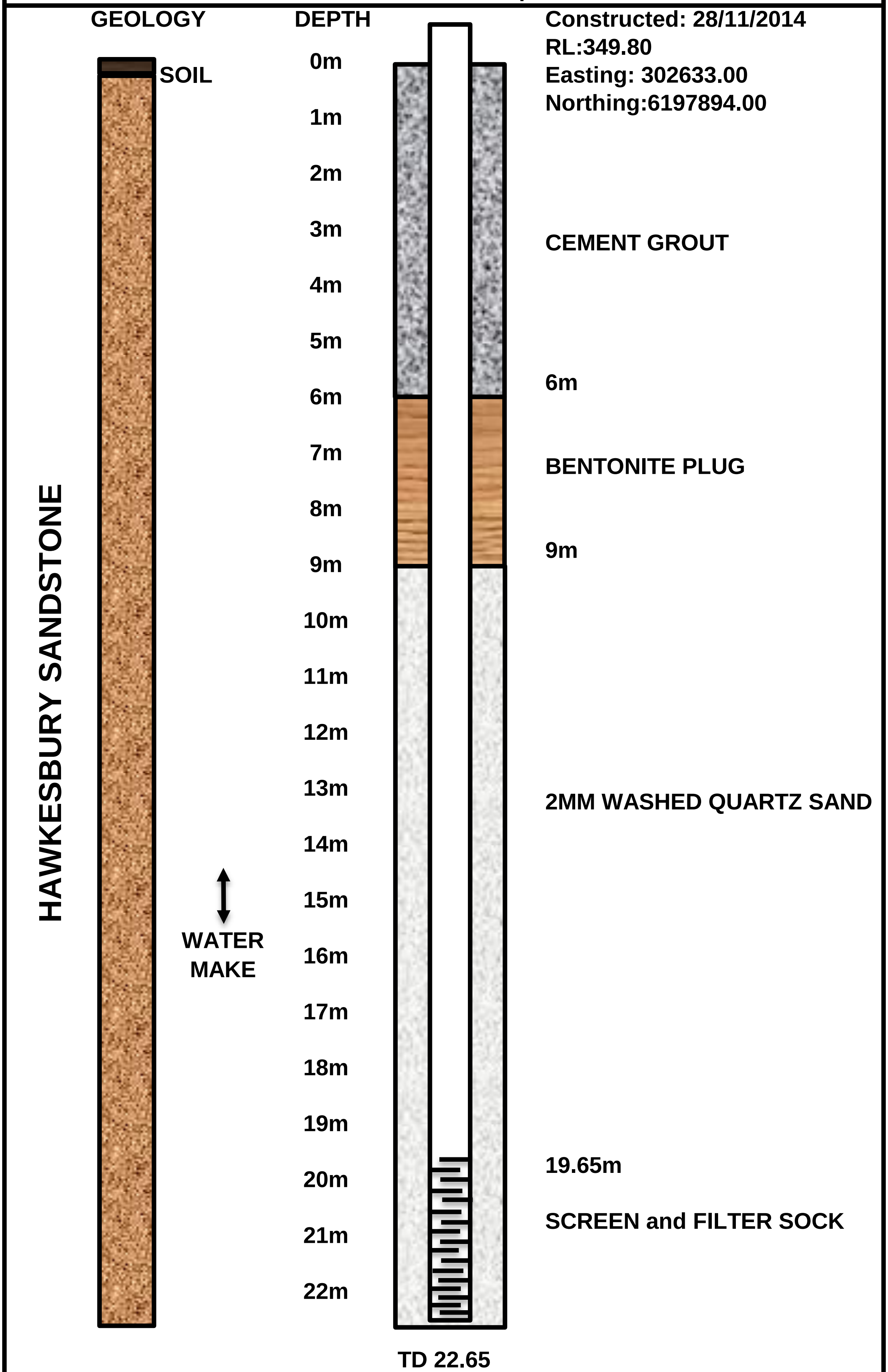
**Hole RV20** **Friday 15/12/2014**



# HOLE WCRV 21

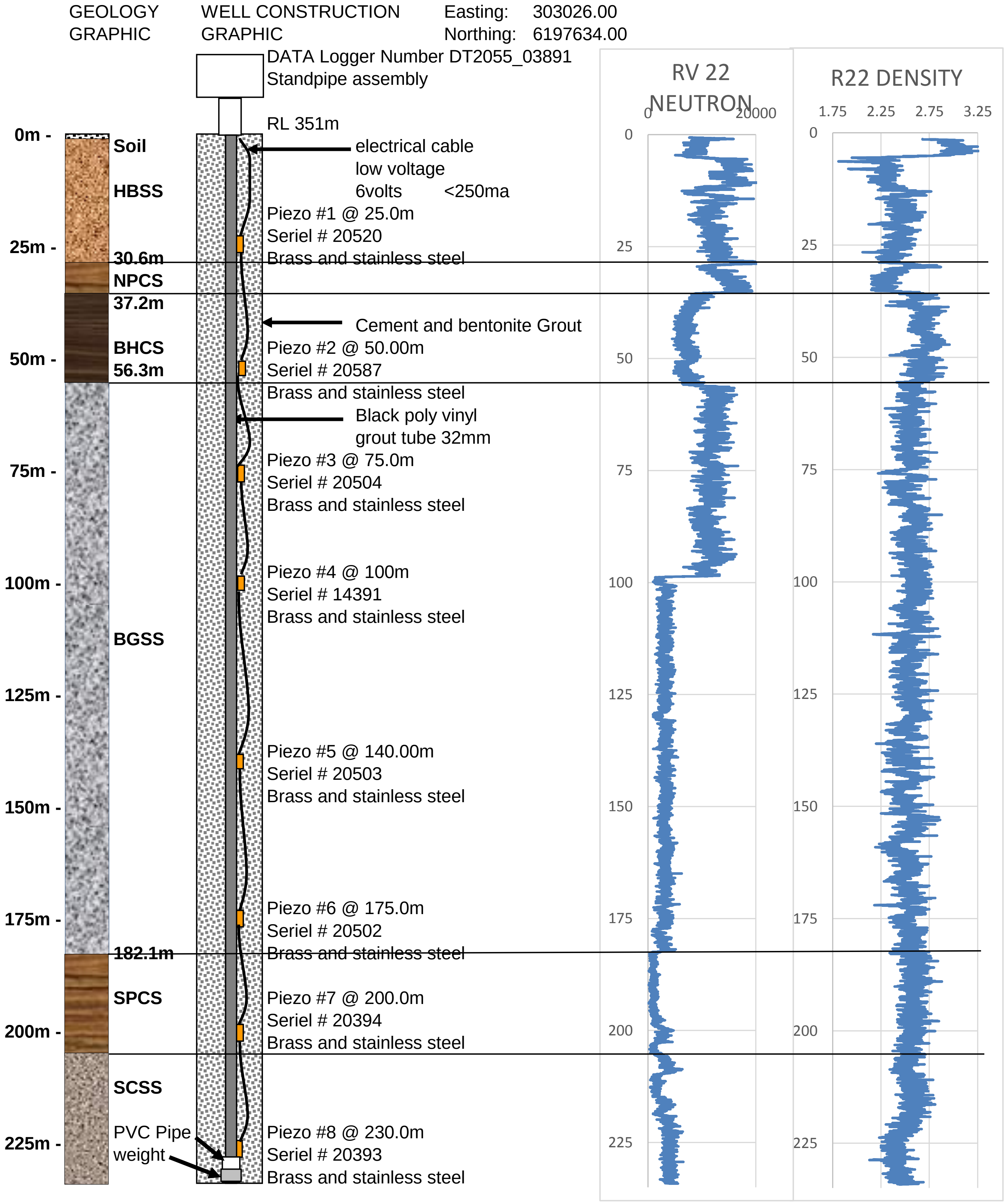
Hole Dia: 99mm PCD
CASING: 6 meters steel

STANDPIPE: 50mm PVC
PVC Stickup: 1.0m



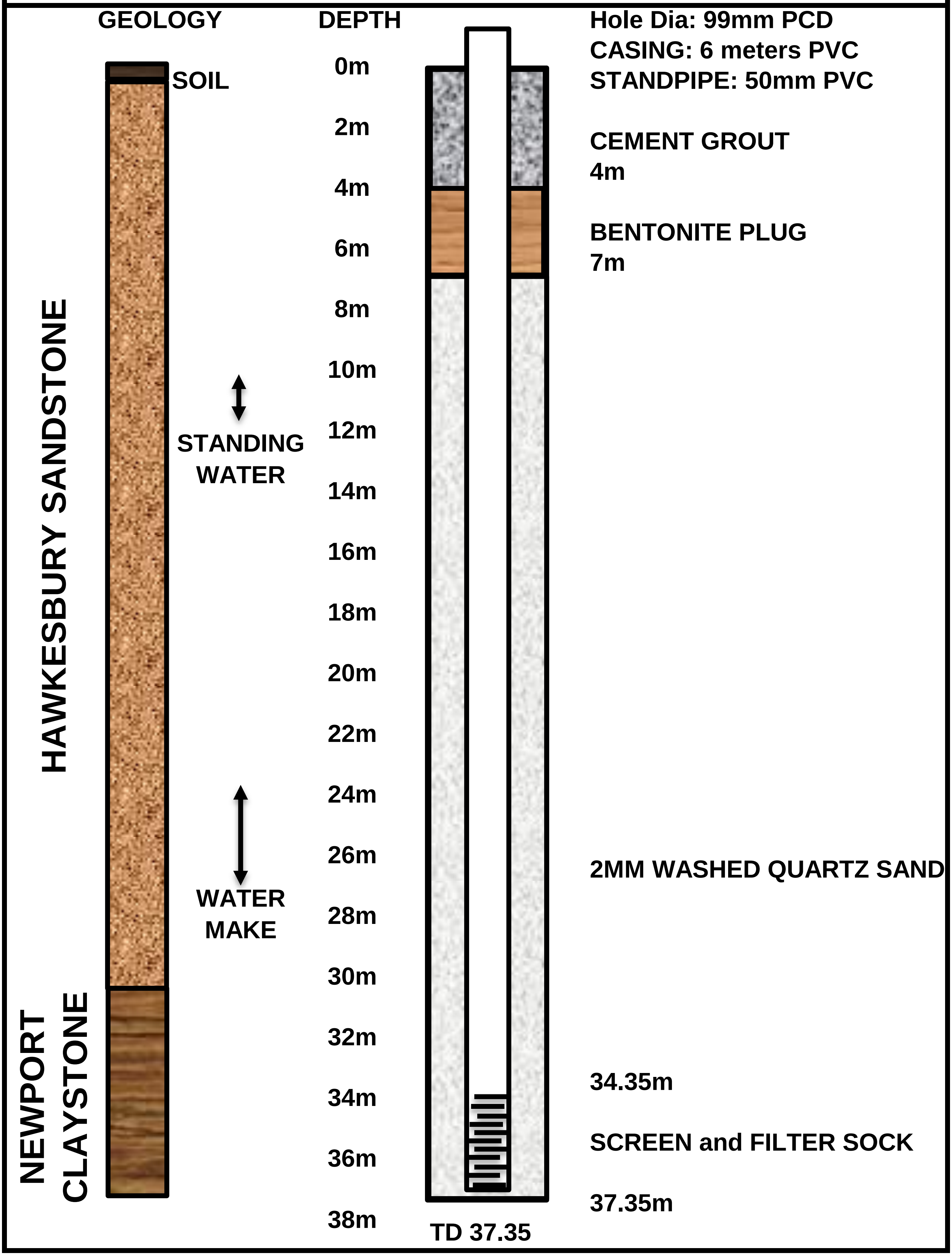
# Wollongong Coal VW PIEZO INSTALLATION
# WELL CONSTRUCTION hole RV22

**Hole RV22** **Thursday 23/10/2014**



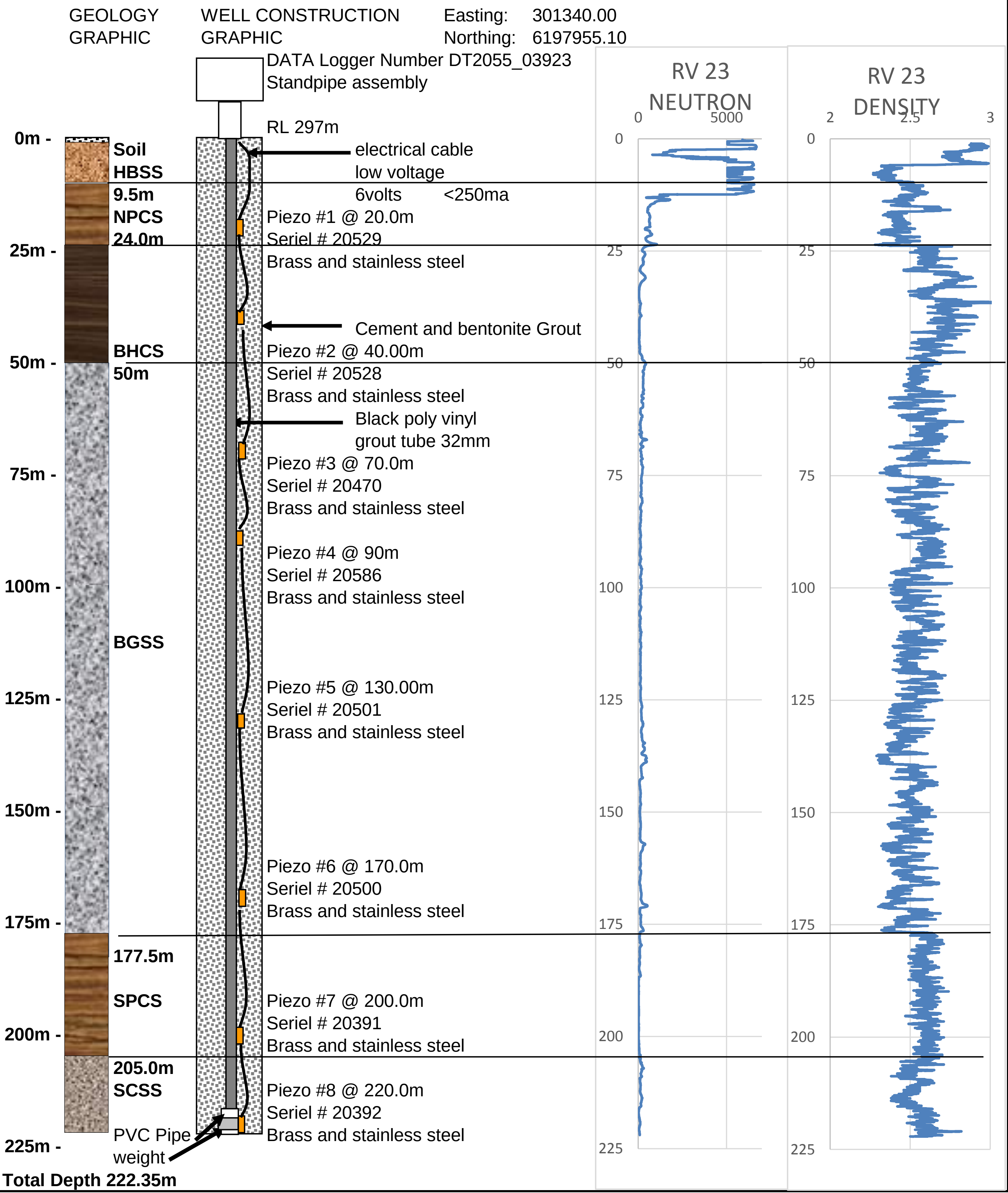

**Total Depth 234.3m**

# HOLE WCRV 22A

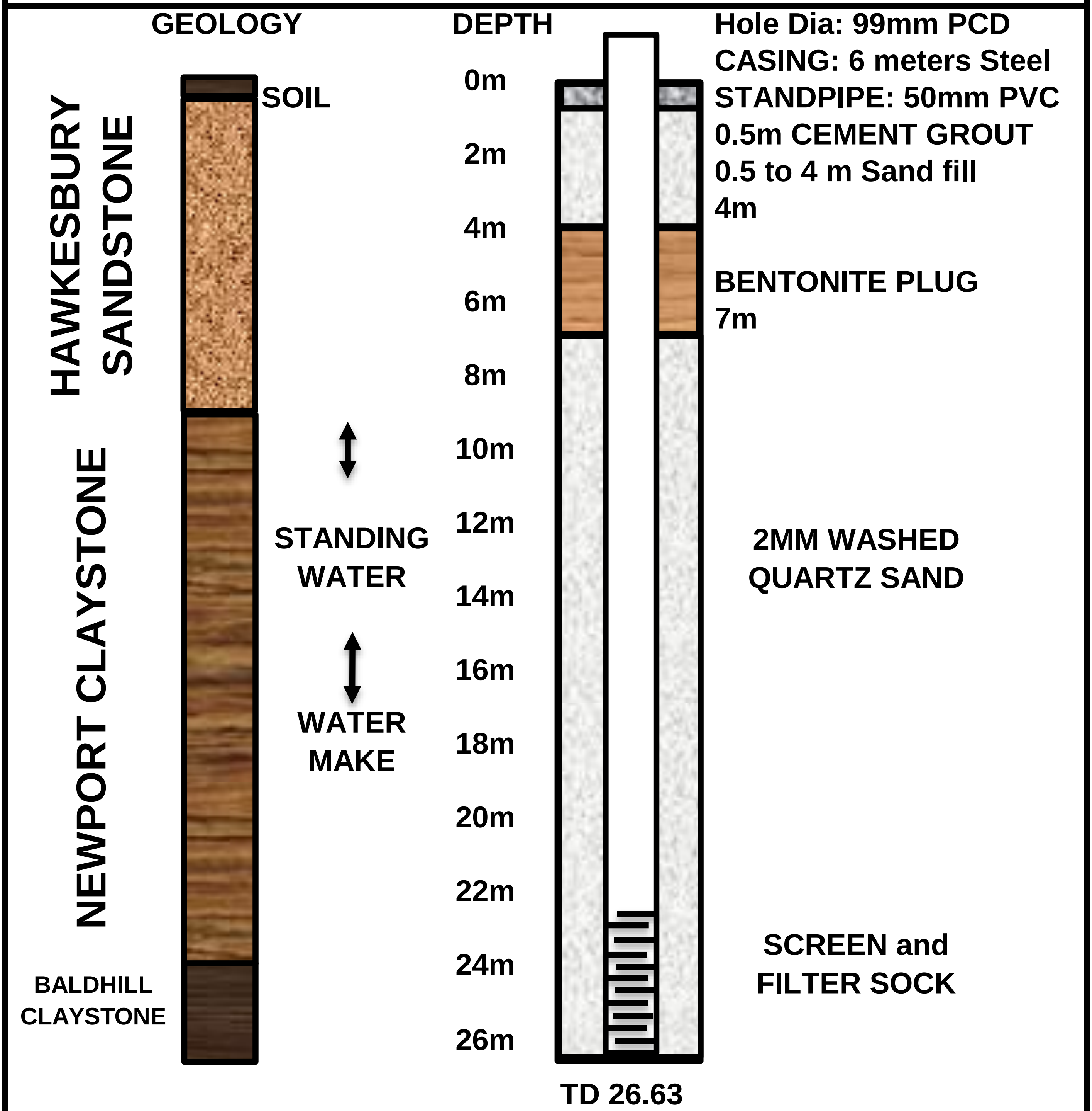


# Wollongong Coal VW PIEZO INSTALLATION
# WELL CONSTRUCTION hole RV23

**Hole RV23** **Friday 21/11/2014**



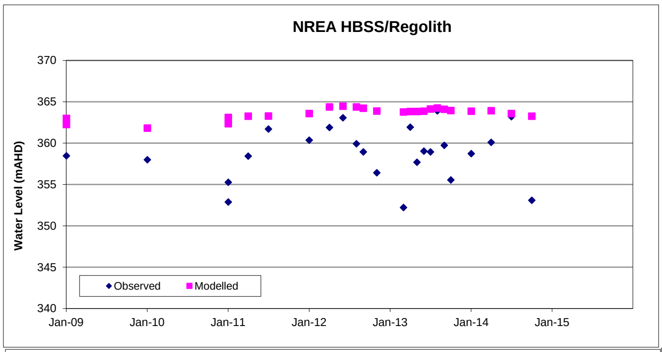
# HOLE WCRV 23A

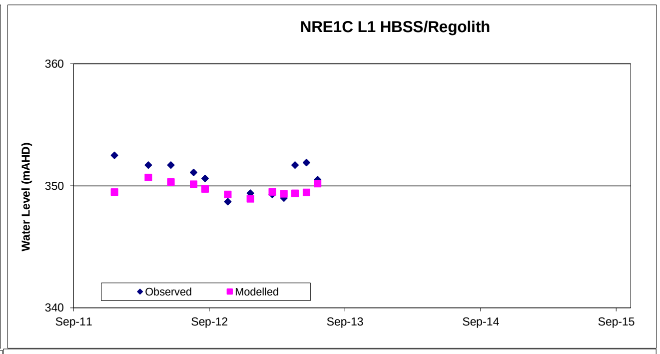


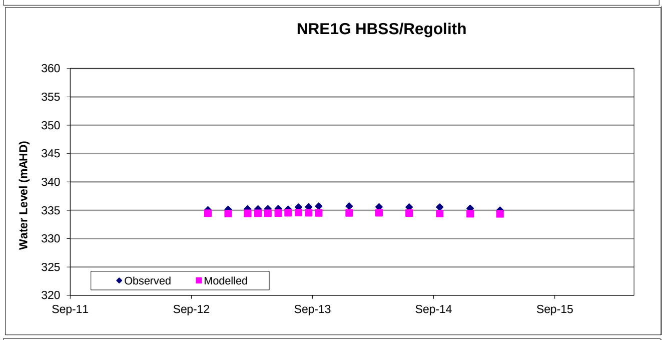
# Appendix C

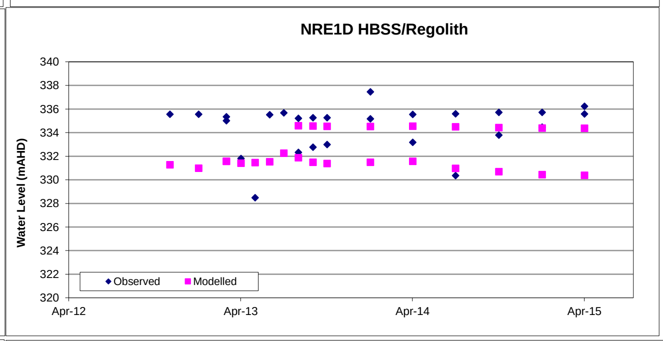
# Piezometer Water Level Calibration Graphs

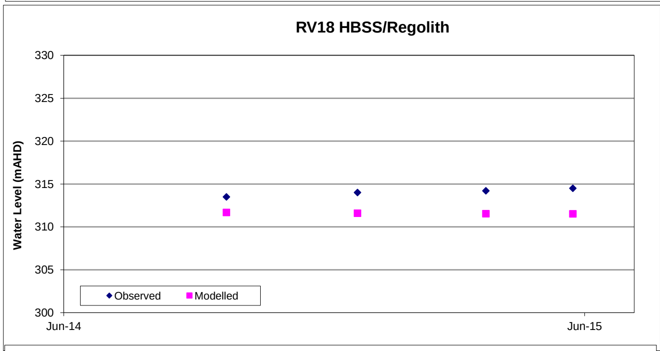
## Upper Hawkesbury Sandstone / Regolith - Layer 1

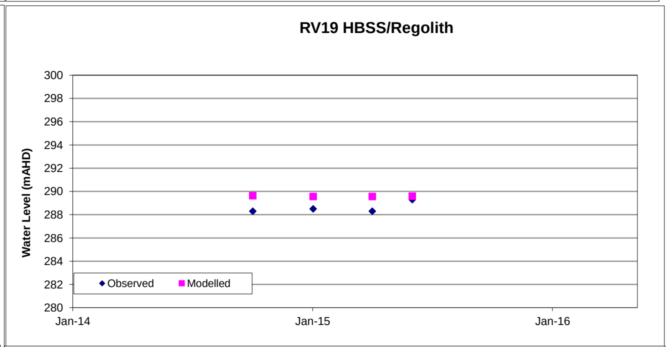


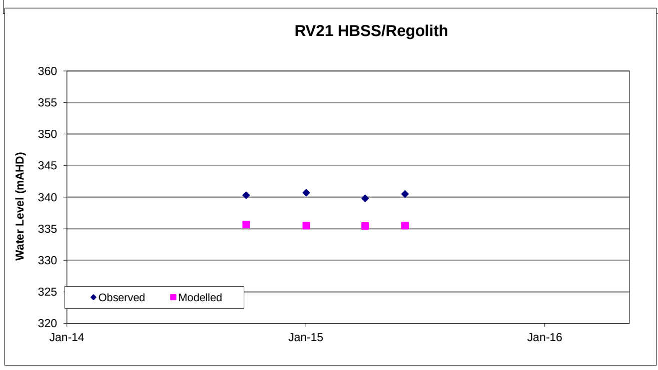



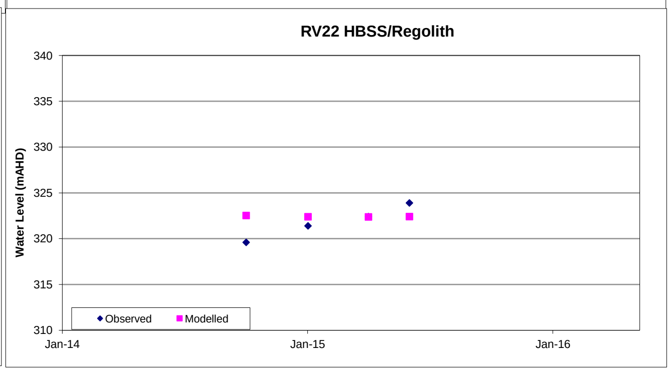



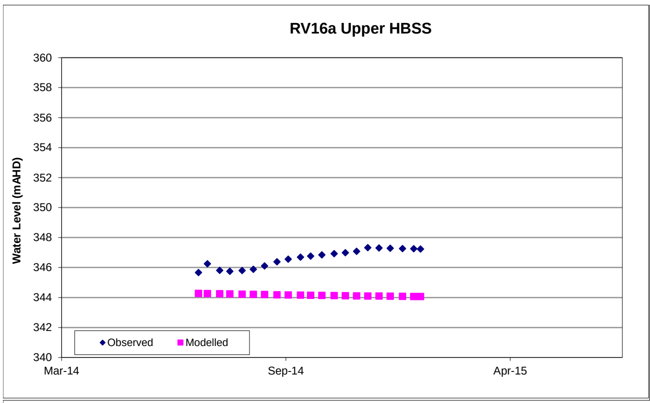



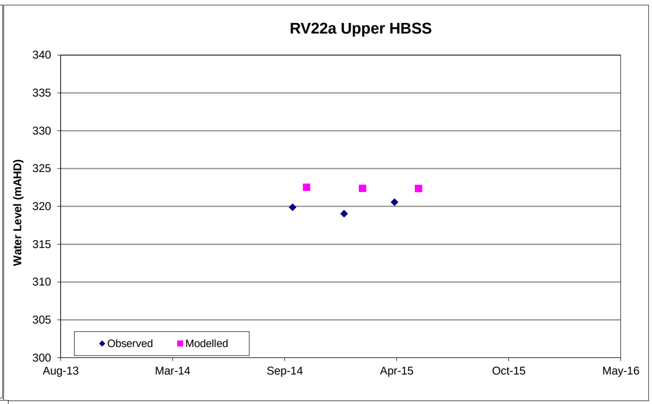



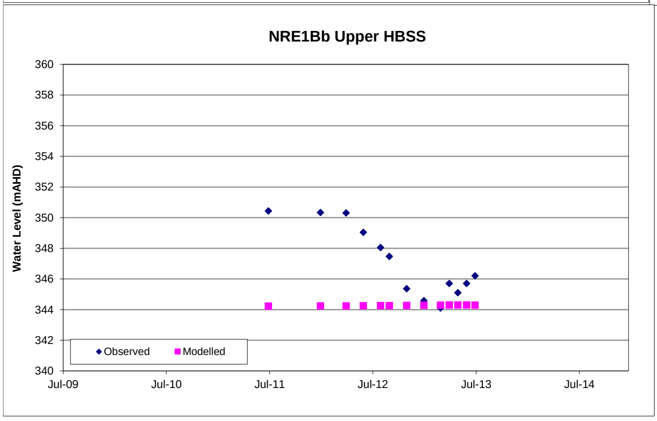



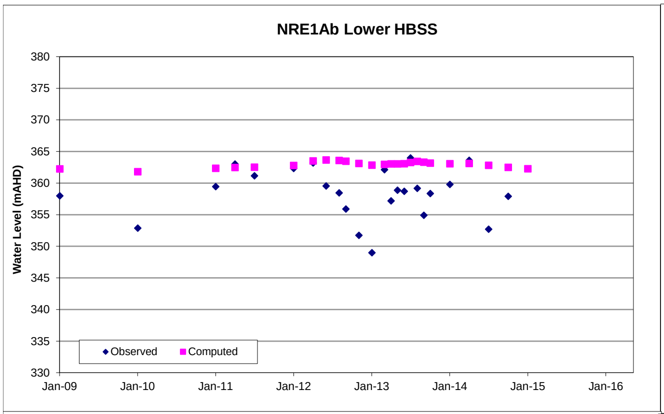
Upper Hawkesbury Sandstone - Layer 2

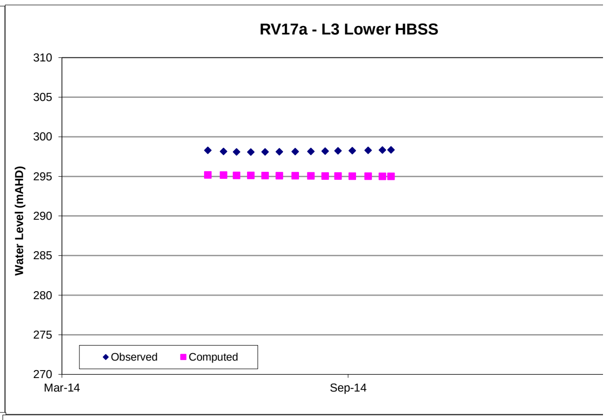


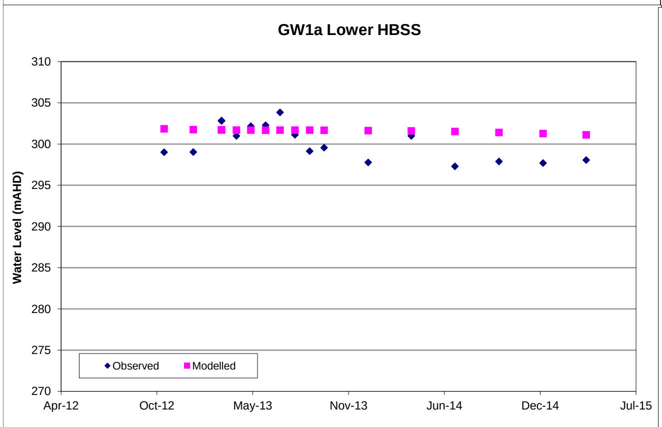



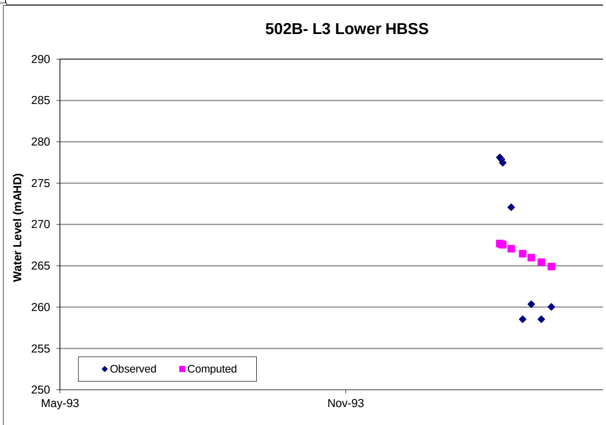



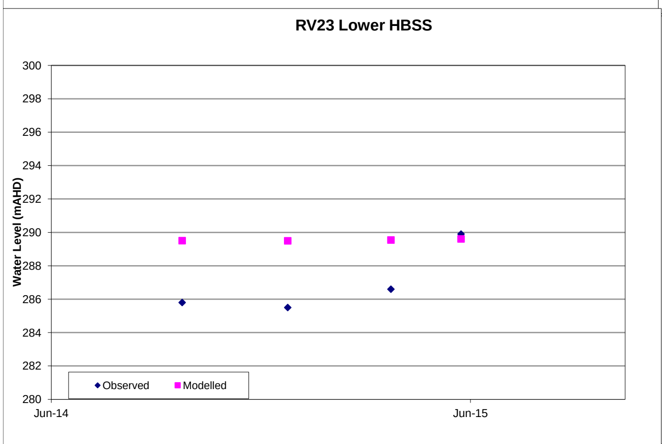
Lower Hawkesbury Sandstone - Layer 3

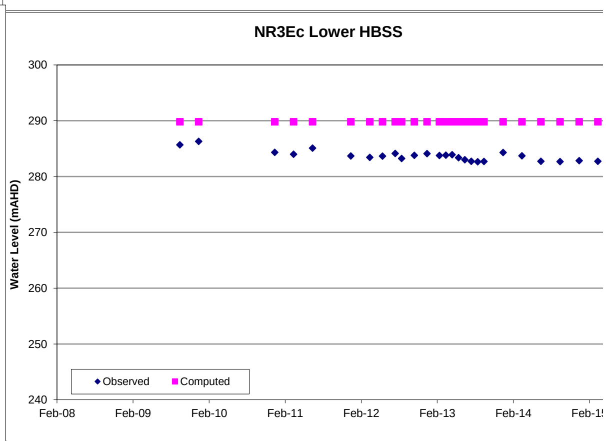


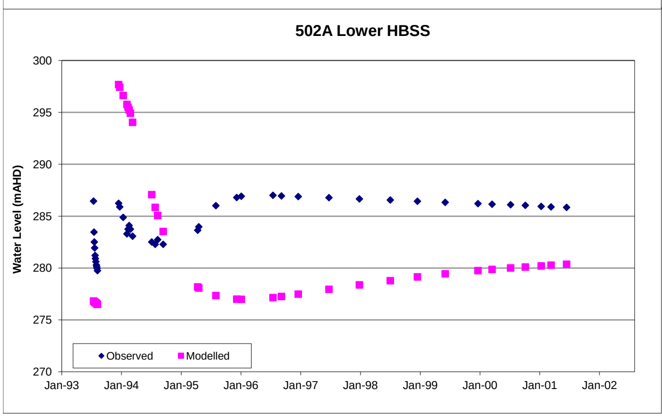



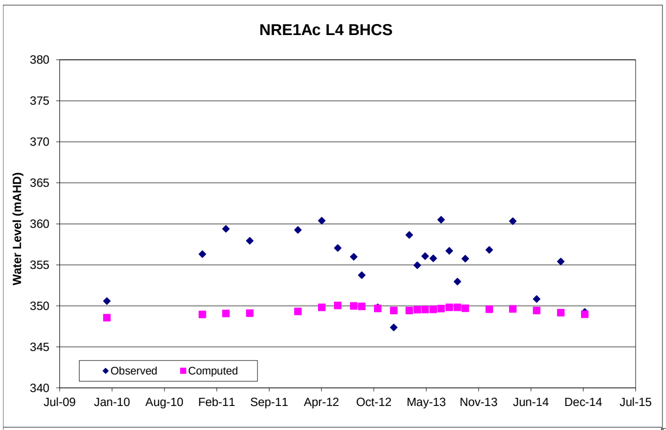



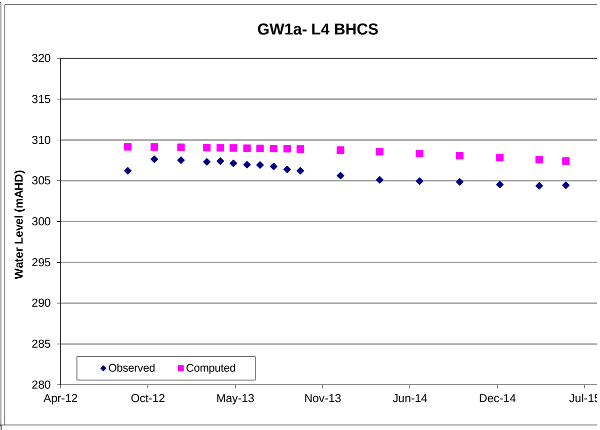



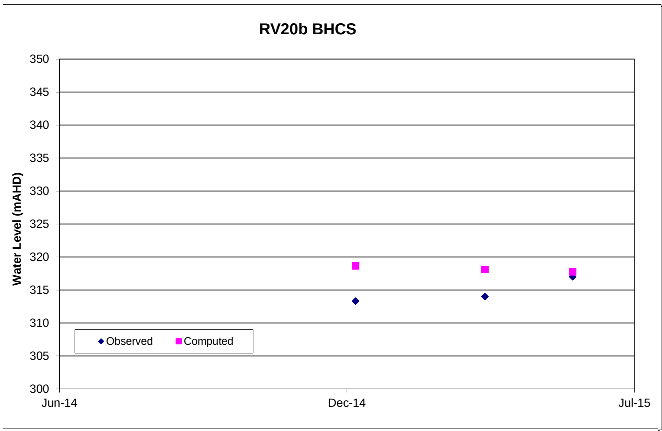



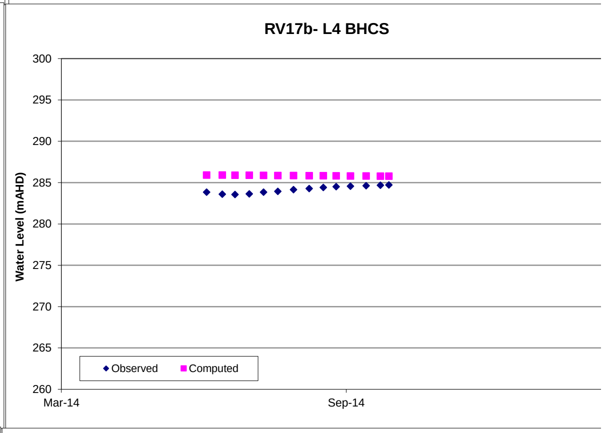



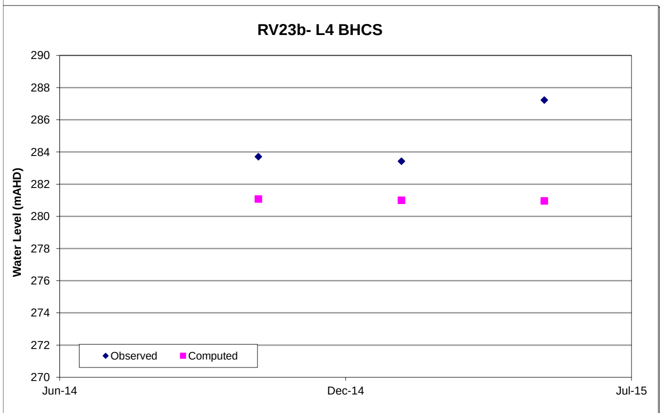
Bald Hill Clay Stone - Layer 4

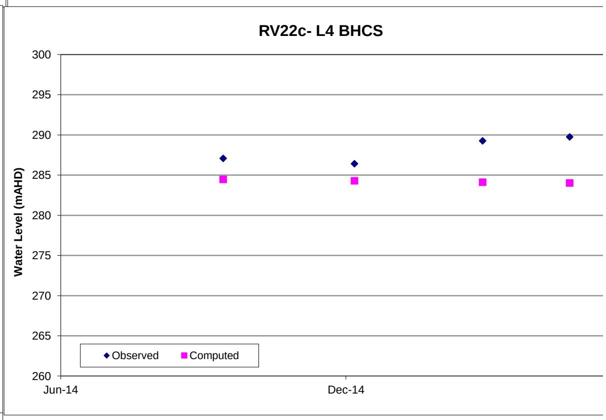


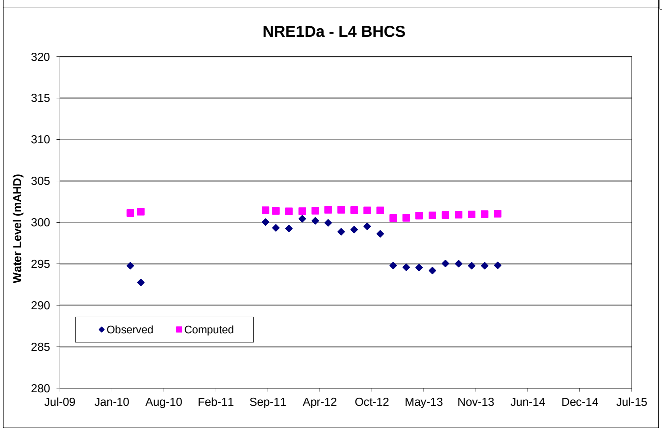



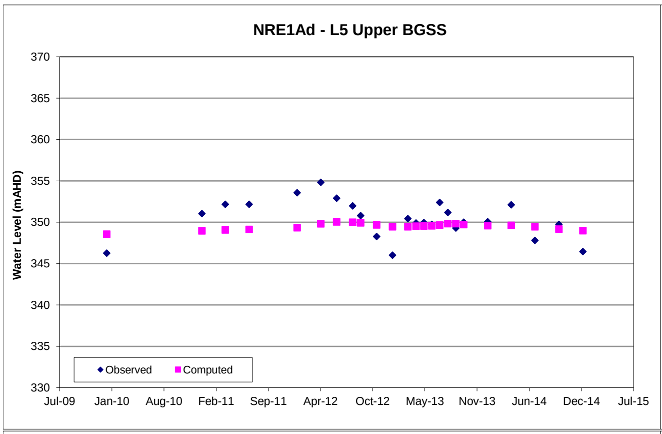



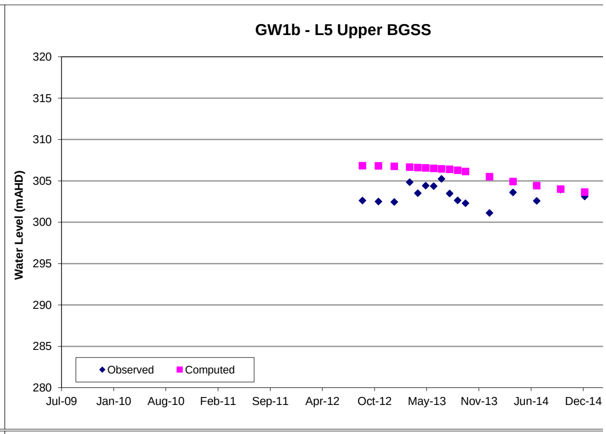



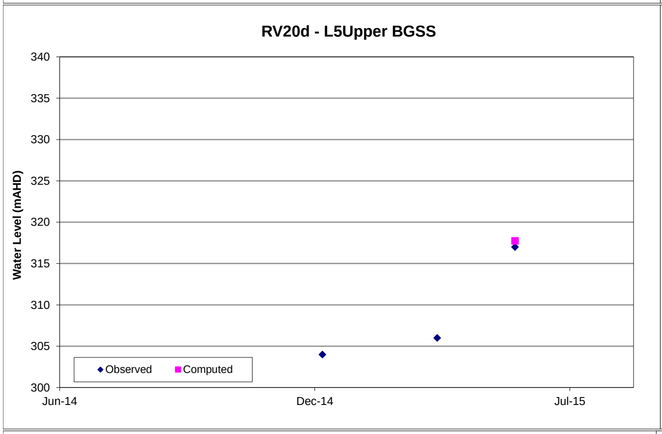



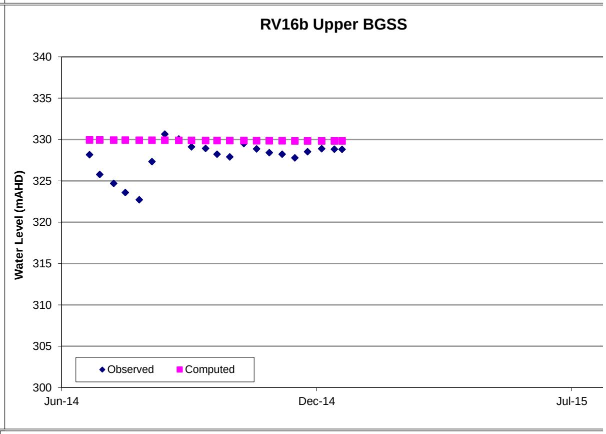



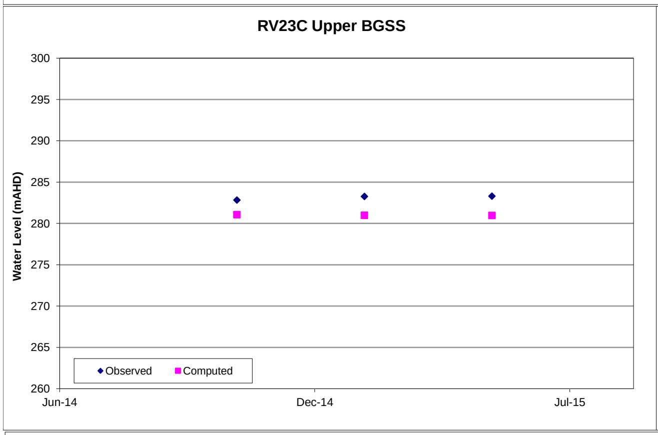
## Upper Bulgo Sandstone - Layer 5

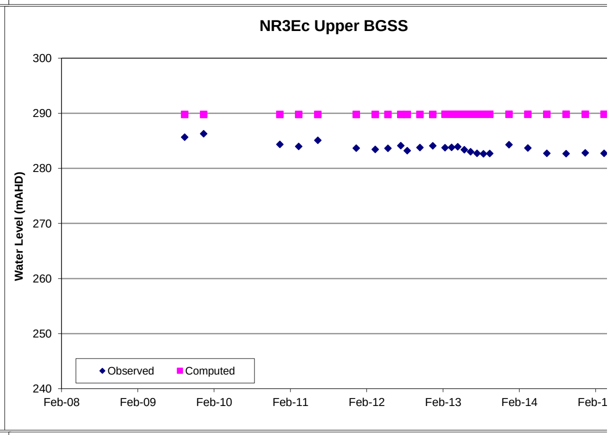


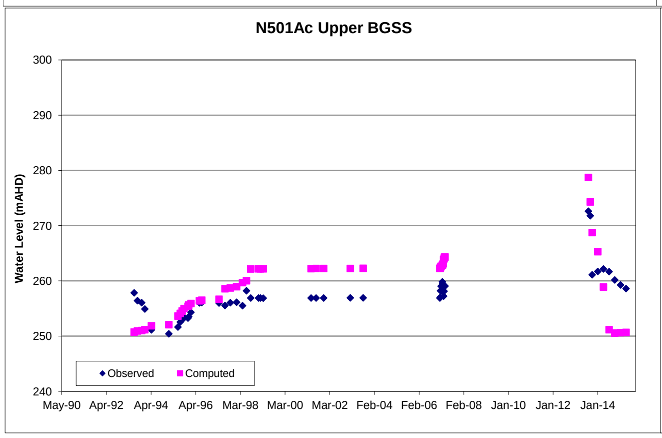



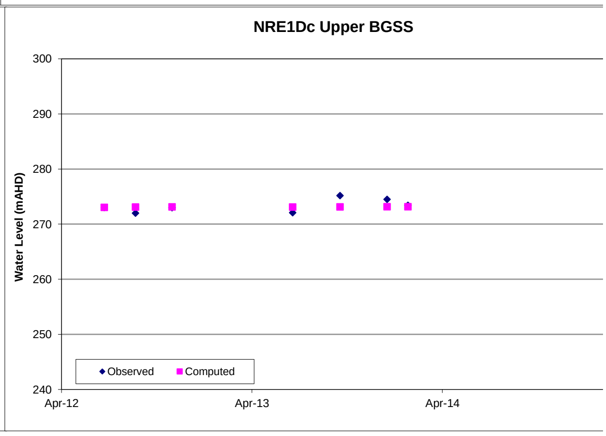



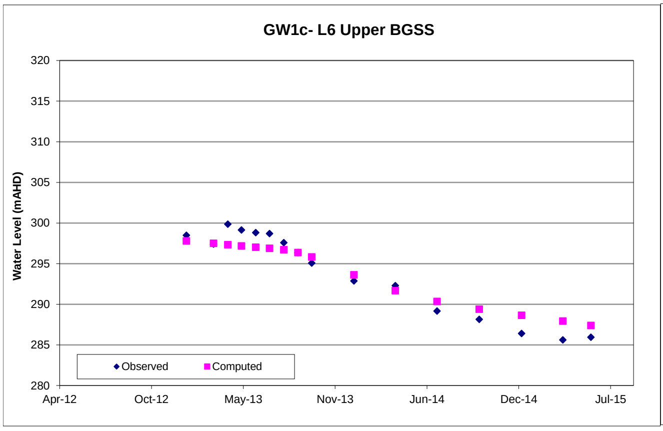



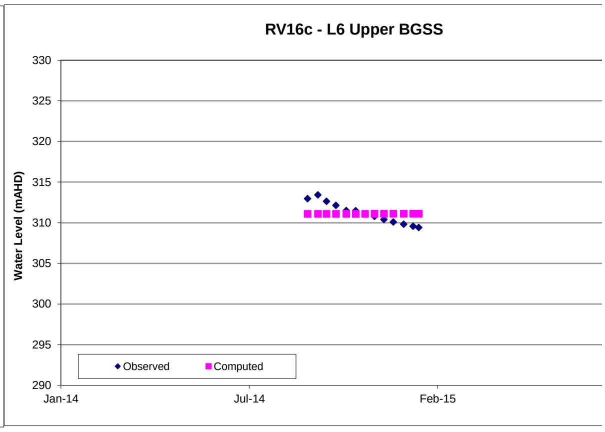



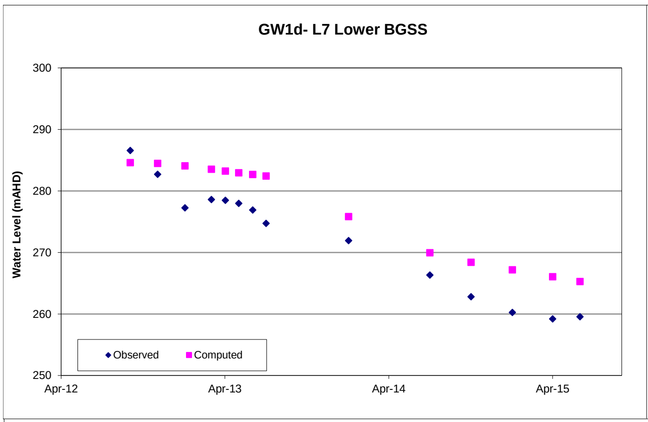



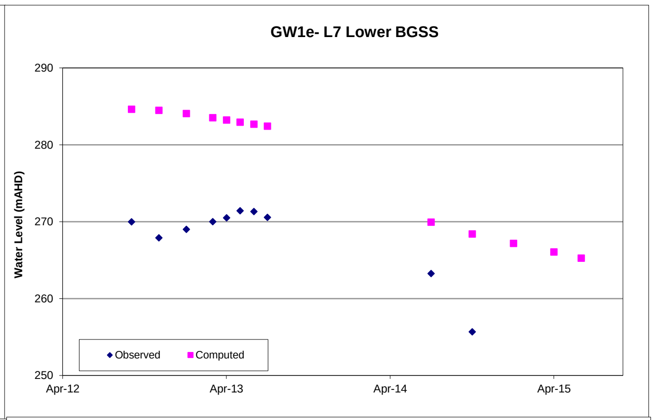
Upper Bulgo Sandstone - Layer 6

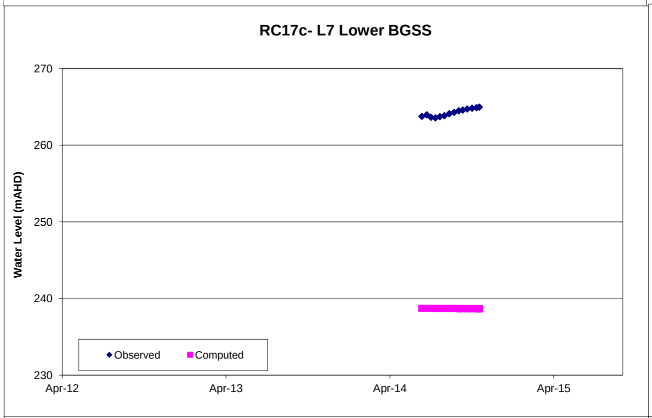


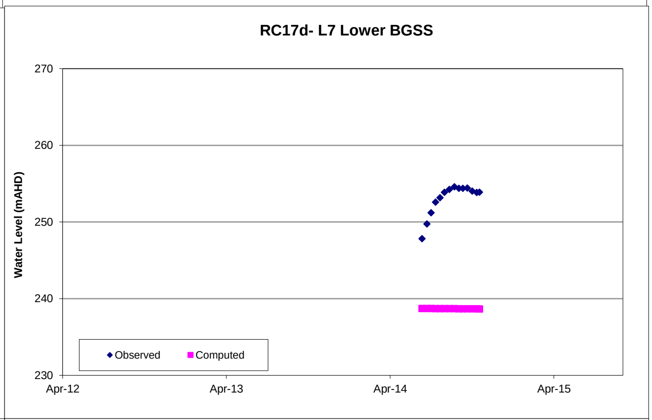



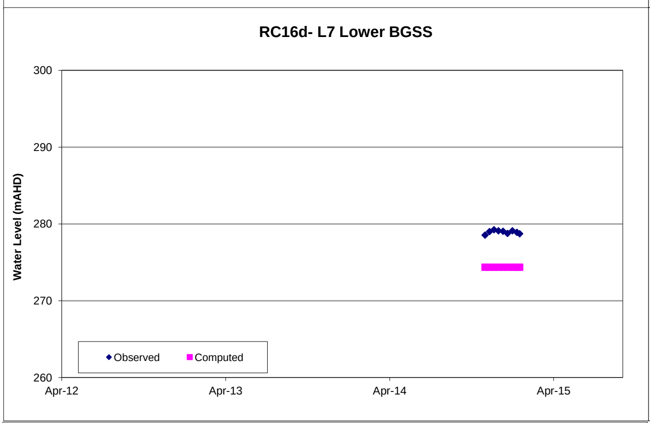
# Lower Bulgo Sandstone - Layer 7

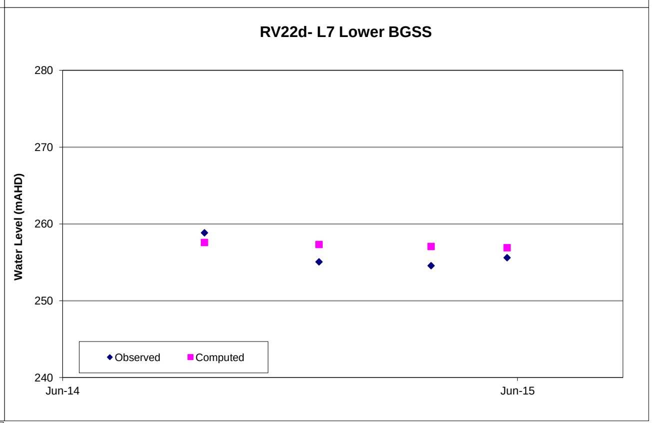


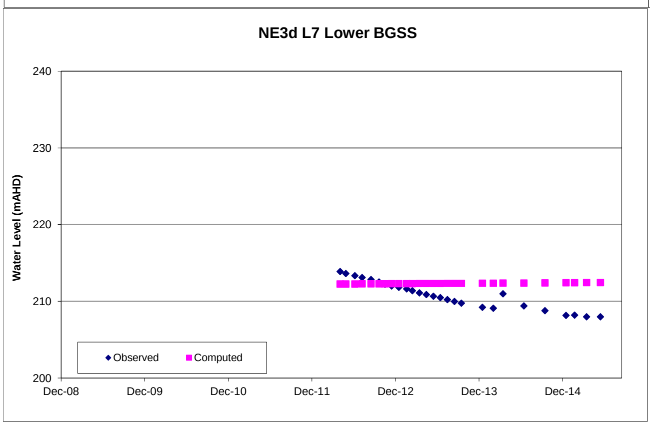



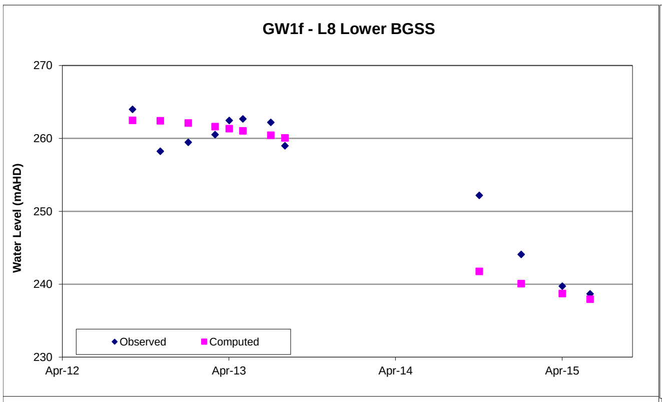



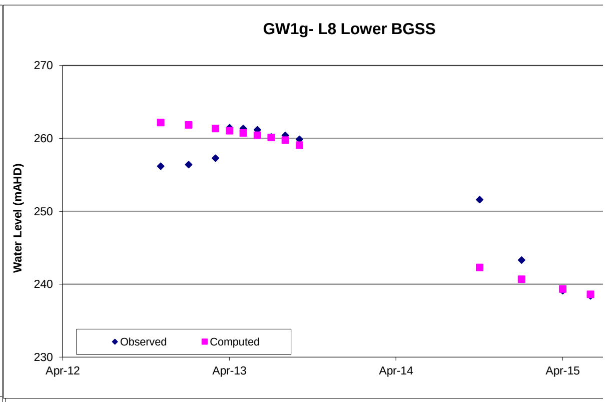



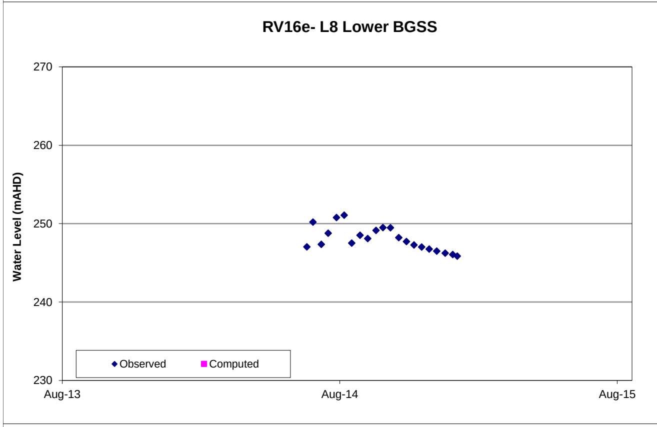



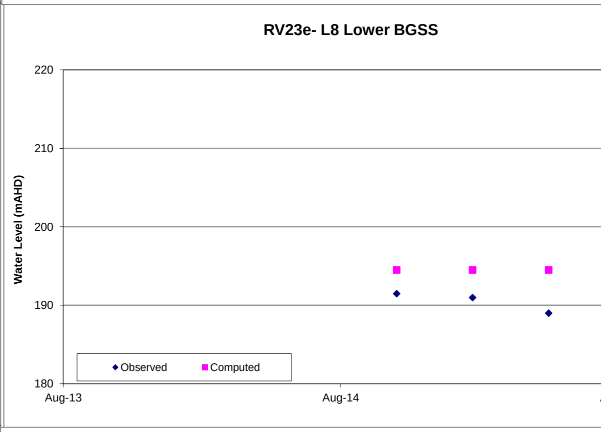



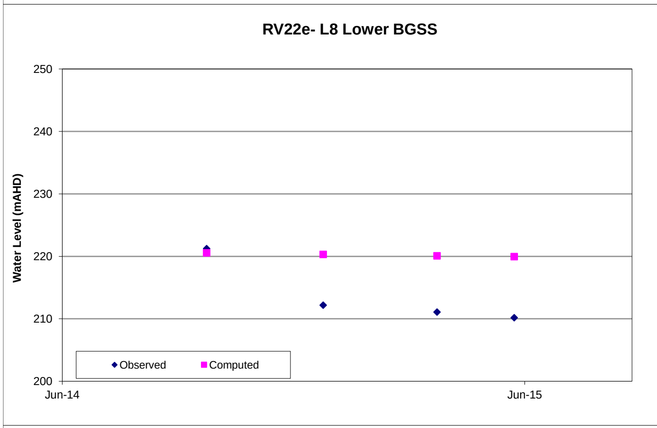
Lower Bulgo Sandstone - Layer 8

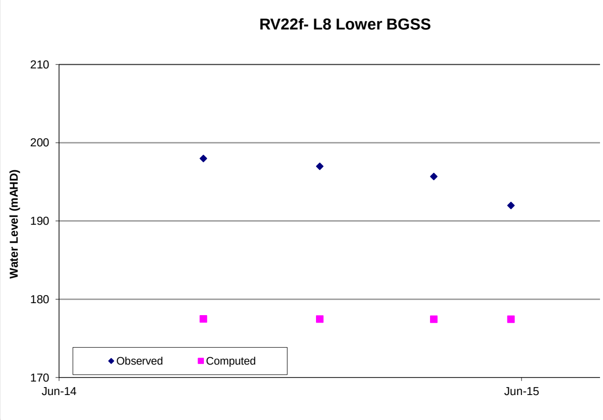


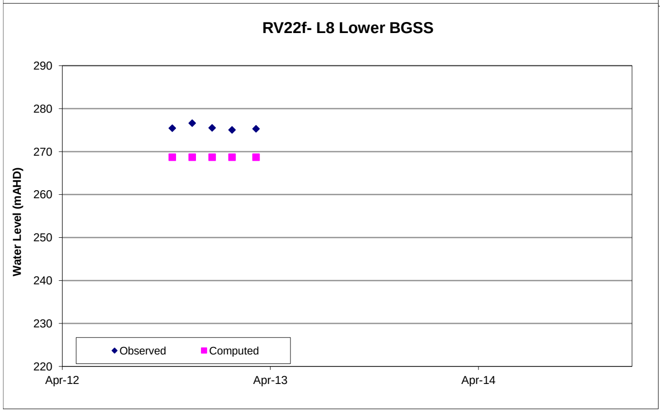



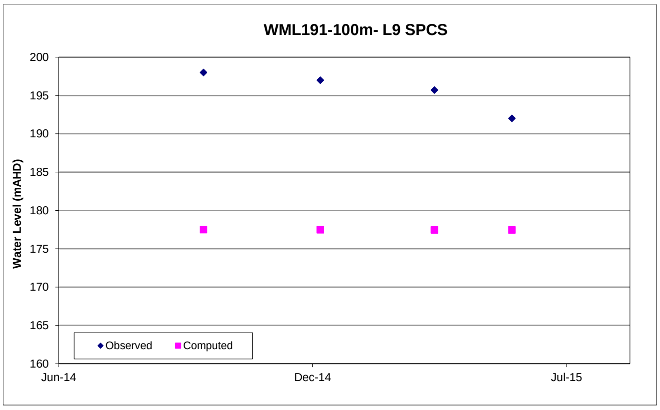



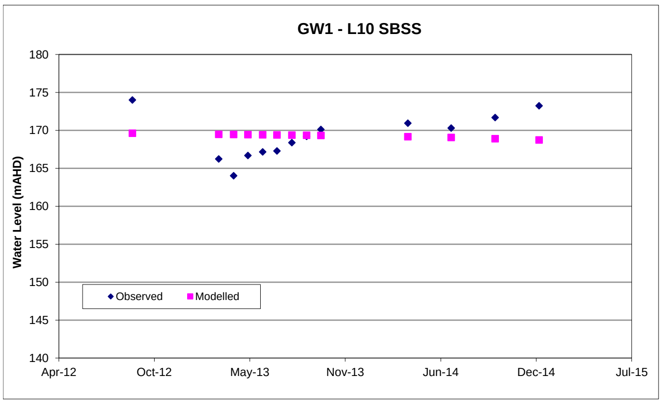



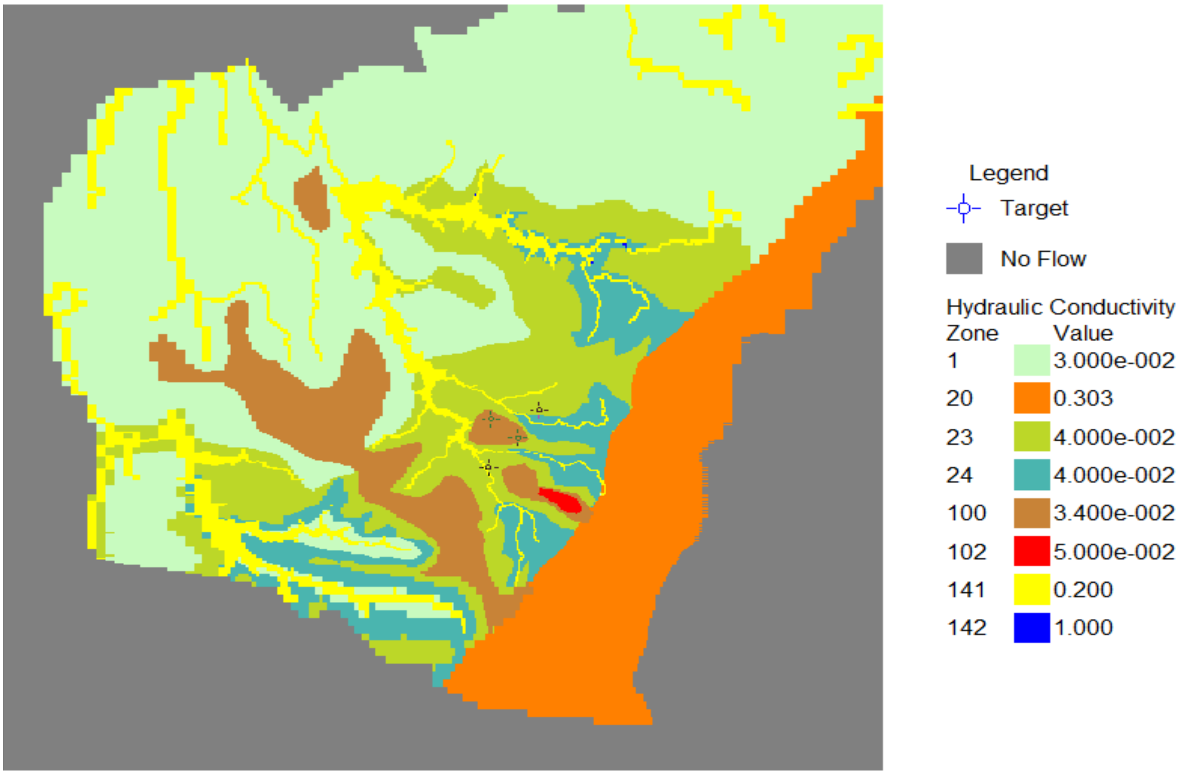

WML191-100m- L9 SPCS
Water Level (mAHD)
200
195
190
185
180
175
170
165
160
Jun-14
Dec-14
Jul-15
Observed
Computed


GW1 - L10 SBSS
Water Level (mAHD)
180
175
170
165
160
155
150
145
140
Apr-12
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Observed
Modelled

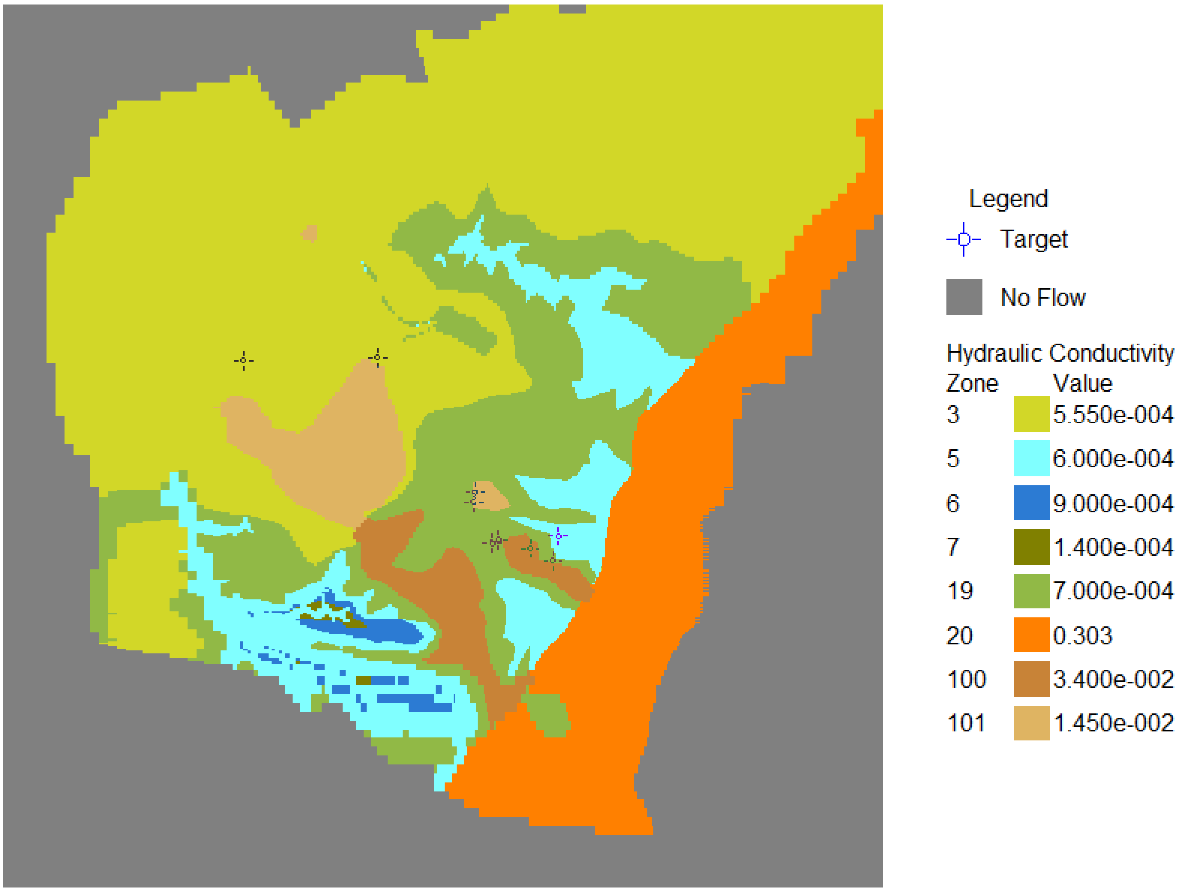
# Appendix D

# Calibrated Hydraulic Conductivity Fields and Rainfall Recharge

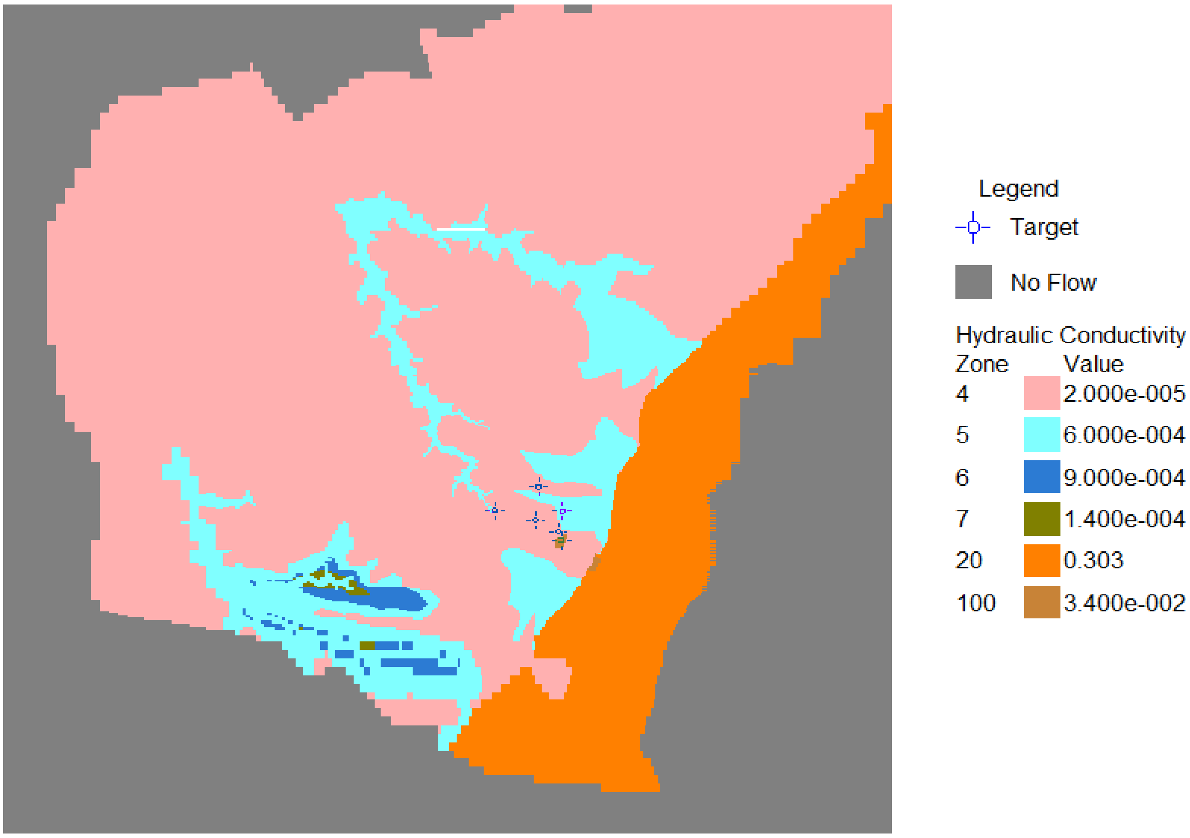
Regolith / Upper Hawkesbury Sandstone (Layer 1)



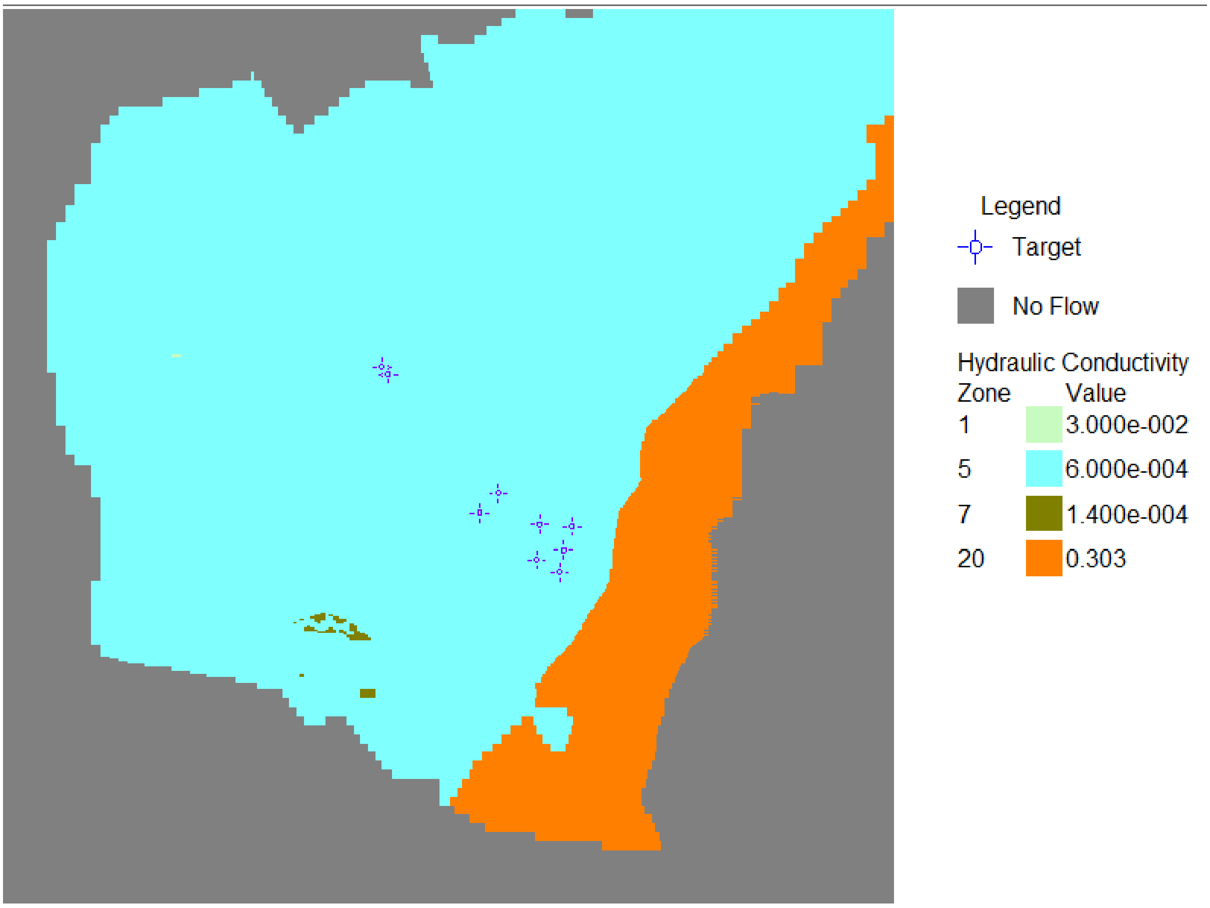

Lower Hawkesbury Sandstone (Layer 3)



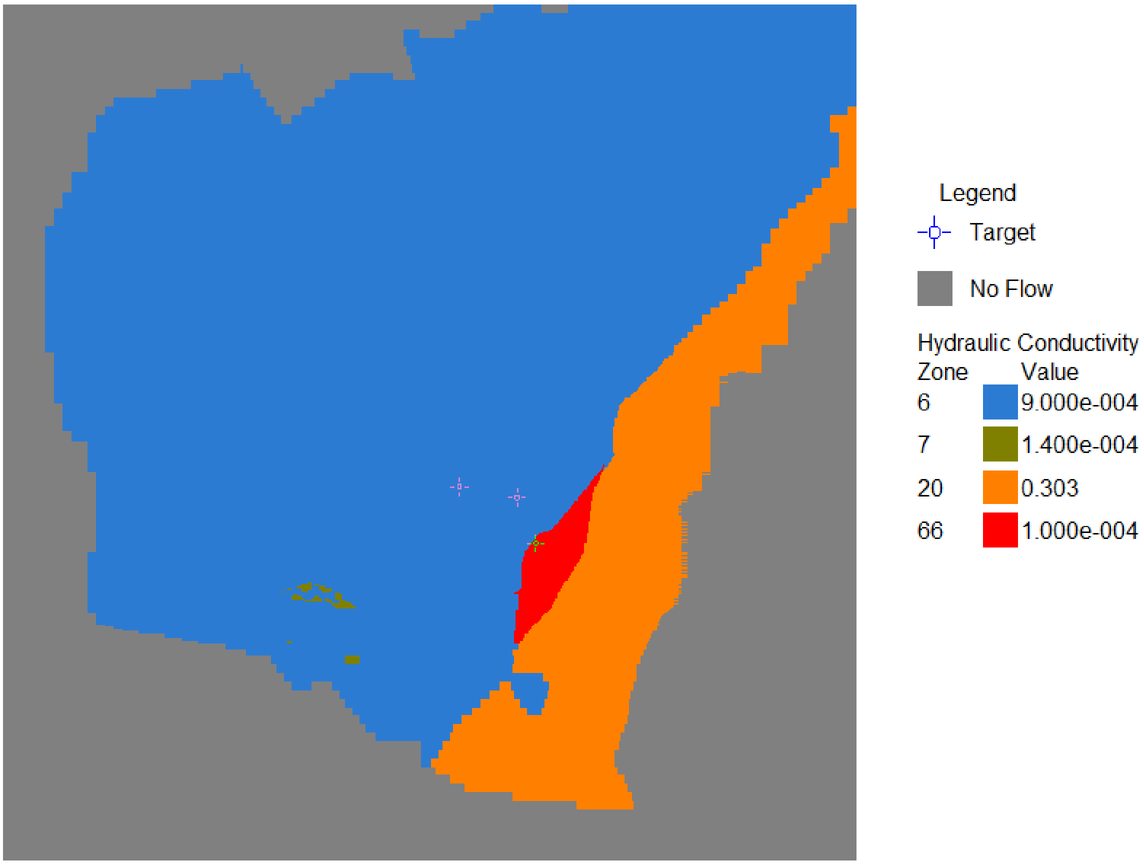
Bald Hill Claystone (Layer 4)



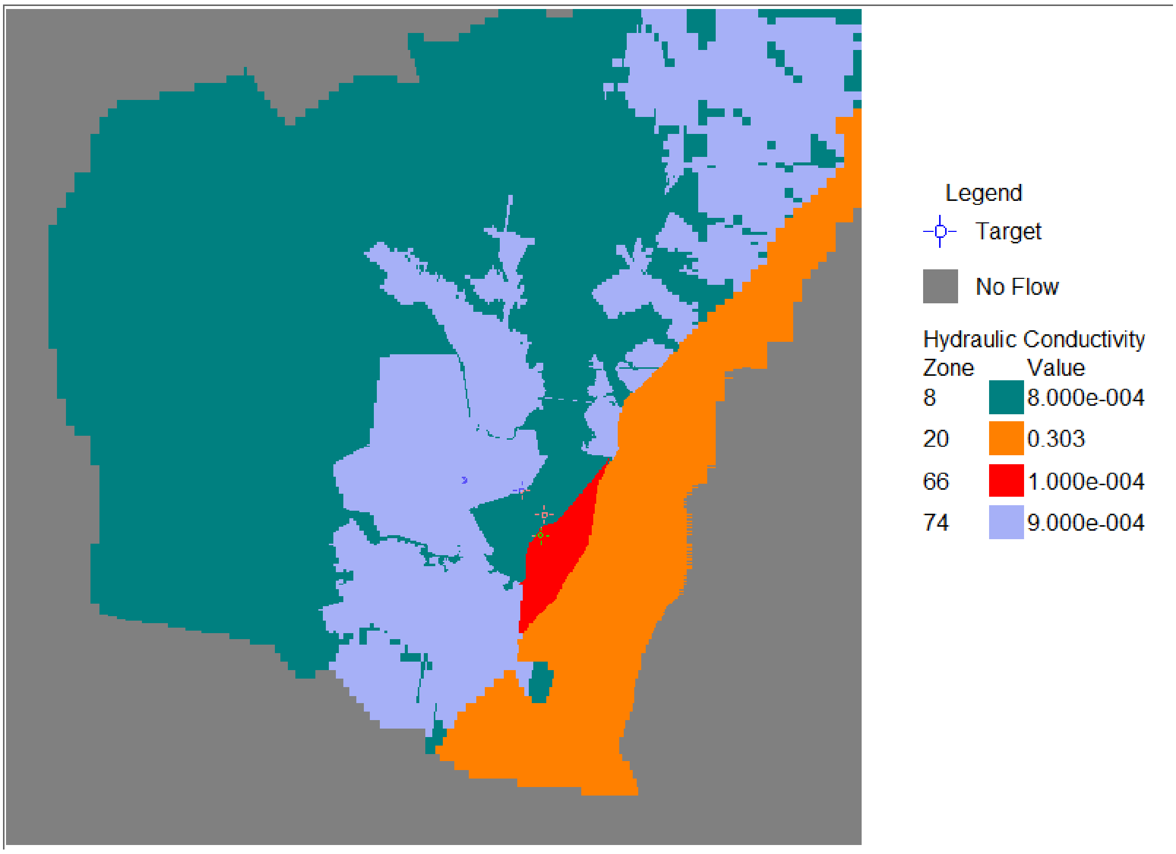

Upper Bulgo Sandstone(Layer 5)



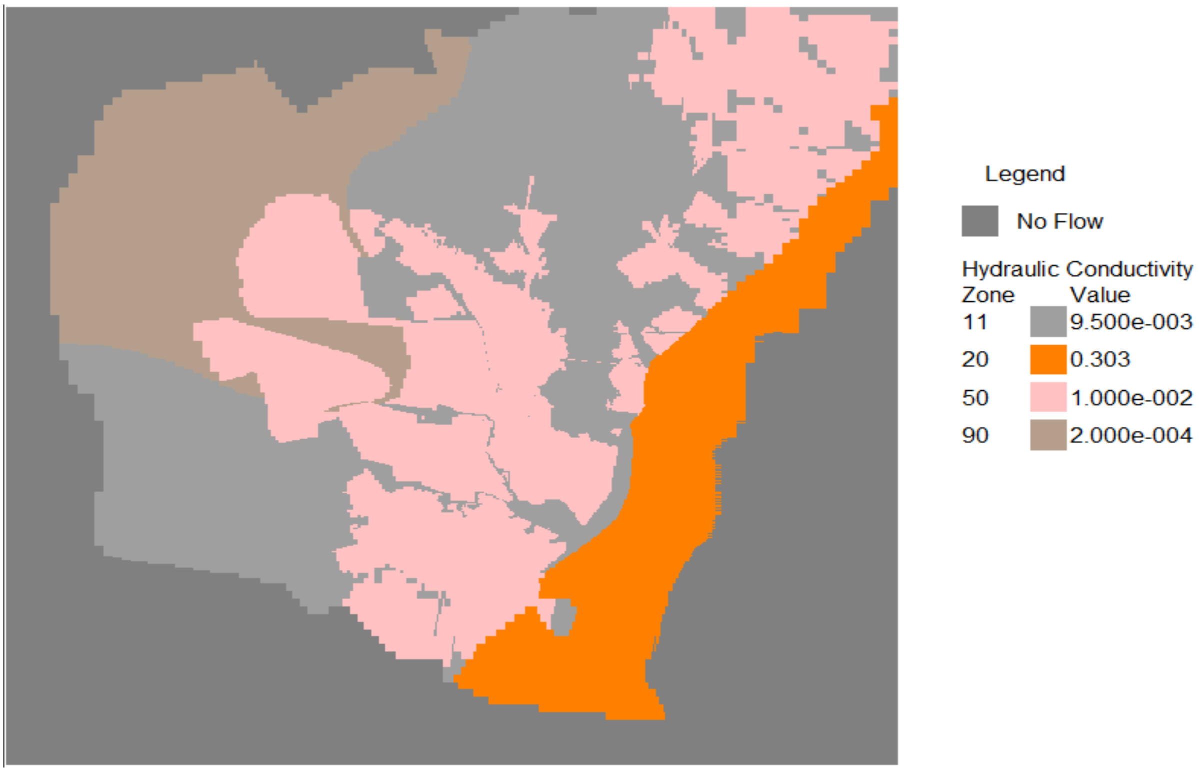
Lower Bulgo Sandstone (Layer 8)



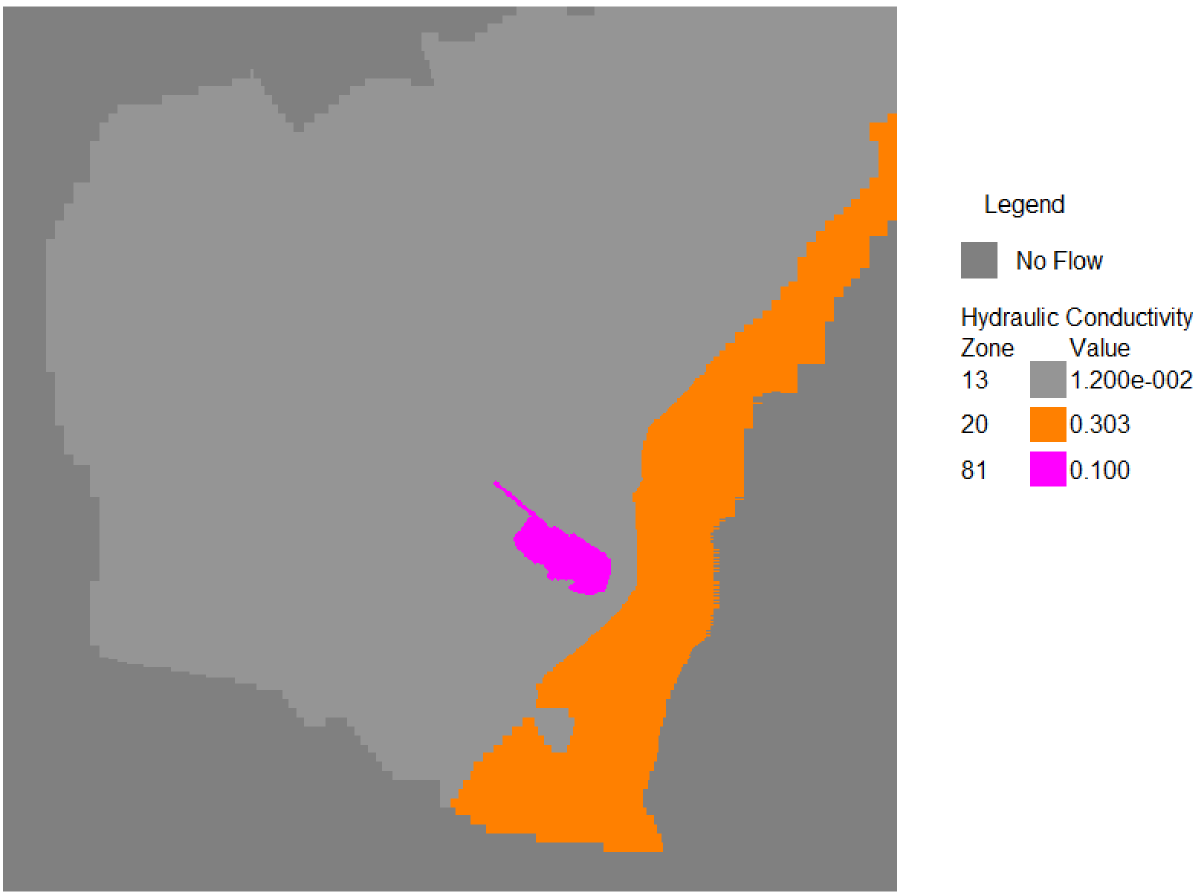

Scarborough Sandstone (Layer 10)



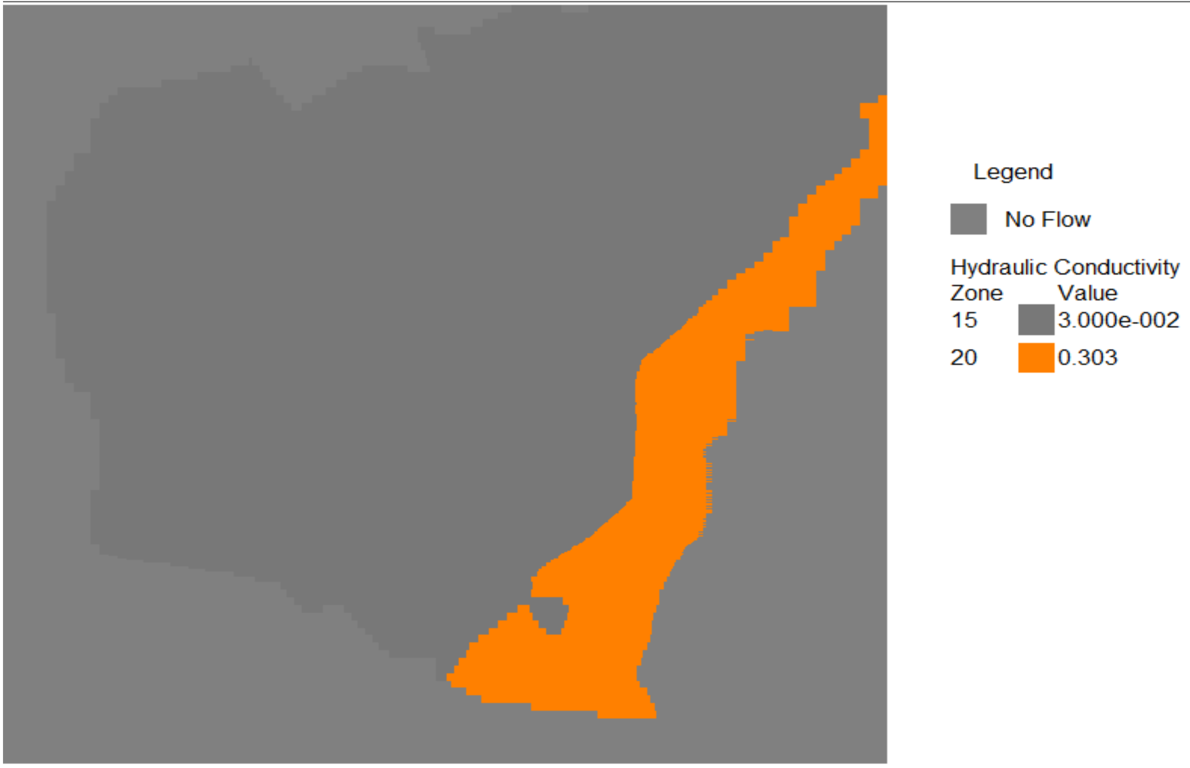
Bulli Coal Seam (Layer 13)



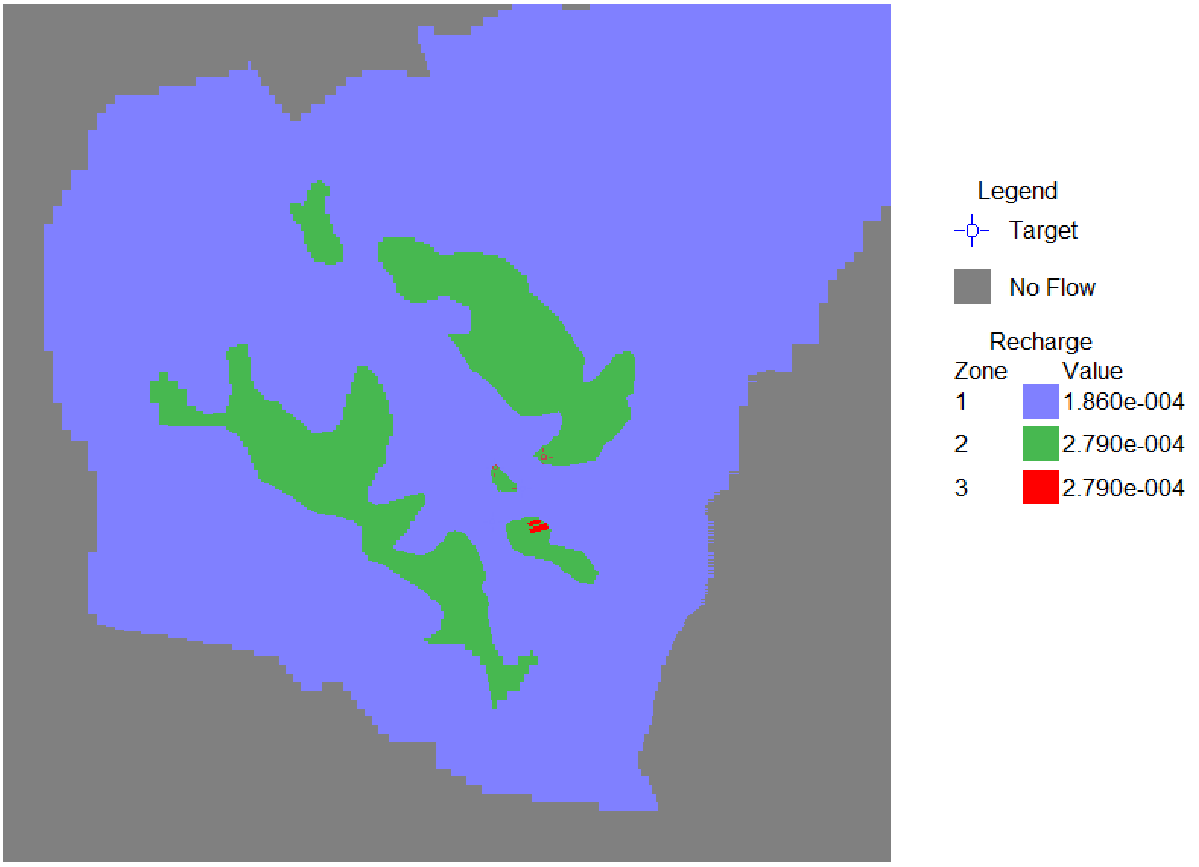

Balgownie Coal Seam (Layer 15)



Wongawilli Coal Seam (Layer 17)



Spatial Recharge Distribution (m/day)



# Appendix E

# 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 15.43 ML/year is predicted from the surface water system associated with the proposed Russell Vale 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.<br>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 F

# HydroSimulations Pty Ltd Peer Review

**Heritage Computing Pty Ltd** ● ABN 75 392 967 126 ● T/A **HydroSimulations**
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noel.merrick@heritagecomputing.com

DATE: 4 September 2015

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: HS2015/34

---

## 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, as well as the western 340 metres (m) of Longwall 6 (from April 2012 to July 2015).

At the request of Hansen Bailey, acting on behalf of Wollongong Coal Ltd, Heritage Computing Pty Ltd (trading as HydroSimulations) has undertaken a series of peer reviews of draft groundwater assessment reports on the Project, culminating in a review report on the Preferred Project groundwater assessment in June 2014 and this review report on the Revised groundwater assessment.

The regulatory and Planning Assessment Commission (PAC) reviews of the Preferred Project documents required a revised groundwater assessment. This has consisted of revision of the conceptual hydrogeological model, inclusion of data from 10 additional boreholes, better understanding of mine inflow dynamics, and updating of the numerical groundwater model.

## 2. Documentation

The following report comprises the current documentation for the groundwater assessment:

1. GeoTerra and GES, 2015, Russell Vale Colliery Underground Expansion Project Russell Vale East Revised Groundwater Assessment, Bellambi, NSW. Report NRE12 - R1A for Wollongong Coal Ltd., 18 August 2015.

It should be noted that this report is not intended to be a standalone document, but refers back to the Preferred Project Report (PPR) for aspects of the Project that are unchanged. The PPR groundwater report is:

2. 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 of Document #2 were conducted on draft reports dated 20 May 2014 and 5 June 2014. An initial review of Document #1 was conducted on a draft report dated 5 August 2015. 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.

As the revised groundwater assessment is of an incremental nature, this review adopts a similar approach. For more substantial comment, the reader is referred to the previous peer review report:

3. HydroSimulations, 2014, Peer Review - Russell Vale Colliery Groundwater Impact Assessment. Report HS2014/2 for Hansen Bailey and Wollongong Coal Ltd., 22 June 2014.

Document #1 has the same report structure as Document #2, with 17 sections:

1. Introduction
2. Relevant NSW / Federal Legislation and Guidelines
3. Previous Groundwater Related Studies
4. Previous and Proposed Mining
5. Russell Vale East 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 Appendices to Document #1 contain:

A. Regulatory Review Summary
B. Piezometer Summary and Installation Logs
C. Piezometer Water Level Calibration Graphs
D. 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) guidelines issued by the National Water Commission in 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

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.

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 written reports 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 PPR review was based on both the MDBC and the NWC checklists, the latter offering essentially a Yes/No opinion rather than the graded assessment offered by the former. For this review the reader is referred to the checklists in Document #3, as no material changes have occurred to the modelling methodology and the review of Document #2 covers more material than in this incremental review.

This review focuses more on consideration of matters raised by the PAC review:

A. Use of the pseudo-soil algorithm instead of the van Genuchten algorithm for simulation of variable saturation.
B. Depth-varying values for drainable porosity (specific yield).
C. Display of measured and predicted calibration hydrographs.
D. Display of pressure head distributions in plan view ("in the coal seams, Bulgo Sandstone and Hawkesbury Sandstone prior to, during and post mining (50 and 100 years)")[4].
E. Post mining steady state groundwater flow systems and areas permanently dewatered.
F. Potential leakage from adits on the escarpment and whether the adits and abandoned workings constrain the recovery of groundwater levels.

## 4. Report Matters

Document #1 is a good quality document of 124 pages length plus four appendices that contain a comparison of observed and simulated hydrographs, piezometer installation details and checklists that address PAC and 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 report is missing a Summary or Conclusion section. It is expected, however, that this will appear in the companion main report for the Project (not seen by this reviewer).

In Section 9.6, dot point 5 for simulation of drainage channels (using the RIV package) is confusing. The stage is said to be 1m above the base of the "surficial layer", which elsewhere is said to be either 2 m or 20 m for model layer 1. There is no mention of the RBOT parameter, unless this is what is meant as the base of the surficial layer. The critical parameter for active streams (gaining or losing) is the driving head "Stage minus RBOT". Although not clear to a reader, it is likely that the driving head is 1 m.

The report includes discussion on alternative representations of the fractured zone [Section 9.13]. Since the release of Document #2 (the PPR report), the use of the Tammetta formula (adapted conservatively for multiple worked seams) has been abandoned and the alternative Ditton algorithm has also not been followed. It is not clear what approach has been adopted. It appears to be empirical adjustment of the

[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.
[4] PAC Review Report, Appendix 5: Groundwater Review Report - Dr Colin Mackie, page 7.

height of fracturing, and adjustment of enhanced hydraulic conductivities from an initial log-linear ramp function, in order to better calibrate observed vertical hydraulic head profiles. Table 5 [Document #1] has fracturing up to and including the Lower Hawkesbury Sandstone [model layer 3] for mining in the Wongawilli Seam. For mining in the Bulli Seam, fracturing goes to the Wombarra Claystone [model layer 11]. In Table 5, there are missing entries for Host (Kz) Layer 18 and Bulli Seam Layer 13, and the Ss for Layer 11 appears high and inconsistent.

There are still sections of repeated text in Section 9.13. Section 12.1 also is not written clearly.

## 5. Data Matters

The reader is referred to Document #3 for more detail on this aspect of the Project, as most of the data analysis was presented in Document #2. In summary:

- The coverage of geology and hydrogeology is particularly good.
- Field-derived permeabilities are summarised.
- The rainfall residual mass (cumulative deviation from the mean) curve has been used effectively to show often strong correlation with groundwater hydrographs.
- There is a very thorough cause-and-effect analysis of hydrographic responses in Document #1.
- The water table pattern in Figure 12, based on measurements and inferred levels, is sensible as it suggests logical groundwater flow from ridges to drainage lines.
- Cross-sections of pre-Project pressure heads show substantial prior depressurisation due to neighbouring mining.
- There is a very thorough analysis of mine inflow components.
- The conceptualisation based on the field investigations and data analysis is justified and well illustrated graphically in Figure 25 for a mining situation.
- The adopted conceptual model is consistent with other studies in the Southern Coalfield.
- Strong evidence is presented for geological faults and other structures having no significant role in the groundwater regime.

## 6. Model Matters

The reader is referred to Document #3 for more detail on this aspect of the Project, particularly the checklist assessment.

There has been a change in the variable saturation option within MODFLOW-SURFACT software, as requested in the PAC review, by adopting a pseudo-soil algorithm instead of the van Genuchten algorithm. Overall, the calibration performance of the model is much the same, with some deterioration from 2.6 %RMS to 3.1 %RMS in relative terms, and from 6 mRMS to 8 mRMS in absolute terms, for calibration to groundwater levels. A good explanation is offered as to why it is always difficult to match VWP responses at any one monitoring site.

It is noted that there are no head calibration targets below the Scarborough Sandstone [model layer 10]. However, the calibration to mine inflows is particularly good [Figure 30].

The adopted evapotranspiration (ET) rate (0.005 m/day = 1,825 m/year) has not changed and still 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 a few metres of ground surface.

Many informative figures for the effects of past and future mining on the groundwater system are presented from Figure 33 to Figure 61, expressed in the form of pressure heads (in metres), potentiometric heads (in mAHD) and drawdowns (in metres). North-South and East-West cross sections are provided pre-mining, at the end of Longwall 5 and at the end of mining, Plan views of drawdowns are provided at the end of mining, and after 100 years and 200 years, for model layer 1 (upper Hawkesbury Sandstone), model layer 3 (lower

Hawkesbury Sandstone), model layer 5 (upper Bulgo Sandstone), model layer 10 (Scarborough Sandstone) and model layer 17 (Wongawilli Seam). Pressure head plan views are provided pre-mining and at the completion of mining for model layer 1 (upper Hawkesbury Sandstone), model layer 3 (lower Hawkesbury Sandstone), model layer 5 (upper Bulgo Sandstone) and model layer 17 (Wongawilli Seam).

Sensitivity analysis and uncertainty analysis are reported in Document #2 where results were shown for 31 alternative model parameterisations, selected from the packer test database of horizontal hydraulic conductivities. In Document #1, the uncertainty in predicted mine inflow is illustrated in Figure 68 for sensitivity to rainfall recharge.

## 7. PAC Issues

Section 2 of this review introduced the main groundwater matters raised by the PAC review:

A. Use of the pseudo-soil algorithm instead of the van Genuchten algorithm for simulation of variable saturation.
B. Depth-varying values for drainable porosity (specific yield).
C. Display of measured and predicted calibration hydrographs.
D. Display of pressure head distributions in plan view ("in the coal seams, Bulgo Sandstone and Hawkesbury Sandstone prior to, during and post mining (50 and 100 years)")[5].
E. Post mining steady state groundwater flow systems and areas permanently dewatered.
F. Potential leakage from adits on the escarpment and whether the adits and abandoned workings constrain the recovery of groundwater levels.

Each of these issues is listed in Appendix A of Document #1 with a cross-reference to the section in the report where a matter is addressed.

### Issue A

The pseudo-soil algorithm has replaced the van Genuchten algorithm for simulation of variable saturation.

### Issue B

The values of drainable porosity (specific yield) adopted in the model are listed in Table 5 (Calibrated Hydraulic Properties). Across 19 model layers, there are eight distinct values for Sy ranging from 0.008 to 0.15.

### Issue C

Measured and predicted calibration hydrographs are displayed in Appendix C at 51 monitoring locations.

### Issue D

Pressure head distributions in plan view are displayed in eight figures for upper Hawkesbury Sandstone, lower Hawkesbury Sandstone, upper Bulgo Sandstone and the Wongawilli Seam. They are shown for pre-mining and end-mining conditions, but not for post-mining at 50 years and 100 years as requested by the PAC review. Instead, *potentiometric* heads are displayed at 100 years and at 200 years after cessation of mining.

### Issue E

The nearest representation of post-mining steady state groundwater flow systems is indicated by recovery potentiometric heads at 100 and 200 years (for a transient simulation). As there is very little difference between the contour maps, for a number of formations, the flow system appears to have recovered within 200 years to a new equilibrium. It would have been beneficial to include a few hydrographs in order to see the rate of recovery and the degree of recovery to pre-mining levels.

The nearest representation of areas permanently dewatered is afforded by the displays of Layer 1 pressure heads before and after mining in Figures 41 and 42. There are no far-field differences but there are some

[5] PAC Review Report, Appendix 5: Groundwater Review Report - Dr Colin Mackie, page 7.

differences over the mining footprint. However, this does not capture the worst case as Figures 38 and 39 indicate that surficial drawdowns continue post-mining.

Document #1 does not clearly identify areas of permanent dewatering.

### Issue F

There is a brief comment on the risk of potential leakage from adits on the escarpment in Section 10.3. There it is stated that "the lowest adit RL is 117mAHD and that elevation is not reached within the 200 years of modelled recovery." "Although it is not modelled to occur, if the recovering groundwater reaches the lowest adit (RL117mAHD), it would be diverted to the licensed discharge point...".

This suggests that the adits and abandoned workings constrain the recovery of groundwater levels.

## 8. 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 Russell Vale East area, and to understand the effects to the 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", and the additional regulatory and PAC requirements since submission of the Preferred Project Report.

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 two tables (Table 10 and Table 11) that address the minimal harm considerations for less productive porous rock water sources and perched ephemeral aquifer 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. The six identified PAC issues related to groundwater are met to varying degrees. Additional comment could be provided on the extent of permanent dewatering of shallow groundwater systems and the risk of leakage from adits on the escarpment.

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 was assessed thoroughly in the PPR groundwater assessment by analysing the outputs of 31 models with parameterisations based on the statistical distribution of packer test permeabilities. Additional investigation of mine inflow uncertainty has been made in the current report for changes in effective recharge due to land surface disturbance.

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,

Dr Noel Merrick

## *APPENDIX I*

## Surface Water Modelling: Response to Planning Assessment Commission

# Russell Vale Colliery

## Underground Expansion Project - Surface Water Modelling: Response to Planning Assessment Commission

Wollongong Coal Limited

0637-15-B5, 14 September 2015

| | |
|---|---|
| **Report Title** | Russell Vale Colliery Underground Expansion Project – Surface Water Modelling: Response to Planning Assessment Commission |
| **Client** | Wollongong Coal Limited<br>PO Box 281, Fairy Meadow, NSW 2519 |
| **Report Number** | 0637-15-B5 |

| Revision Number | Report Date | Report Author | Reviewer |
|---|---|---|---|
| 5 | 14 September 2015 | MJB | DN |

For and on behalf of WRM Water & Environment Pty Ltd
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PO Box 10703 Brisbane Adelaide St Qld 4000
Tel 07 3225 0200

Michael Batchelor
**Principal Civil Engineer**

# Executive Summary

The New South Wales Planning Assessment Commission (PAC) has reviewed the Russell Vale Colliery Underground Expansion Project (UEP). The PAC has stated that it does not have sufficient information to determine the merits of the proposal with the confidence required for approval.

Since completion of the previous surface water investigations for the UEP, WCL has expanded and improved the surface water monitoring network in the catchments overlying the UEP. The expanded network includes flow monitoring stations in the main channel and on minor tributaries of Cataract Creek. Water level data collected from this network over the period between October 2014 and July 2015 has been converted to time series of flow data at key locations. Streamflow data from the Cataract River at Corrimal No. 1 streamflow gauge has also been obtained from Water NSW.

Wollongong Coal Limited (WCL) engaged WRM to address some of the surface water-related issues raised by the PAC by drawing on the newly acquired monitoring data.

**Observed response of local catchments to rainfall**

The new Cataract River flow record shows that the catchment runoff response is similar to that evident in the Bellambi Creek data (used for calibration of the rainfall-runoff for WRM's previous model studies), but Cataract River baseflow seems to be more persistent than Bellambi Creek baseflow. In previous studies it was proposed that there may be instream losses from Bellambi Creek.

New data obtained for Cataract Creek at CC8, and for the Cataract Creek tributaries, indicates that at finer scales, the catchment characteristics are more complex than is apparent from the other data.

While the period of record is short, and the rating curves require more field gauging to ensure the flow estimates are accurate, during recent wet periods, the measured flows in catchments overlying the proposed longwall panels appear to be locally higher than in upstream reaches of Cataract Creek. In tributary CT2 for example, there is a strong, persistent baseflow response, which may be indicative of groundwater discharge.

**Comparison of observed and modelled catchment response**

The new flow data was compared to the results of rainfall-runoff modelling undertaken for previous impact assessments for the UEP (WRM, 2014). The results indicate that within the limitations of the available catchment and climate data, the model adopted for previous analysis provides a reasonable representation of flows in the Cataract River at Corrimal No. 1.

However, based on recently obtained short-term flow records measured at CC8 on Cataract Creek and at gauges on its minor tributaries, the rainfall-runoff model may:

- over-estimate very low flows in the downstream reaches of Cataract Creek;
- under-estimate flows generated in the minor tributary catchments - especially during wetter periods - and therefore also in the downstream reaches of Cataract Creek.

**Basis of reservoir loss estimates**

For previous assessments of the potential impact of streamflow losses on Cataract Reservoir yield, a range of potential average losses between 0.5 ML/d and 10 ML/d were assumed. A worst-case assessment of potential tributary losses was made by assuming that all runoff from areas upstream of the extent of underground workings could be lost. Previous assessments assumed that all parts of the Cataract Creek catchment contributed similar amounts of runoff. A modified assessment was also made assuming the impacted tributaries contribute proportionally more runoff to downstream flows. The results show that with these conservative assumptions, the losses would be approximately 7.3 ML/d on average. Further details of the basis of this loss estimate are provided in this report.

# Contents

## List of Figures



## List of Tables

# 1 Introduction

## 1.1 BACKGROUND

The environmental assessment for the Russell Vale Colliery Underground Expansion Project (UEP) has been placed on exhibition and a number of submissions were received from government agencies and the public.

In response, Wollongong Coal Limited (WCL) has modified the project as described in the Preferred Project Report (PPR):

- Reducing the total ROM coal production from 31 Mt to 4.7 Mt;
- Removing all proposed longwall mining from Russell Vale West and removing Longwall (LW) 8 from Russell Vale East; and
- Changing the dimensions and orientations of the remaining longwall panels at Russell Vale East.

The application has also been reviewed by the New South Wales Government Department of Planning and Environment (DPE) and the New South Wales Planning Assessment Commission (PAC).

WRM Water and Environment (WRM) prepared surface water modelling studies to support the surface water impact assessment. The results of these investigations were presented in the report entitled Russell Vale Colliery Wonga East Underground Expansion Project Surface Water Modelling, dated 30 May 2014 – Report No 0637-07-A4 (WRM, 2014), which provides detailed information on the potential impacts of the project on the magnitude, frequency and duration of flow in the streams flowing to Cataract Reservoir.

## 1.2 STUDY AREA

The proposed workings are contained within the mining authorities for Russell Vale Colliery, namely Consolidated Coal Lease 745 (CCL745) and Mining Lease 1575 (ML1575).

Coal will be extracted from the Wongawilli Seam by longwall extraction from 8 new panels (Longwall panels 1, 2, 3, 6, 7, 9, 10 and 11) in the Russell Vale East (previously Wonga East) area. These areas are shown in Figure 1.1.

The Study Area for this investigation comprises the west-flowing catchments of potentially impacted and adjacent streams in the vicinity of the project. As shown in Figure 1.1, the UEP's underground operations are proposed to occur below the catchments of Bellambi Creek, Cataract Creek and Cataract River, which flow north-west from the Illawarra Escarpment to Cataract Reservoir. Cataract Reservoir is a component of the Upper Nepean water supply scheme, and is managed by Water NSW. Subsidence-induced cracking could potentially impact the magnitude, frequency and duration of flows in these streams, as well as the water chemistry.

## 1.3 ISSUES RAISED BY THE PAC

In its report on the review of the Russell Vale Colliery Underground Expansion Project, the PAC stated that it does not have sufficient information to determine the merits of the proposal with the confidence required for approval.

It has stated that it may be possible for the proposal to be approved if additional information provided a greater level of confidence in the protection of water quality and quantity in the Sydney Catchment Area.

Wollongong Coal Limited (WCL) requested WRM address specific issues raised in the PAC report, where additional information may be available.

The PAC raised a number of concerns in relation to potential impacts to upland swamps and water resources, which were consistently raised by the various stakeholders:

Specifically, the PAC raised a need for future investigations to address the following:

- measurement and estimation of surface flows including baseflow and subsequent inclusion of baseflow measurements as calibration targets in model calibration (for groundwater modelling);
- site specific studies and hydrological and ecological monitoring and fine scale models are needed to characterise the hydrology and ecological requirements of the swamps;
- justification for scenarios used to model losses in tributary flow, losses of streamflow in Cataract Creek and losses in catchment yield to Cataract Reservoir is needed;
- evidence to support the assumption that the contribution of a swamp to streamflow is proportional to its catchment area;
- modelling of pools within the project area, supported by monitoring data from existing longwall mining panels to determine potential losses from pools on Cataract Creek due to fracturing of rockbars and loss of surface water to groundwater (underflow); and
- consideration of the predicted impacts to streamflow from subsidence, together with the predicted loss of baseflow from depressurisation to determine the total predicted impact to streamflow.

## 1.4 NEW SITE-SPECIFIC WATER DATA

WCL has recently expanded and improved its surface water monitoring network. The expanded network includes flow monitoring stations in the main channel and on minor tributaries of Cataract Creek, including locations downstream of swamps potentially impacted by the UEP. The new monitoring stations should allow more accurate flow records to be constructed for Cataract Creek and its tributaries.

Streamflow data from the Cataract River at Corrimal No. 1 streamflow gauge has also been obtained from Water NSW.

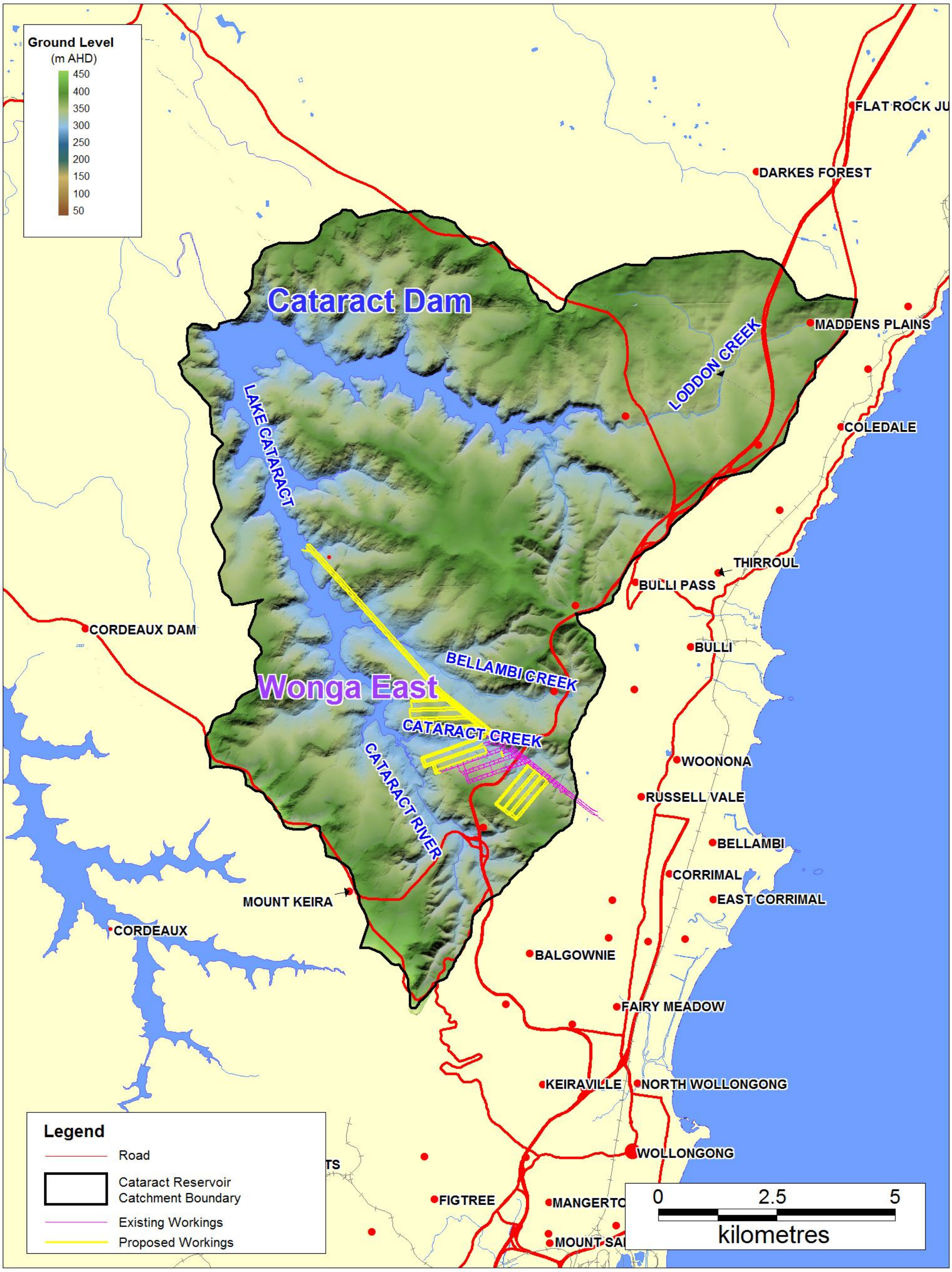



**Figure 1.1** Proposed project and study areas

# 2 Scope of work

Wollongong Coal Limited (WCL) engaged WRM to address some of the surface water related issues raised by the PAC by drawing on the newly acquired monitoring data:

- Review streamflow data obtained from Water NSW's Cataract River at Upper Corrimal No. 1 streamflow gauge;
- Review gauging data and rating curve information derived since installation of new streamflow monitoring stations on Cataract Creek and its tributaries;
- Refine the theoretical rating curves for the gauging stations using the available data (undertaken by Sentinel Pty Ltd);
- Use the rating curves to derive streamflow hydrographs for the period of available record;
- Compare the derived streamflow hydrographs to the modelled streamflow hydrographs;
- Review the rainfall-runoff model adopted for the impact assessment, in light of the new data;
- Review the methodology used to derive an upper bound to potential UEP-induced catchment losses for comparison with previous analysis;
- Revisit the impact assessment with the new losses and in light of the new runoff data, including an assessment of the small impacts of the UEP to the Bellambi Creek and Cataract River catchments.

# 3 Additional surface water flow data

Since completion of previous surface water modelling investigations for the UEP, WCL has expanded and improved the surface water monitoring network in the catchments overlying the proposed project.

The expanded network includes flow monitoring stations in the main channel and on minor tributaries of Cataract Creek. The newly-installed flow monitoring equipment will allow relatively accurate depth-flow relationships to be derived.

Flow data collected from this network over the period between October 2014 and July 2015 was obtained for this study for comparison with runoff modelling undertaken for the previous assessment.

WCL engaged Sentinel Pty Ltd to develop a rating curve for the existing monitoring station on Cataract Creek at CC8. This enabled water level data collected there since January 2013 to be converted to a flow time series. Sentinel noted potential inaccuracies in the rating curve in high flows, and there are possible inconsistencies in the water level datum over time. As a result, this data should be used with caution, but is nonetheless useful for comparative purposes.

In addition to the WCL data, WRM has obtained streamflow data and site details from Water NSW's Cataract River at Corrimal No. 1 streamflow gauge, which was not available for previous investigations.

The locations of the flow monitoring stations used for the analysis are shown in Figure 3.1. The catchment areas to each gauging station are summarised in Table 3.1.

**Table 3.1 Catchment areas to streamflow gauges**

| Gauging Station | Owner | Period of record | Catchment Area (ha) |
|---|---|---|---|
| Bellambi Creek at South Bulli No. 1 | Water NSW | 15/8/1991-19/6/1995 | 932.1 |
| Cataract River at Corrimal No. 1 | Water NSW | 28/9/2006-19/3/2015* | 949.0 |
| Cataract Creek at CC8 | WCL | 7/1/2013-19/6/2015 | 417.4 |
| Cataract Creek at CC4 | WCL | 22/10/2014-24/4/2015 | 153.8 |
| Cataract Creek at CC3 | WCL | 22/10/2014-24/4/2015 | 109.5 |
| CT1A | WCL | 22/10/2014-2/3/2015 | 27.5 |
| CT2 | WCL | 20/10/2014-23/4/2015 | 25.0 |
| CT3A | WCL | 21/10/2014-23/6/2015 | 11.9 |
| CT3 | WCL | 20/10/2014-23/4/2015 | 13.2 |
| CT4A | WCL | 21/10/2014-23/4/2015 | 0.3 |

*excludes earlier part of record prior to June 1992

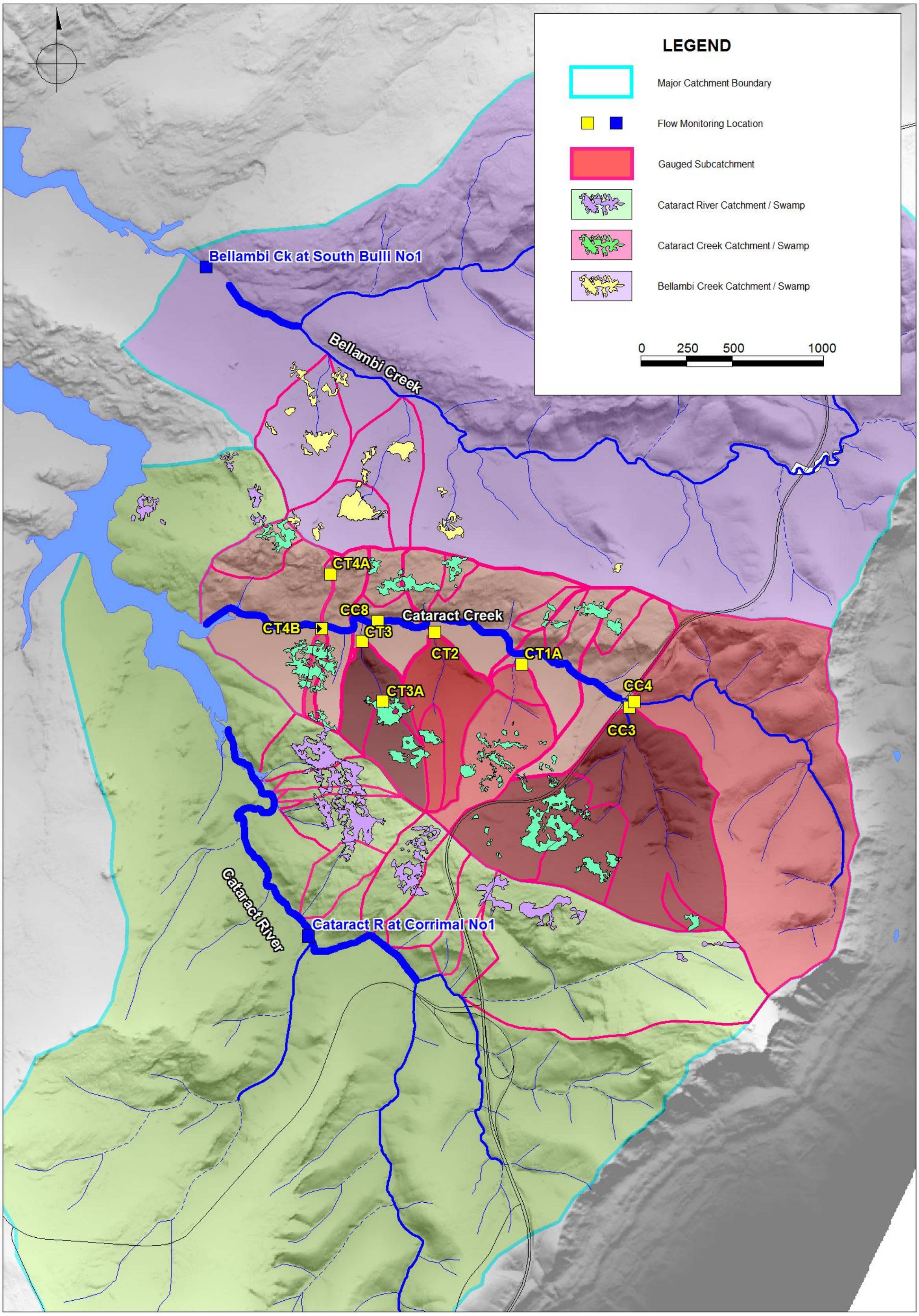



Figure 3.1 Locations of surface water monitoring stations

## 3.1 WATER NSW DATA – CATARACT RIVER AT CORRIMAL NO. 1

The main contiguous part of the streamflow data record obtained for the Cataract River at Corrimal No. 1 is shown in Figure 3.2 below (red areas are gaps in the record). Records existed for the periods as early as May 1990, however, as there is a large gap in the record from June 1992 to September 2006, the earlier data prior to June 1992 was disregarded for this analysis.

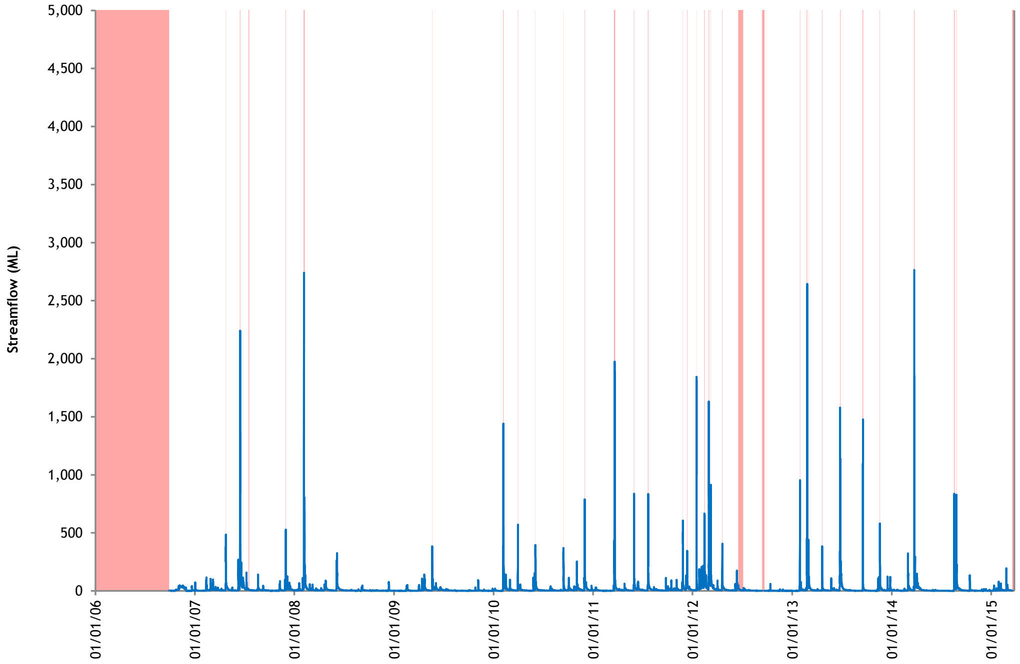
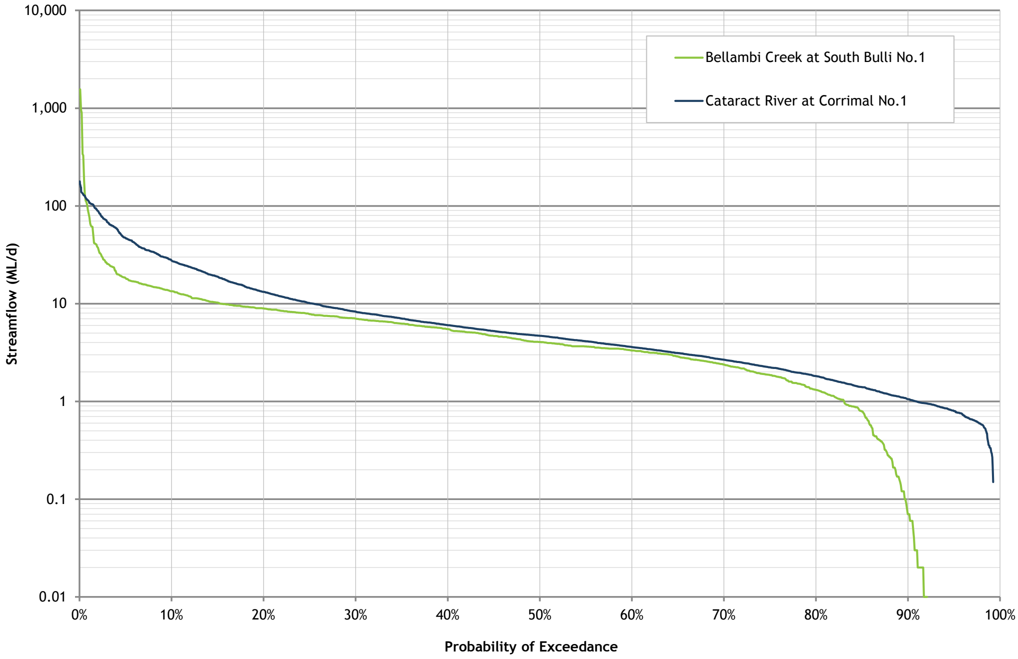


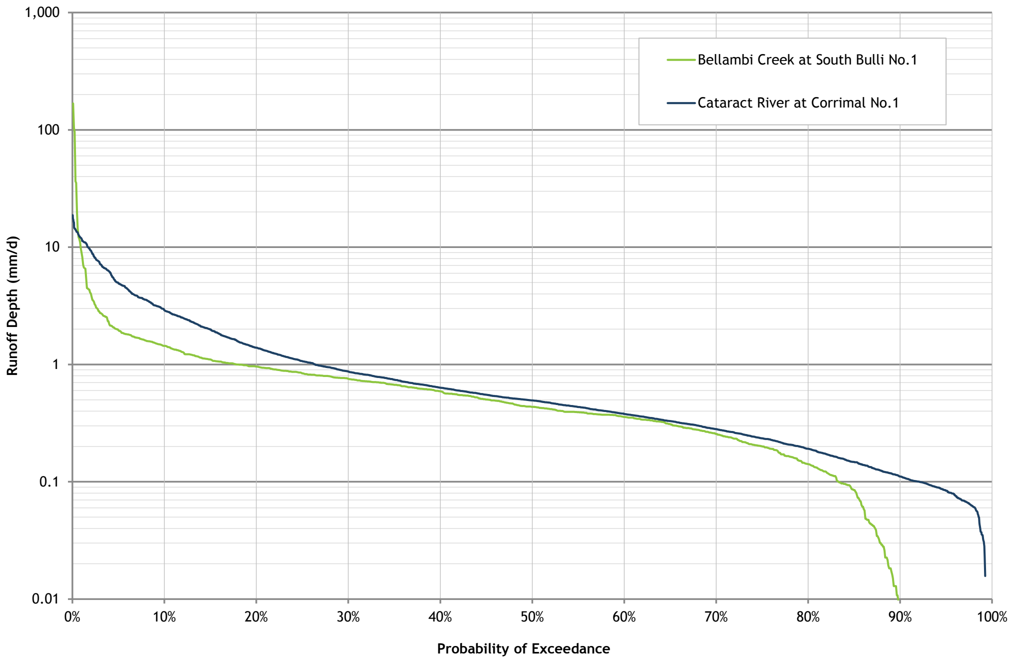

**Figure 3.2 Daily streamflow record - Cataract River at Corrimal No.1 (2006-2015)**

The flow-duration curves for Cataract River at Corrimal No. 1 derived from this data are shown in Figure 3.3 along with the curves for Bellambi Creek at Bulli No.1 for comparison (noting that the periods of record are not the same). Previous surface water balance modelling for the project (WRM, 2015) was based on catchment models validated against the Bellambi Creek streamflow gauge.

Figure 3.4 shows the runoff-duration curves for the two gauges (derived by dividing flow by catchment area so that the behaviour of the two catchments can be directly compared). The curves are very similar between the 25% and 75% exceedance probability levels. However, the Cataract River curve indicates higher runoff during large flows (<1% probability), and more persistent low flows (with very few periods of no flow).




## Figure 3.3 Flow-duration curves – Cataract River and Bellambi Creek




## Figure 3.4 Runoff-duration curves – Cataract River and Bellambi Creek

## 3.2 WCL DATA – CATARACT CREEK TRIBUTARIES

WCL provided streamflow data collected at the new tributary monitoring stations in the Cataract Creek catchment. All available streamflow data is shown in Figure 3.5 below.

Streamflow was derived from measured water levels using theoretical rating curves developed by Sentinel Pty Ltd supplemented with a small number of low flow gaugings by WCL staff. As such, the flow estimates must be used with caution, especially in high flows. Notwithstanding these limitations, and the relatively short period of record, some interesting observations can be made from the data:

- Very little useful data was available from CT1A, CT4A, or CT4B;
- The period from November 2014 to January 2015 was unusually dry, with flow ceasing at various times at all stations except CT2;
- Streamflow at CC3 and CC4 was generally significantly higher than in the minor downstream tributaries (as would be expected, due to the larger catchment areas to these stations);
- During the higher flows during late April, unit runoff at CC3 was similar to CC4 (See Figure 3.8). However during lower flow periods, the baseflow recession was much steeper at CC3. The CC3 catchment overlies previously completed Bulli and Balgownie Seam workings, whereas CC4 is in a catchment underlain by only Bulli Seam workings;
- Streamflow generally increased from less than 0.1 ML/d in early January 2015 to at least several ML/d in late April 2015 at all gauges;
- Streamflow at CT2 did not tend to rapidly respond to rainfall. The hydrograph is more typical of baseflow, and during the wetter periods, the measured streamflow exceeded runoff. This may indicate that the dominant source of runoff in this catchment is groundwater discharge. While significant runoff is generally observed at CT3A, very little runoff is observed at CT3. It is not clear if this is due to problems with the CT3 gauge or location, or if it is as a result of losses between the two gauges;
- Unit runoff (total runoff divided by catchment area) at CT2 and CT3 is typically higher than at CC3 and CC4. This may be due to groundwater discharge, or differences in the runoff characteristic in these areas;
- In late May 2015, there was a 2 week period of reduced flow at CT2, CT3, and CT3A. The reason for this unknown, but could be consistent with temporary impacts due to mining-induced subsidence.

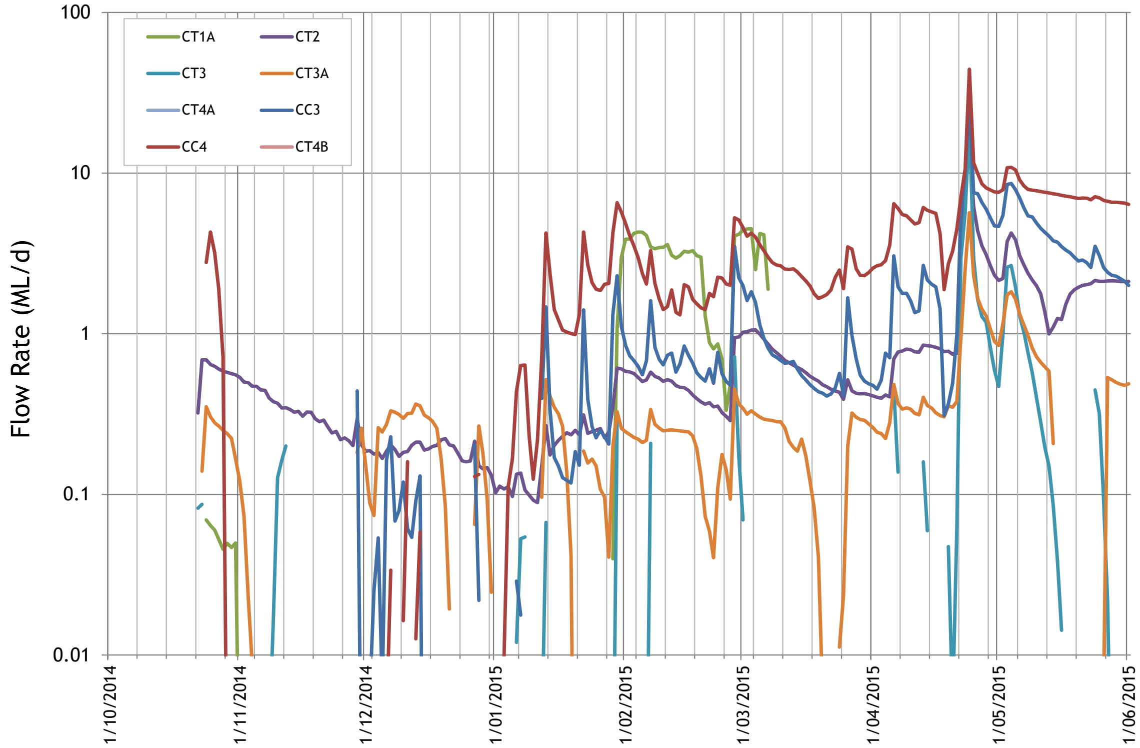



**Figure 3.5 Streamflow at WCL monitoring stations in Cataract Creek catchment**

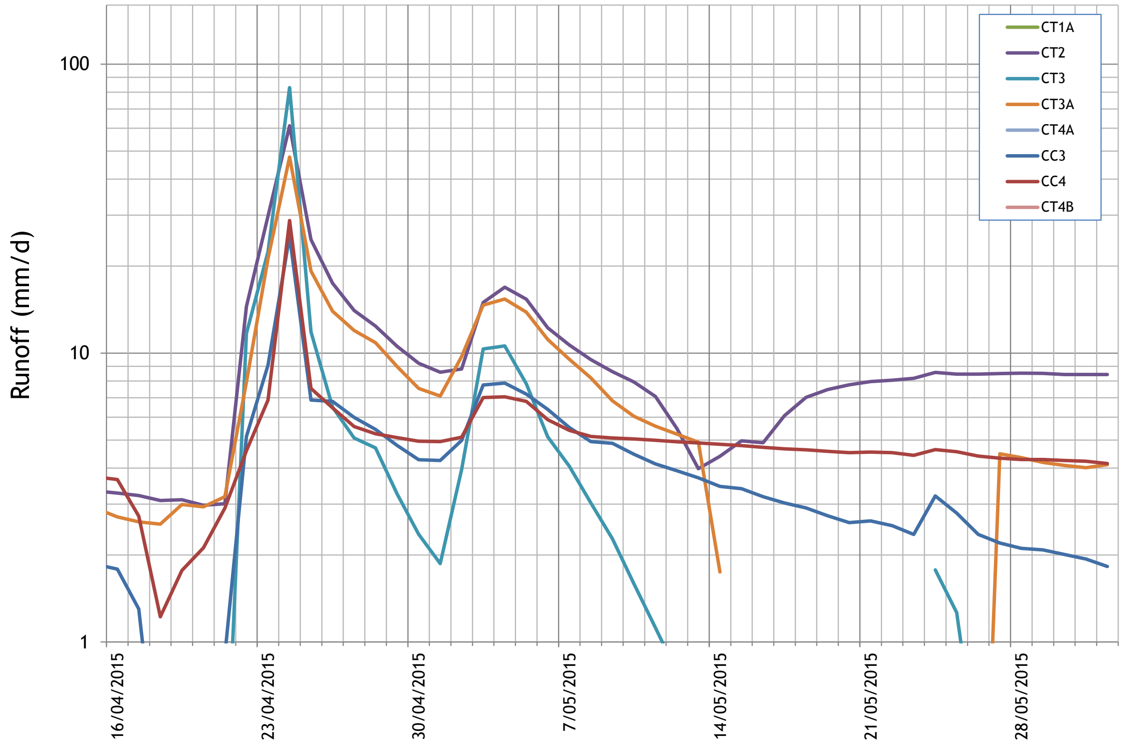



**Figure 3.6 Unit runoff at Cataract Creek tributary monitoring stations - April-May 2015**

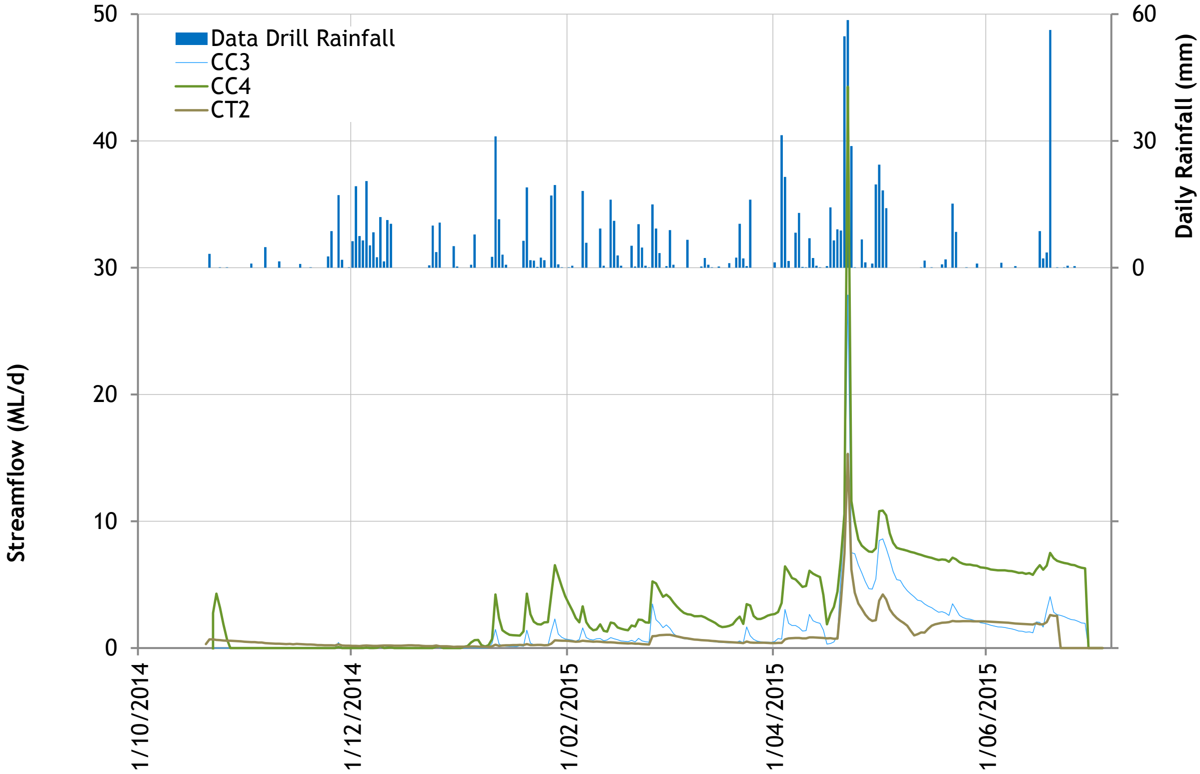



**Figure 3.7** **Streamflow at surface water monitoring locations in Cataract Creek**

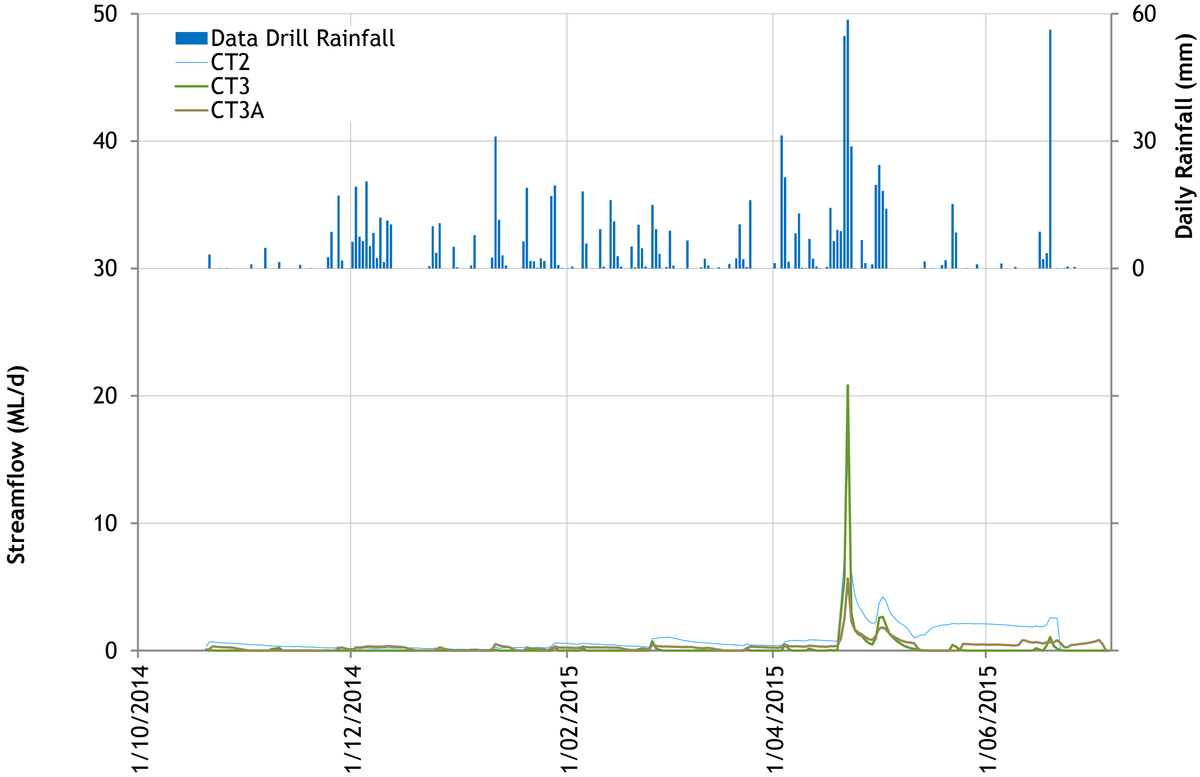



**Figure 3.8** **Streamflow at selected tributary surface water monitoring locations in Cataract Creek**

# 4 Catchment modelling

As there are no long-term streamflow records available for the catchments of interest, catchment modelling (using the AWBM) was used to extend the available streamflow data both temporally and spatially so that the relative impact of streamflow losses could be assessed.

The AWBM model parameters adopted for previous catchment modelling for the UEP (WRM, 2014) are summarised in Table 4.1 below, and the rainfall dataset for catchment modelling is described in Appendix A.

**Table 4.1 AWBM parameters – calibration to Water NSW monitoring station data**

| AWBM parameter | Bellambi Creek at South Bulli No.1 |
|---|---|
| A1 | 0.134 |
| A2 | 0.433 |
| BFI | 0.317 |
| C1 | 6 |
| C2 | 94 |
| C3 | 240 |
| $K_{base}$ | 0.976 |
| $K_{surface}$ | 0.632 |

These parameters were previously derived by calibrating AWBM models to recorded streamflow at Bellambi Creek and Loddon River (WRM, 2015).

As noted in the previous studies, 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.

The most significant discrepancy was that the model tended to underestimate the frequency of no-flow periods. Very low flows less than 1 ML/d appeared 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. It was postulated that low flows may have been affected by historical streamflow loss through subsidence-induced cracking of Bellambi Creek. The discrepancy would be consistent with a streamflow loss of 0.3 ML/d.

The results of the calibrated runoff model are compared to the daily Cataract River at Corrimal No. 1 streamflow record in Figure 4.1 Modelled and observed streamflow - application of previous AWBM parameters to catchment to Cataract River at Corrimal No. 1

and to the frequency curve in Figure 4.2. The simulated flow-duration curve is generally a good match to the observed curve, especially for lower flows. However, larger flows appear to be overestimated by the rainfall-runoff model. Possible explanations for this discrepancy could include differences in catchment rainfall compared to the data drill dataset or problems in the rating curve for the gauge.

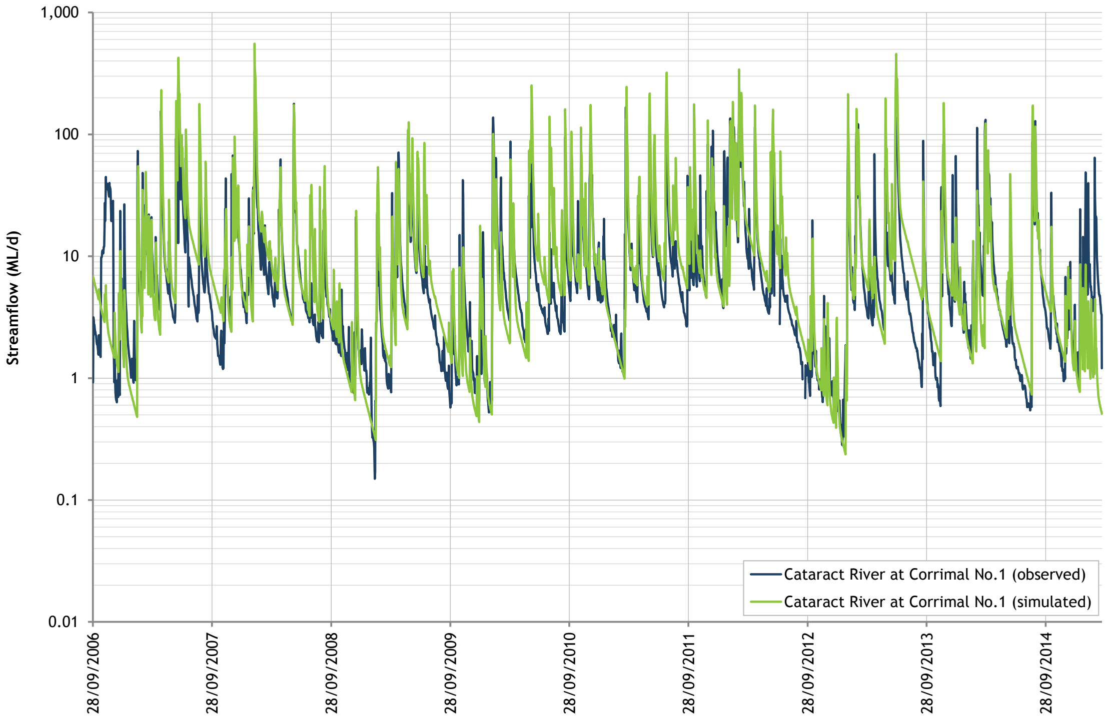



**Figure 4.1 Modelled and observed streamflow - application of previous AWBM parameters to catchment to Cataract River at Corrimal No. 1**

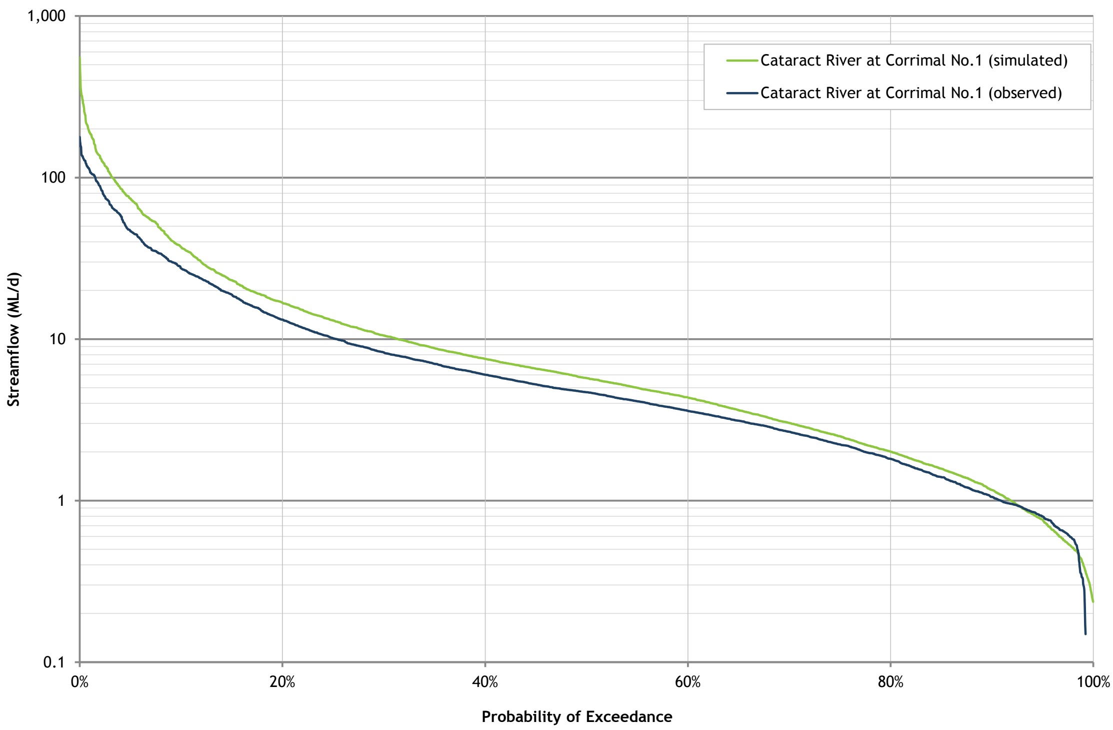



**Figure 4.2 Flow-duration curves - application of previous AWBM parameters to catchment to Cataract River at Corrimal No. 1**

Figure 4.3 compares the results of the catchment modelling to the flow observations for CC8 on Cataract Creek. The model reproduces some aspects of catchment behaviour well. However, in the first half of the record, the model overestimates the very low flows, and in the latter half of the record, it underestimates flow.

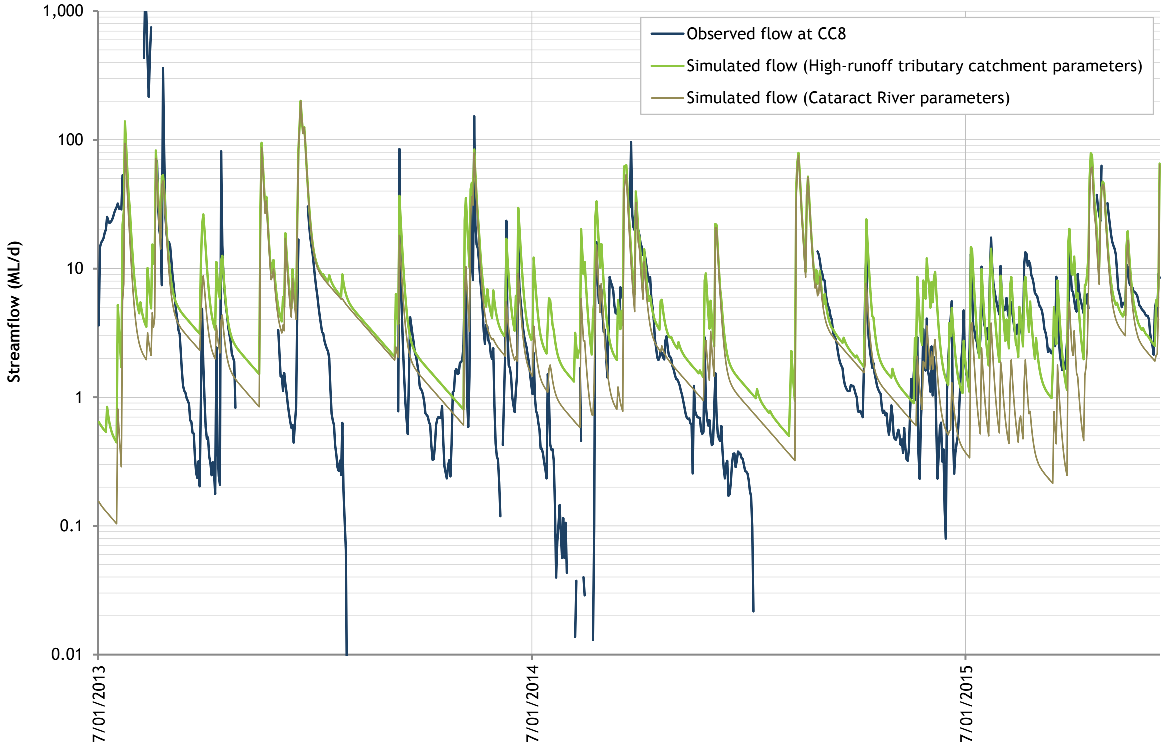



**Figure 4.3 Modelled and observed flows – application of previous AWBM parameters to catchment to Cataract Creek at CC8 gauge**

These discrepancies are possibly due to datum shifting during the period of record, however, the general upward trend in flow in the first half of 2015 is consistent with observations at the tributary gauges. It is possible that in the earlier period there is a loss of streamflow in upstream reaches, and in the later period, there is a gain in streamflow through groundwater discharge – possibly from the tributary catchments upstream of CT2 and CT3.

An alternative, “high runoff” AWBM parameter set (with all moisture store capacities set close to zero) was used to derive a second modelled flow series from these tributary catchments. Figure 4.3 shows the results of modelling applying the two parameter sets.

The alternative “high runoff” parameter set might be representative of conditions where the catchment remains saturated due to groundwater discharge or where catchment runoff discharges via deep groundwater flow (e.g. via subsidence cracks) without significant evapotranspiration – and probably represents a feasible upper limit for the volume of catchment runoff from these areas. This significantly improves the fit post-January 2015 – but does not necessarily represent the physical characteristics of the catchment.

# 5 Impact assessment

Several unnamed tributaries of Cataract Creek, Bellambi Creek and Cataract River may be impacted by subsidence cracking. Figure 5.1 shows the contributing catchment areas of the tributaries that will be affected by subsidence.

For previous assessments of the potential impact of streamflow losses on Cataract Reservoir yield, a range of potential average losses between 0.5 ML/d and 10 ML/d were assumed (WRM, 2015).

For comparison, the potential impact on surface flow of losing all subsidence-affected tributary streamflow within, and upstream of, the areal extent of the proposed underground workings was assessed in a “worst case” scenario by removing these areas from the catchment model. These areas are shown in Figure 5.1. Catchments which overlie secondary workings or lie downstream of potentially affected secondary workings were assumed to continue to contribute runoff.

As described in Section 3 and 4, there is some evidence from the limited tributary flow data to suggest that some Cataract Creek sub-catchments may sometimes contribute significantly more flow than others due to additional groundwater seepage effects. The “worst case” assessment therefore assumes that runoff contribution from the lower tributary streams is proportionally higher (using the “high runoff” AWBM model described in Section 4), than the parts of the catchment upstream of CC3 and CC4 (using original AWBM model parameters used for the previous assessments). This is illustrated in Figure 5.2.

The original AWBM model parameters (WRM, 2015) were used to estimate runoff and assess the potential flow loss from the Bellambi Creek and Cataract River catchments.

The results of the analysis are summarised in Table 5.1 to Table 5.4.

The likelihood of losing all streamflow to the underground workings via subsidence cracking is very improbable, and represents an upper bound to potential losses.

Nonetheless, the total worst case loss from all tributaries is approximately 7.3 ML/d - which is within the range of values considered in the impact assessment for Cataract Reservoir (WRM, 2014).

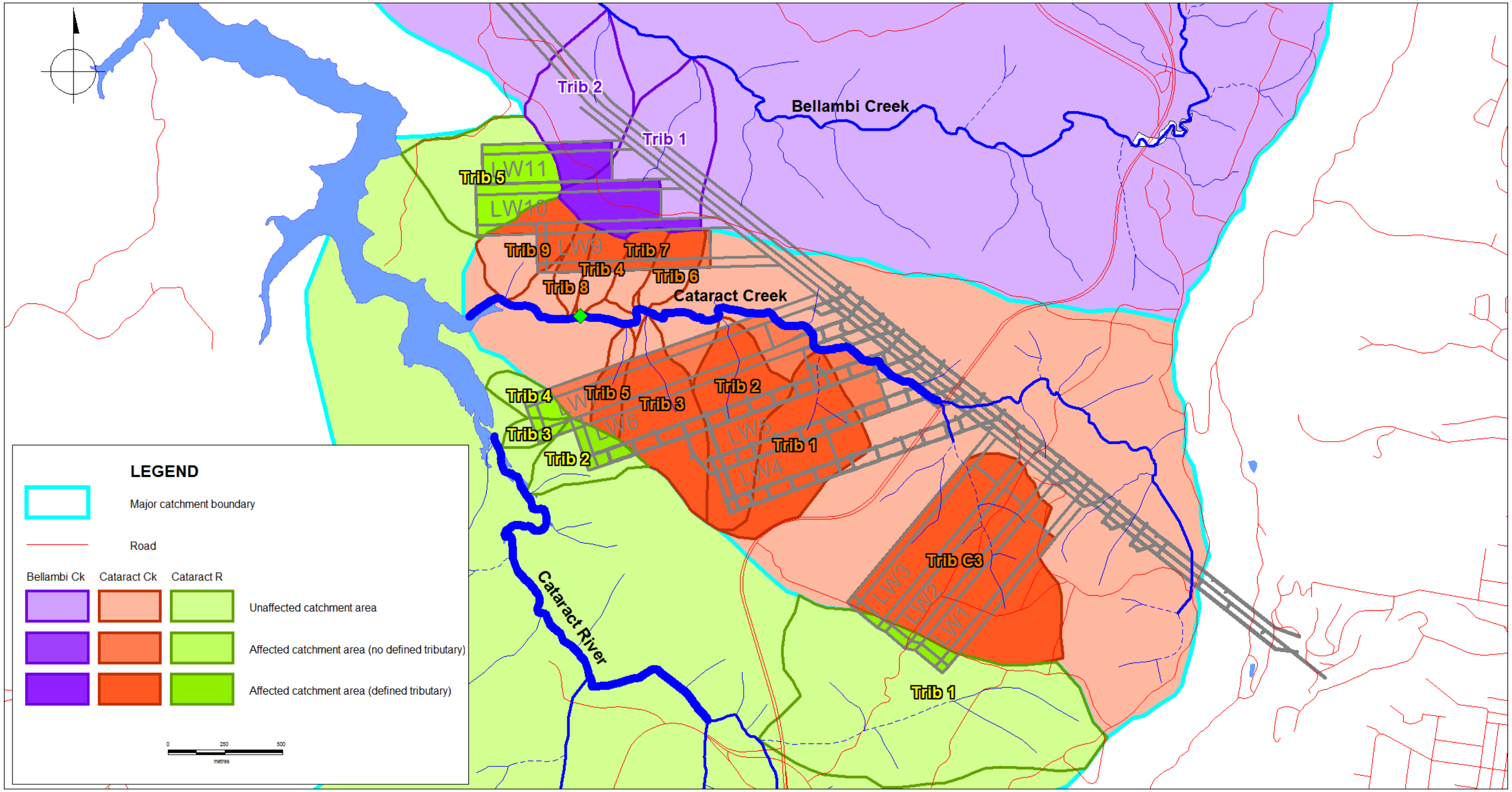



**Figure 5.1 Tributary Sub-catchment areas of Cataract River, Cataract Creek and Bellambi Creek**

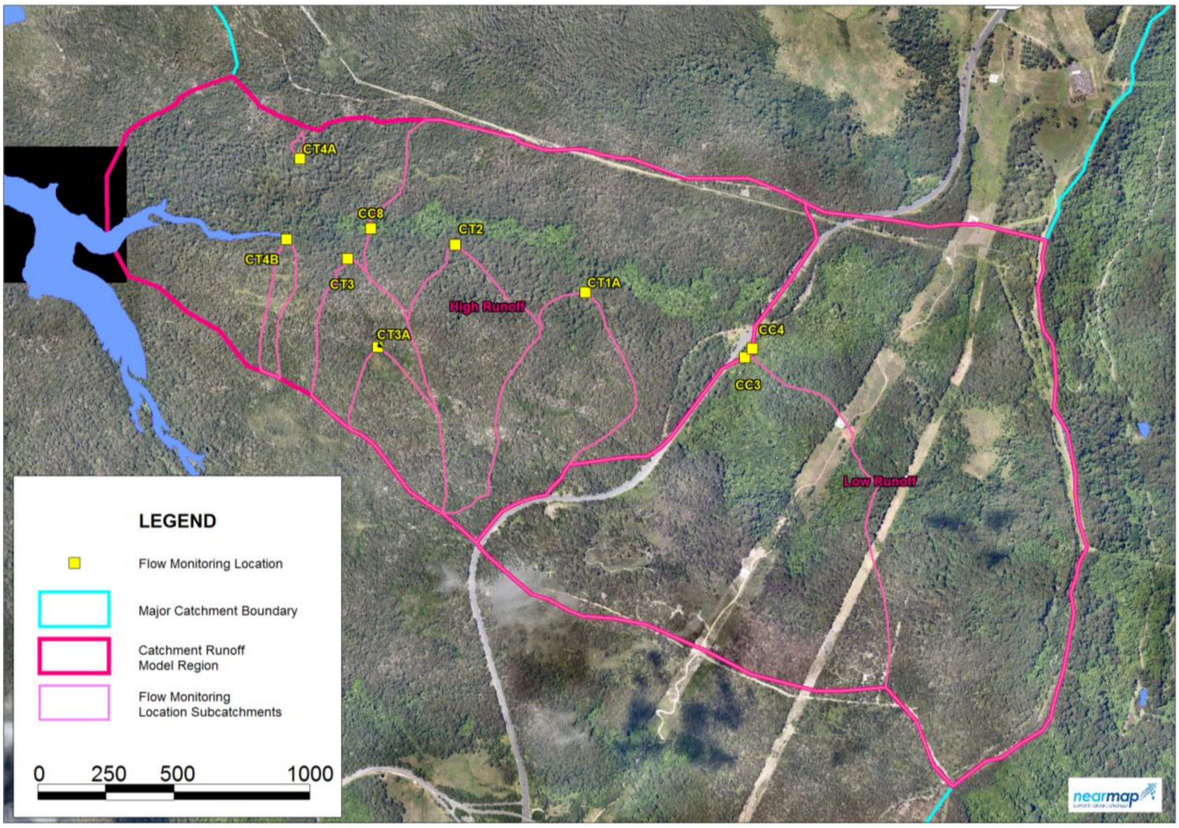



**Figure 5.2 Adopted distribution of catchment runoff parameters for worst case loss assessment**

Table 5.1 Tributary losses - Cataract Creek, worst case loss assessment

| Catchment | Area (ha) | Total Flow (ML/d) | | Baseflow (ML/d) | |
|---|---|---|---|---|---|
| | | Average | Median | Average | Median |
| Cataract Creek (presubsidence) | 518 | 12.97 | 4.91 | 4.11 | 2.91 |
| **Potential flow loss from:** | | | | | |
| Tributary C3 | 67.2 | 2.27 | 1.01 | 0.72 | 0.58 |
| Tributary 1 | 28.8 | 0.97 | 0.43 | 0.31 | 0.25 |
| Tributary 2 | 26.8 | 0.91 | 0.40 | 0.29 | 0.23 |
| Tributary 3 | 22.3 | 0.75 | 0.33 | 0.24 | 0.19 |
| Tributary 4 | 3.1 | 0.10 | 0.05 | 0.03 | 0.03 |
| Tributary 5 | 4.4 | 0.15 | 0.07 | 0.05 | 0.04 |
| Tributary 6 | 3.7 | 0.12 | 0.06 | 0.04 | 0.03 |
| Tributary 7 | 3.2 | 0.11 | 0.05 | 0.03 | 0.03 |
| Tributary 8 | 2.6 | 0.09 | 0.04 | 0.03 | 0.02 |
| Tributary 9 | 6.8 | 0.23 | 0.10 | 0.07 | 0.06 |
| Residual areas (LW7) | 19.0 | 0.64 | 0.29 | 0.20 | 0.17 |
| Residual areas (LW9) | 1.0 | 0.03 | 0.01 | 0.01 | 0.01 |
| *All affected areas (total)* | *188.9* | *6.38* | *2.83* | *2.02* | *1.64* |

Table 5.2 Tributary losses - Bellambi Creek, worst case loss assessment

| Catchment | Area (ha) | Total Flow (ML/d) | | Baseflow (ML/d) | |
|---|---|---|---|---|---|
| | | Average | Median | Average | Median |
| Bellambi Creek (presubsidence) | 932 | 21.66 | 6.22 | 6.87 | 4.29 |
| **Potential flow loss from:** | | | | | |
| Tributary 1 | 12.3 | 0.28 | 0.08 | 0.09 | 0.06 |
| Tributary 2 | 4.8 | 0.11 | 0.03 | 0.04 | 0.02 |
| *All affected areas (total)* | *17.1* | *0.40* | *0.11* | *0.13* | *0.08* |

Table 5.3 Tributary losses - Cataract River, worst case loss assessment

| Catchment | Area (ha) | Total Flow (ML/d) | | Baseflow (ML/d) | |
|---|---|---|---|---|---|
| | | Average | Median | Average | Median |
| Cataract River (presubsidence) | 1,796 | 41.71 | 11.97 | 13.22 | 8.26 |
| | | | | | |
| **Potential flow loss from:** | | | | | |
| Tributary 1 | 3.6 | 0.08 | 0.02 | 0.03 | 0.02 |
| Tributary 2 | 4.0 | 0.09 | 0.03 | 0.03 | 0.02 |
| Tributary 3 | 1.3 | 0.03 | 0.01 | 0.01 | 0.01 |
| Tributary 4 | 2.0 | 0.05 | 0.01 | 0.01 | 0.01 |
| Tributary 5 | 13.1 | 0.30 | 0.09 | 0.10 | 0.06 |
| *All affected areas (total)* | *24.1* | *0.56* | *0.16* | *0.18* | *0.11* |

Table 5.4 Tributary losses - by panel, worst case loss assessment

| LW Series | Catchment | Tributary | Average Total Flow (ML/day) | Total Loss for LW Series (ML/day) |
|---|---|---|---|---|
| 1-3 | Cataract Creek | Tributary C3 | 2.27 | 2.35 |
| | Cataract River | Tributary 1 | 0.08 | |
| 4-7 | Cataract Creek | Tributary 1 | 0.97 | 3.60 |
| | | Tributary 2 | 0.91 | |
| | | Tributary 3 | 0.75 | |
| | | Tributary 5 | 0.15 | |
| | | Residual areas (LW4-7) | 0.64 | |
| | Cataract River | Tributary 2 | 0.09 | |
| | | Tributary 3 | 0.03 | |
| | | Tributary 4 | 0.05 | |
| 9-11 | Cataract Creek | Tributary 4 | 0.10 | 1.39 |
| | | Tributary 6 | 0.12 | |
| | | Tributary 7 | 0.11 | |
| | | Tributary 8 | 0.09 | |
| | | Tributary 9 | 0.23 | |
| | | Residual areas (LW9-11) | 0.03 | |
| | Bellambi Creek | Tributary 1 | 0.28 | |
| | | Tributary 2 | 0.11 | |
| | Cataract River | Tributary 5 | 0.30 | |

# 6 Summary of findings

## 6.1 OBSERVED RESPONSE OF LOCAL CATCHMENTS TO RAINFALL

The catchment runoff response apparent in the recently observed Cataract River flow record is very similar to the Bellambi Creek dataset (used for calibration of the rainfall-runoff model in the original surface water models), but baseflow is more persistent for Cataract River.

However, new data obtained for Cataract Creek at CC8, and for the Cataract Creek tributaries, indicates that at finer scales, the catchment characteristics are more complex than is apparent from the other data.

During recent wet periods, the measured flows in catchments overlying the proposed longwall panels appear to be locally higher than in upstream reaches of Cataract Creek. In tributary CT2 for example, there is a strong, persistent baseflow response, which may be indicative of groundwater discharge. This appears to be supported by data collected at CC8, which indicates an increase in streamflow post December 2014 which cannot be accounted for by climate conditions alone.

## 6.2 COMPARISON OF OBSERVED AND MODELLED CATCHMENT RESPONSE

The newly acquired flow data was compared to the results of rainfall-runoff modelling undertaken for previous impact assessments for the UEP (WRM, 2014). The results indicate that within the limitations of the available catchment and climate data, the model adopted for the original analysis provides a reasonable representation of lower flows in the Cataract River at Corrimal No. 1. This supports the continued use of the parameters used previously for surface water impact assessment modelling. High flows are overestimated. This could be due to non-uniform catchment rainfall or to errors in the rating curves for the gauge.

Based on recently obtained short-term flow records measured at CC8 on Cataract Creek and at gauges on its minor tributaries, the rainfall-runoff model may:

- over-estimate very low flows in the downstream reaches of Cataract Creek
- under-estimate flows generated in the minor tributary catchments – especially during wetter periods - and therefore also in the downstream reaches of Cataract Creek.

These discrepancies may be due to:

- in-stream losses along Cataract Creek of the order of 1 ML/d during dry periods; and
- groundwater discharge during wetter periods.

However, the differences could also be simply due to errors in the rating curves (which require further confirmation with field velocity measurements) or recording datum.

## 6.3 BASIS OF RESERVOIR LOSS ESTIMATES

For previous assessments of the potential impact of streamflow losses on Cataract Reservoir yield, a range of potential average losses between 0.5 ML/d and 10 ML/d were assumed. A worst-case assessment of potential tributary losses was made by assuming that all runoff from areas upstream of the extent of underground workings could be lost. Further details of the basis of this loss estimate are provided in Section 5.

Previous assessments assumed that all parts of the Cataract Creek catchment contributed similar amounts of runoff. A modified assessment was also made assuming the impacted tributaries contribute proportionally more runoff (by conservatively setting the capacity of all AWBM soil moisture stores for these sub-catchments to zero). The results show that even under such a “worst case” scenario, losses are 7.3 ML/d on average, and therefore within the range of 0.5 ML/d to 10 ML/d assumed previously.

# 7 References


| | |
|---|---|
| WRM, 2014 | *'Russell Vale Colliery Wonga East Underground Expansion Project Surface Water Modelling', Report prepared for Wollongong Coal Limited by WRM Water & Environment Pty Ltd, Report No. 0637-07-A4, 30 May 2014.* |
| WRM, 2015 | *'Russell Vale Colliery Underground Expansion Project Surface Water and Salt Balance Modelling', Report prepared for Wollongong Coal Limited by WRM Water & Environment Pty Ltd, Report No. 0637-14-C3, 3 March 2015.* |
| Sentinel, 2015 | *'WOLLONGONG COAL RATINGS REVIEW', Report prepared for Wollongong Coal Limited by Sentinel Pty Ltd, REPORTJ000288, 26 May 2015.* |

# Appendix A Climate data

## Contents

# A1 Rainfall data

## A1.1 BUREAU OF METEOROLOGY AND WATER NSW DATASETS

Water NSW collects rainfall data at a number of stations spread throughout the catchments of the dams it operates. The locations of these stations relevant to this study are shown in Figure A.1.

The data records from these stations commence in 1983, and contain gaps (where data is either missing or poorly recorded). This is denoted in the figures below in red, which show data collected over the full available period of record.

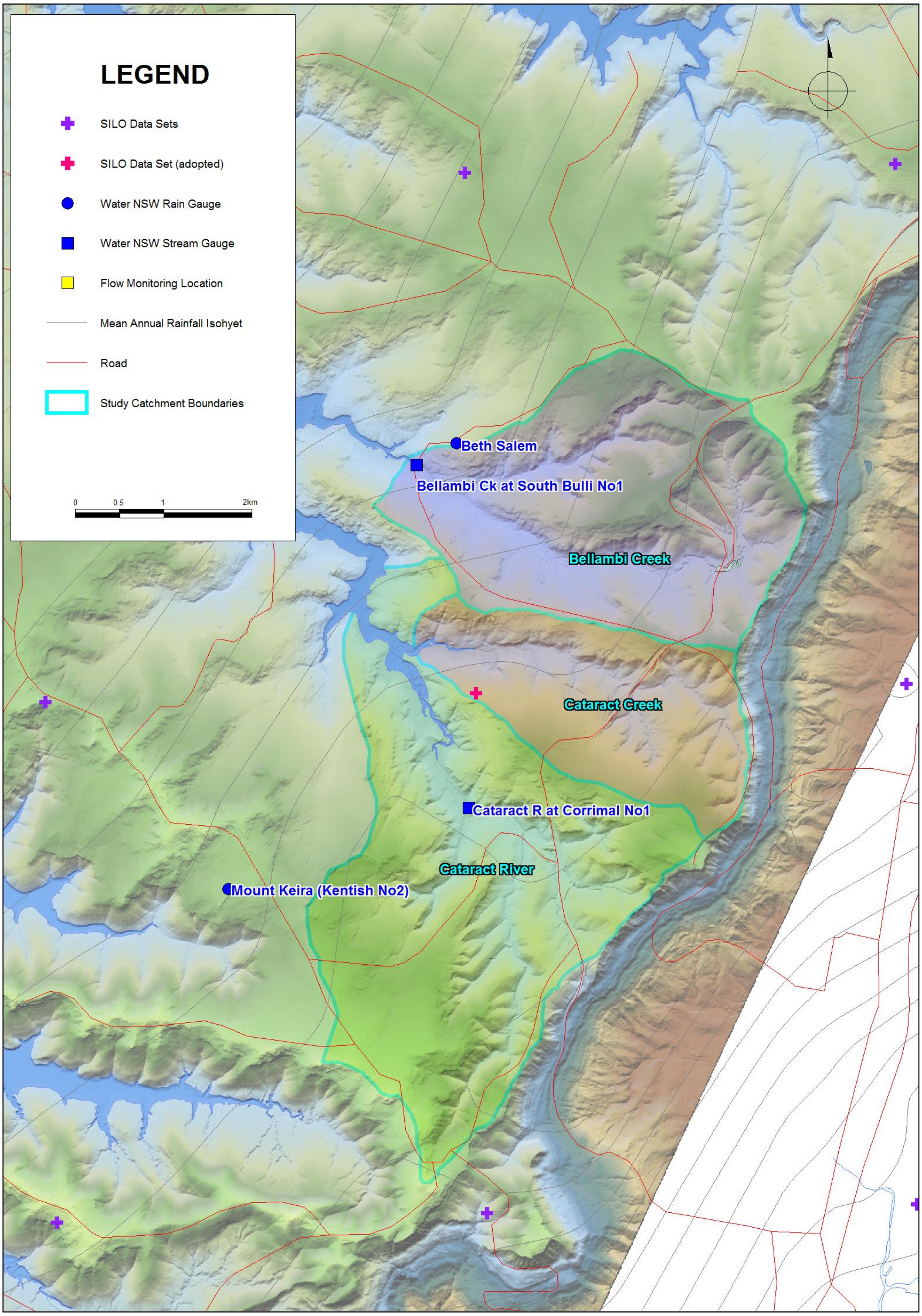



**Figure A.1 – Locations for climate datasets compared to subject catchments**

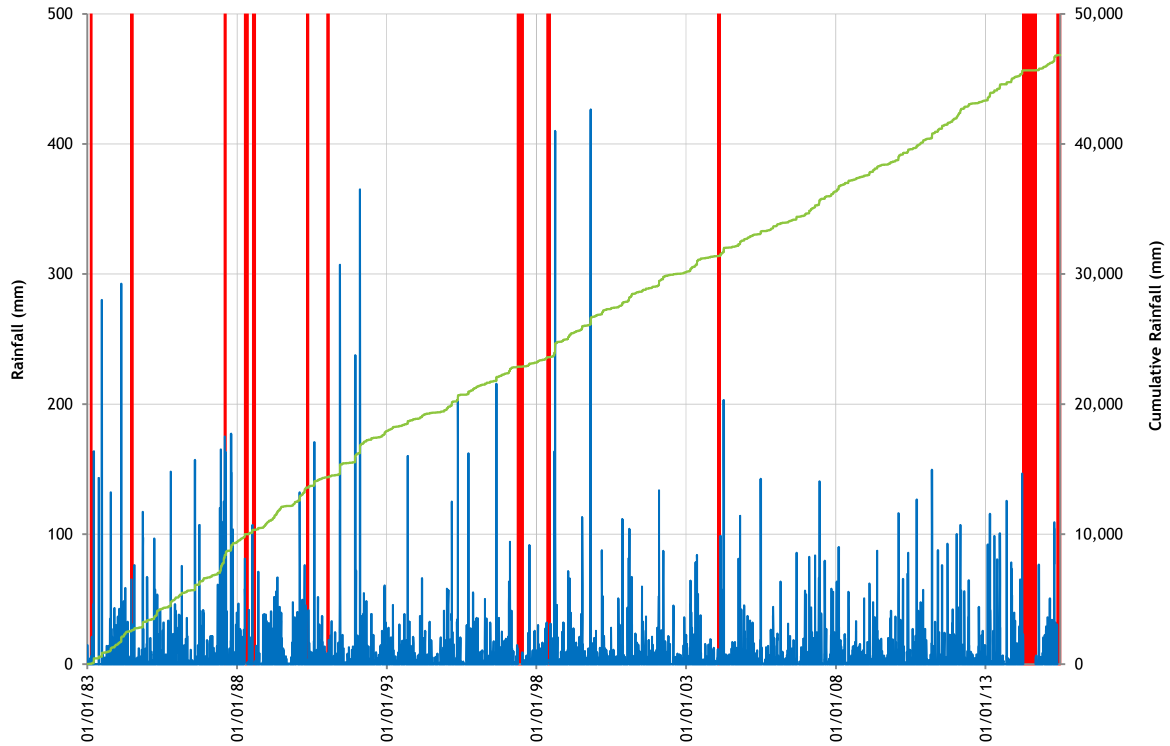



**Figure A.2 – Rainfall record at Water NSW station 568067 - Beth Salem**

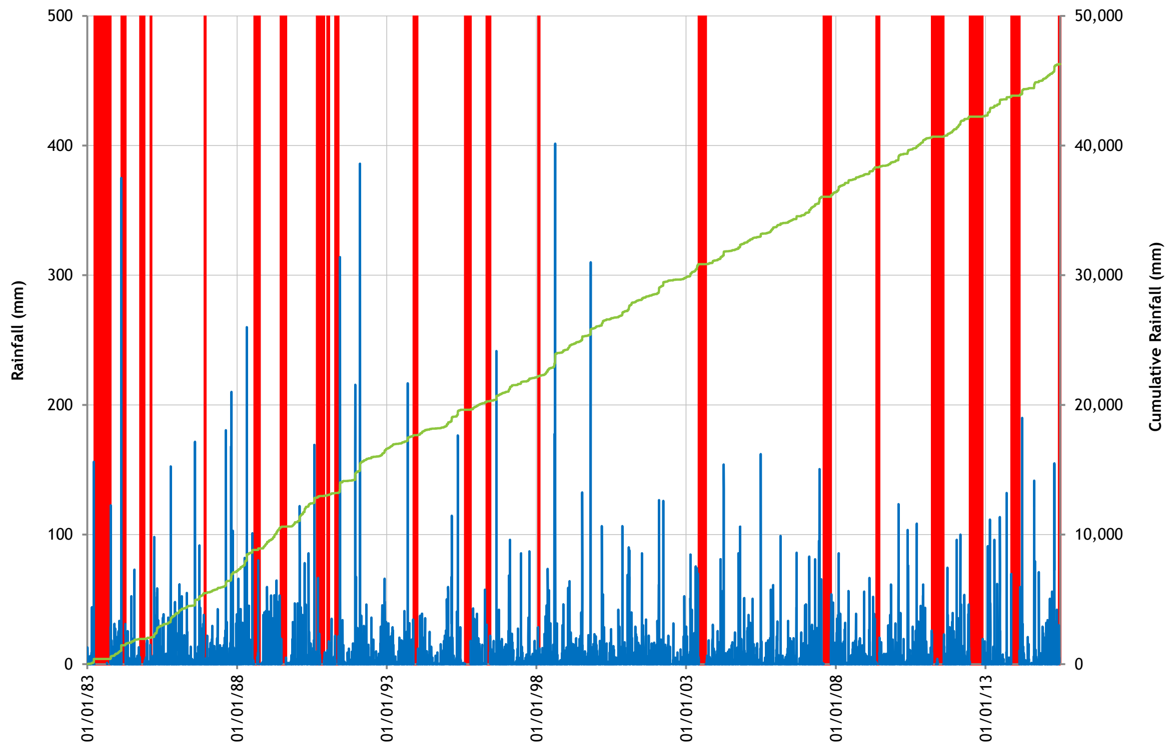



**Figure A.3 – Rainfall record at Water NSW station 568097 - Mt Keira (Kentish No. 2)**

## A1.2 SILO DATASETS

SILO is an enhanced climate database hosted by the Science Delivery Division of the Queensland Department of Science, Information Technology, Innovation (DSITI). SILO contains Australian climate data from 1889 (current to yesterday), in a number of ready-to-use formats, suitable for research and climate applications. SILO data offers the significant advantages of being complete, up to date and gap-free. Two main types of data are available:

- Patched Point Data: a daily time series of data at a point location consisting of station records which have been supplemented by interpolated estimates when observed data are missing. Patched datasets are available at approximately 4,600 Bureau of Meteorology recording stations around Australia, including the Cataract Dam rainfall station.
- Data Drill: a daily time series of data at a point location consisting entirely of interpolated estimates. The data are taken from gridded datasets and are available at any grid point over the land area of Australia. The gridded datasets are interpolated surfaces derived either by splining or kriging the observational data. The grids are stored on a regular 0.05° x 0.05° grid, which is approximately 5 km x 5 km.

The closest Patched Point Data set available is at the Cataract Dam gauge. Due to the very high rainfall gradients in the study area, this gauge is not near enough to the study area to be of any material use to this investigation.

Figure A.1 displays the availability of SILO dataset grid across the study area, and the adopted location. As the area is one of high rainfall variability, careful selection of the correct dataset location was critical.

As shown in Figure A.4, annual rainfall within the Cataract Creek catchment has varied between 667 mm in 1941 and 2,951 mm in 1950 over the rainfall record. The mean annual rainfall over the entire record period is 1,521 mm.

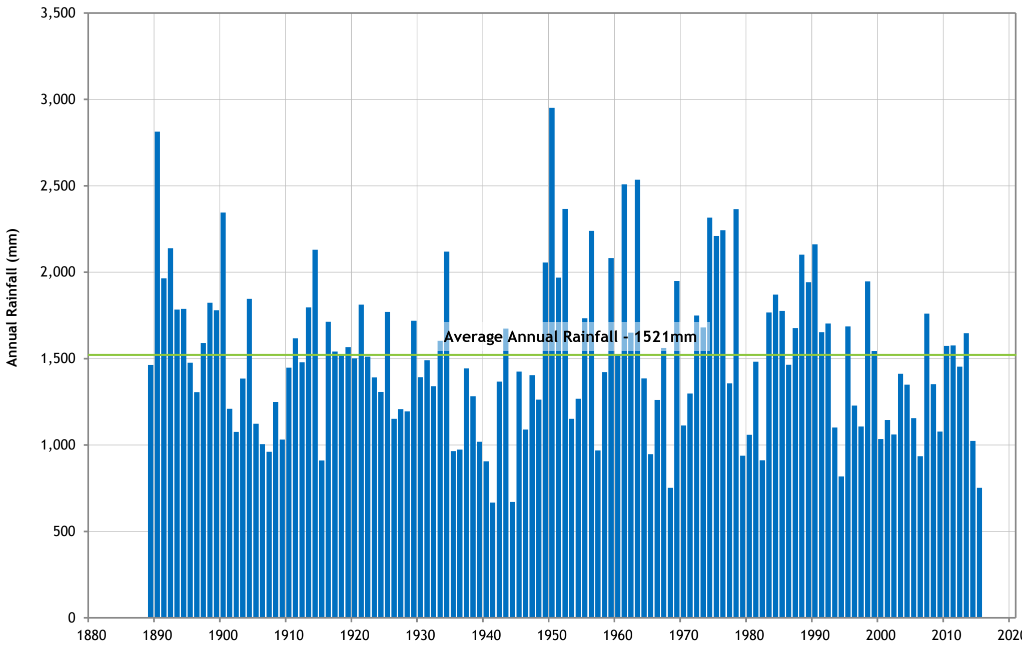



**Figure A.4 – Annual rainfall record - Data Drill**

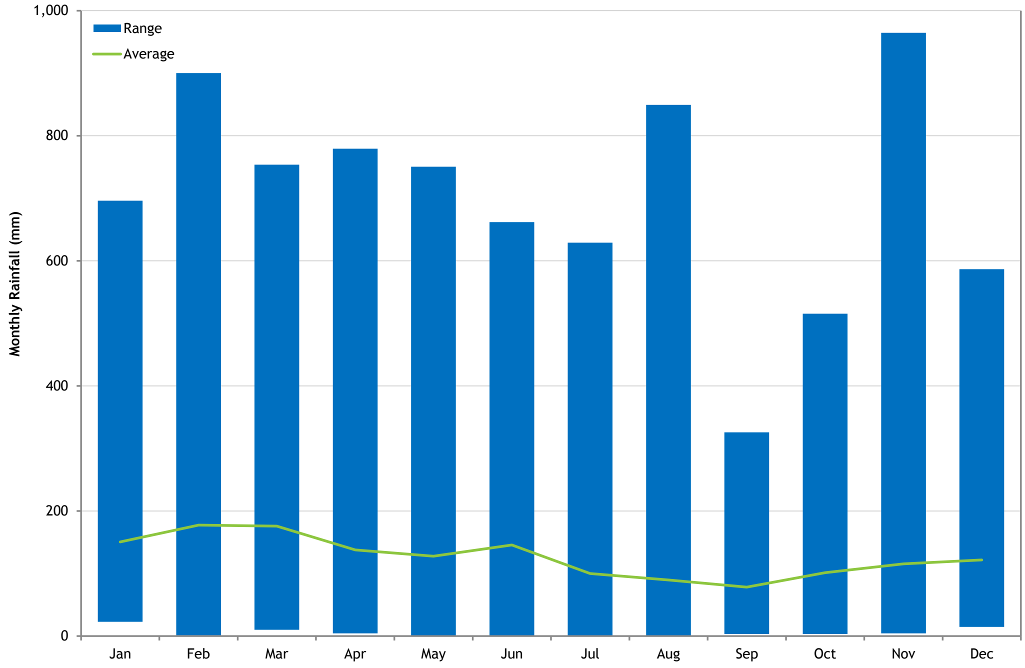



**Figure A.5 – Monthly rainfall - Data Drill**

## A1.3 SPATIAL VARIABILITY

The project is located in a region of very high rainfall gradient to the west of the Illawarra escarpment. This is illustrated in Figure A.1 which also shows mean annual rainfall isohyets in the area. It is therefore important to ensure that the rainfall data sources selected for plotting rainfall residual is reasonably representative of nearby rainfall.

The length and quality of physical rainfall gauge records varies. Continuous data in an overlapping period for the three gauges in the study area runs from 1983.

Rainfall residual curves for the Water NSW stations are compared with the selected SILO dataset residual curve in the following plots for the catchments in the study area. The curves show that while there are some differences in total rainfall over this period, the shapes of the curves are similar with few instances where significant rainfall events and dry periods are not common to all records.

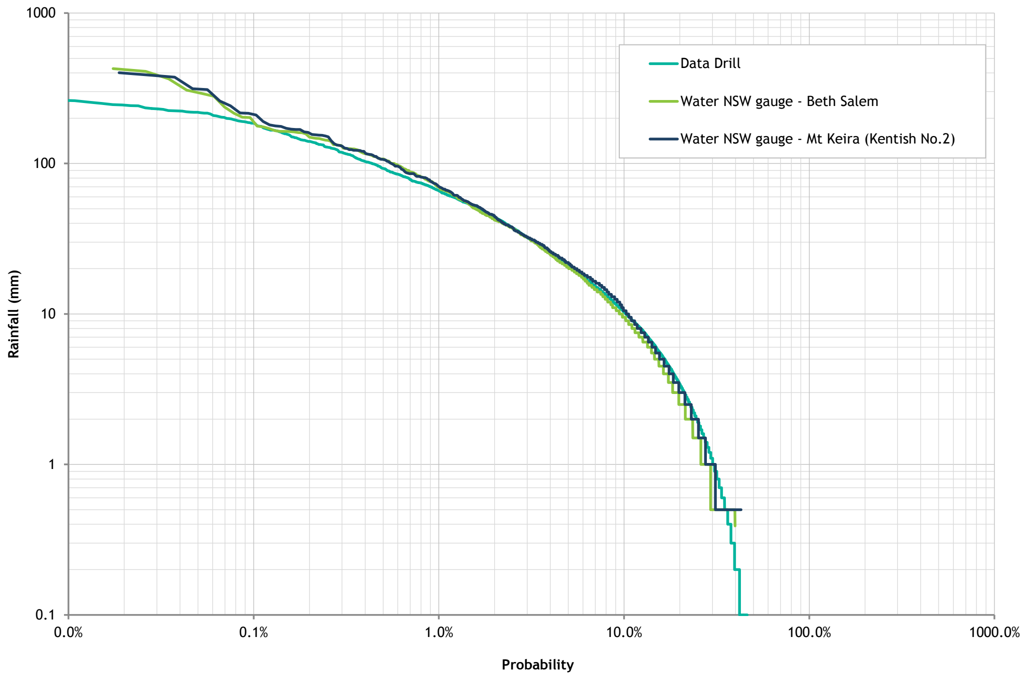



**Figure A.6 – Comparison of rainfall frequency between Water NSW data and Data Drill**

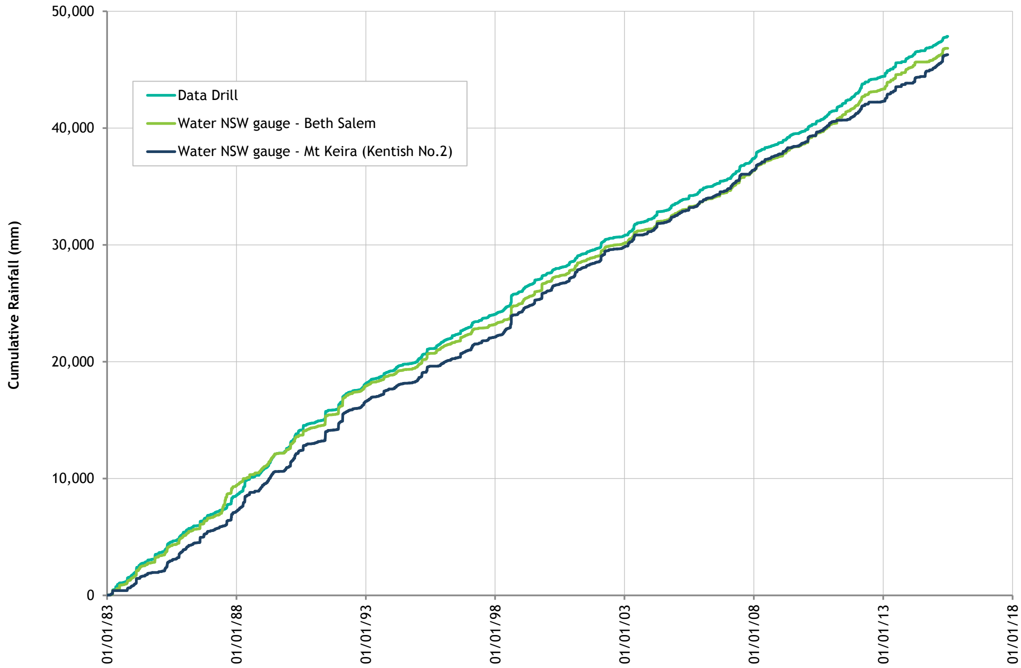



**Figure A.7 – Comparison of cumulative rainfall between Water NSW data and Data Drill**

Figure A.7 shows a reasonably close correlation between the three data sets. Compared to the Water NSW records, the Data Drill overestimates the occurrence of smaller rainfall events and underestimates the occurrence of larger rainfall events. The variation between relatively close Water NSW gauges further demonstrates the high variability in rainfall in the Cataract Reservoir catchment.

*APPENDIX J*

**Independent Risk Assessment –**

**Addendum Report (Ecology)**

# Underground Expansion Project
# Independent Risk Assessment – Addendum Report

**Prepared for Wollongong Coal Ltd and the Independent Risk Assessment Panel**

**23 September 2015**

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# Contents

# 1. Introduction

## 1.1 Background

Following the assessment of the Underground Expansion Project (UEP) by the NSW Planning Assessment Commission (PAC), Wollongong Coal Ltd was requested to undertake an Integrated Risk Assessment of the UEP, with a particular focus on matters related to subsidence and water. The risk assessment was required to be overseen by an Independent Risk Assessment Panel (IRAP).

Subsequently, an integrated risk assessment was undertaken with input from Wollongong Coal Ltd and its technical specialists which was provided to the established IRAP for review. Following the submission of the draft risk assessment to the IRAP, additional information has been requested by the IRAP.

This report addresses those requests from the IRAP that relate to upland swamps, insofar as they relate to the scope of the risk assessment.

## 1.2 Objectives of the addendum report

A meeting between Wollongong Coal's ecological technical specialist and members of the IRAP determined the requirement for clarification of several items of the draft risk assessment. In its formal response, the IRAP has asked for clarification around existing items and/or requested additional information.

This addendum report addresses the IRAP requests relating to ecology, with responses provided in Section 2 and additional information provided in Section 3.

# 2. Response to questions

With regard to the risk assessment, the IRAP raised several questions or comments during the meeting of 24 August 2015 and in its formal written response dated 10 September 2015. A response to these questions and comments is provided in Table 1.

**Table 1 Questions or comments raised by the IRAP**

| Question | Response |
|---|---|
| **Justify use of the 200 mm vertical subsidence zone as the likely extent of impacts.** | Tensile strains, compressive strains and tilts were initially used to determine upland swamps at risk of negative environmental consequences and thus requiring further investigation as per the thresholds outlined in DoP (2010), OEH (2012) and DoE (2014). The risk of potential bedrock fracturing was assessed using predictions of tensile and compressive strains provided by SCT Operations, and the risk of significant changes in flow were assessed using flow accumulation modelling showing changes in tilts across the study area produced by predicted subsidence levels.<br>Data obtained from SCT Operations indicates that where vertical subsidence levels are below 200 mm, tensile strains are predicted to be less than 0.5 mm/m, compressive strains are predicted to be less than 1.2 mm/m and tilts are predicted to be less than 2 mm/m. These values are well below the thresholds outlined in DoP (2010), OEH (2012) and DoE (2014) to identify upland swamps at risk of negative environmental consequences and requiring further investigation. Thus, this level of subsidence was used to show the likely extent of subsidence impacts. |
| **An overall/cumulative risk rating for each swamp is recommended.** | An overall risk classification for each swamp is provided in Section 3.4.<br>It is not possible to quantitatively determine a cumulative risk for each swamp, as many of the risk factors outlined in the risk assessment are highly interrelated, stemming from one causal factor but presenting risks to different features. For example, cracking of bedrock beneath a swamp can lead to multiple consequences, including reduced quality of water flowing into Cataract Reservoir, detrimental effects on swamp ecosystems, increased susceptibility to fire and reduction in baseflow provided by the swamp. The risk assessment demonstrates that some impacts present a risk to water quality, while others present a risk to the |

| Question | Response |
|---|---|
| | ecosystems supported by the swamp. Given that the risks to each swamp have discrete outcomes, the individual risks cannot be added to generate a cumulative risk classification. |
| **In overall terms, and in simple language, what is the overall risk of significant damage to CCUS4? Although this swamp is rated as a high risk of bedrock cracking, it is rated as being at low risk of consequential ecological damage, but this is not readily apparent in the risk register.** | The overall risk to upland swamp CCUS4 is rated as 'High' (see Section 3.4 for further discussion).<br>The greatest risk of impact to CCUS4 arises from the potential for cracking of bedrock beneath the swamp or fracturing of the controlling rockbar, leading to drying of the swamp and detrimental effects on the swamp ecosystem. Given that CCUS4 is at high risk of consequential ecological damage, impacts to this upland swamp will be offset in accordance with the Offset Strategy. |
| **Where have the predicted subsidence parameters been provided for swamps CCUS24 and CRUS6 and where are the swamps located? Clearly state in the risk register.** | Subsidence predictions for all upland swamps, including CCUS24 and CRUS6, are provided in Table 3 of Section 3.3. Values for all upland swamps are provided for ease of comparison. |
| **BS11311 indicates that swamp CRUS1 has been undermined by Longwall 6 with no observable impacts and that no further impacts are anticipated. Given the fact that Longwall 6 has been only partially extracted at this stage, is it possible that subsidence at the swamp has not been fully developed and that further impact may occur as mining continues?** | Upland swamp CRUS1 is located at the eastern end of Longwall 6, approximately 225 metres from future extraction of remaining sections of Longwall 6. Future impact to this swamp from further extraction of Longwall 6 is unlikely.<br>The upper reaches of swamp CRUS1 are located south of Longwall 7. Subsidence effects from Longwall 7 are predicted to be below thresholds identified as placing this upland swamp at further risk of impact. Although some further, minor, subsidence may occur, it is unlikely to result in additional subsidence impacts of negative environmental consequences.<br>CRUS1 will continue to be monitored as a part of the upland swamp monitoring program. |
| **The swamps appear to form into two groups:**<br>• **Recession rate 15-25 mm/day – BCUS4, CRUS1, CCUS4, CCUS5;**<br>• **Recession rate 40 + mm/day – CCUS2, CCUS3 CCUS6.**<br>**What does this approximate analysis say about the hydrologic processes? Rates of less than 25 mm/day probably reflect evapotranspiration plus some outflow (e.g. CCUS4).**<br>**Higher recession rates suggest either there is a more direct outflow pathway or the water** | High recession rates in CCUS3, CCUS6 and CCUS2 (see hydrographs in Appendix 1) may suggest that water is being lost from the base of the swamp into the underlying sandstone, possibly as a result of prior mining. However, as swamp CCUS3 and CCUS6 are small, with essentially no humic matter and numerous shallow outcropping or subcropping sandstone outliers, it is equally possible that these swamps have little storage capacity and drain / evaporate rapidly as a result.<br>This assertion may be reflected in the differences observed in CCUS2, which shows an indicative |

| Question | Response |
|---|---|
| **holding characteristics of these swamps are very different to the first group.** | recession rate of 40 mm/day, compared to 65 mm/day (CCUS6) and 100+ mm/day (CCUS3). CCUS2 has deeper soils and greater humic development. |
| **From the clearest mapping (Figure 10 of the Preferred Project Report – Biodiversity, Biosis, June 2014) it appears that the following swamps have not been assessed:**<br>• **CCUS3 located over Longwall 5 – already mined;**<br>• **CCUS6 located over Longwall 4 – already mined;**<br>• **CCUS7 located north of Cataract Creek – not due to be undermined;**<br>• **CCUS8 located north of Cataract Creek – over the main headings**<br>• **CCUS9 located north of Cataract Creek – over the main headings**<br>• **All BCUS swamps except 4 and 11 – not due to be undermined.** | An initial risk assessment was undertaken to determine upland swamps at risk of negative environmental consequences.<br>The thresholds identified by DoP (2010), OEH (2012) and DoE (2014) were used to determine upland swamps at risk of negative environmental consequences that required further investigation. These swamps were not identified during this initial risk assessment as being at risk of negative environmental consequences. |
| **CCUS4 is rated as having 6 risk aspects, the most serious of which are cracking beneath the swamp and cracking of the controlling rock bar (leading to a 'High' risk rating). How should the other four 'medium' risks be considered in respect to the overall risk to the swamp?** | As stated above, given the discrete outcomes, the individual risks to upland swamps should not be summed to produce a cumulative risk. These risks must be considered independently.<br>The overall risk to upland swamp CCUS4 is rated as 'High' (as discussed in Section 3.4). |
| **BCUS4 gets a 'medium' risk rating on 4 aspects while CCUS1 and CCUS2 get a 'medium' rating for cracking beneath the swamp.** | All three swamps (CCUS1, CCUS2 and BCUS4) may be at risk of some detrimental effects to swamp ecosystems, either through fracturing of bedrock or redirection of surface flows due to tilting. BCUS4 supports sub-communities reliant on permanent waterlogging and is therefore currently less susceptible to fire, whereas CCUS1 and CCUS2 support drier sub-communities. Therefore, there is greater potential for increased susceptibility to fire within swamp BCUS4. Conversely, the drier swamps (CCUS1 and CCUS2) have less potential to become more susceptible to fire.<br>CCUS1 and BCUS4 also have moderate sized catchments and may contribute to sustained baseflow. However, only a small section of the catchment of CCUS1 will be subsided whilst 81% of the catchment of BCUS4 will be subsided and this may result in a small reduction in baseflow to Cataract Reservoir |

| Question | Response |
|---|---|
| **A summary on the level of dependence of vegetation communities/swamps on groundwater would be beneficial, either in the risk assessment supporting technical information report or in the notes column of the risk register.** | This information is provided in Section 3.1 and the presentation delivered to the IRAP (reproduced in Appendix 2). |

# 3. Additional information

This section of this report provides additional information requested by the IRAP.

## 3.1 Information on root depth, interaction with perched groundwater systems and dependence of vegetation communities and upland swamps on perched groundwater

Vegetation within upland swamps is reliant on water uptake from their roots systems, with species able to tolerate various levels of inundation and waterlogging. Root morphology may be a critical driver in the vegetation composition of upland swamps, with water uptake from shallow versus deeper root systems, and the depth of perched groundwater likely to determine vegetation communities within upland swamps.

Five vegetation sub-communities (Tea tree Thicket, Cyperoid Heath, Banksia Thicket, Restioid Heath and Sedgeland) occur within upland swamps, with the distribution of these communities related to gradients in water regimes and soil chemistry (Keith et al. 2006). Tea-tree Thicket occurs in the deepest, wettest parts of a swamp where the perched groundwater system often shows surface expression and soils are composed of organic material. This community is dominated by a mix of tall shrubs with a dense ground cover of species such as Pouched Coral Fern *Gleichenia dicarpa*. Cyperoid Heath occurs in peaty mineral soils subject to intermittent levels of waterlogging and is dominated by a dense stratum of large sedges with some emergent shrubs. These two communities often occur in the lowest central sections of a swamp subject to inundation. The drier margins of swamps often contain nutrient poor sandy clay colluvium soils, rather than more humic organic soils outlined above, and are subject to lower levels of inundation with the perched groundwater system rarely showing surface expression. These areas support a mosaic of plant communities, including Banksia Thicket, consisting of tall shrubs and a species-poor understorey; Restioid Heath, consisting of a diverse understorey of sedges and open shrub layer; and Sedgeland, dominated by small sedges with an open shrub layer. The presence of the five communities is likely to be driven by the interaction between the root system of the associated plant species and interaction with the perched groundwater system.

Historic research by Groves & Specht (1965) within wet heath on groundwater podzols, found that the majority of the root system within this ecosystem was confined to the top 30 centimetres (12 inches) of soil, with only 10-20 % of roots penetrating below more than 60 to 90 centimetres (2 to 3 feet). Research into peat mires within New Zealand (Agnew et al. 1993) recorded the roots of Spreading Rope-rush *Empodisma minus* being concentrated within the top 7 to 10 centimetres of the surface layers, with fibrous roots seldom recorded to depths greater than 50 centimetres. The same study found that Pouched Coral Fern could possess living buds to a depth of 19 to 22 centimetres below the surface layers. Investigations by Bell et al. (1995) found that members of the Epacridaceae developed lateral root with tap roots rarely extending to depths greater than 0.7 metres while data from Dawson and Pate (1995) suggest that species such as Banksia species have deeper tap roots, enabling them to access deeper groundwater systems and soil moisture.

Access to perched water tables has previously been shown to influence the persistence and distribution of species (and plant functional groups) tolerating excessive wetness with little influence on species occurring in drier environments (Groom et al. 2000). Groom et al. (2000) found that Myrtaceous shrub species grouped as 'preferring excessive wet conditions with shallow rooting depths' decreased in abundance following groundwater drawdown greater than two metres within an unconfined aquifer (in combination with prevailing climatic conditions of reduced rainfall). The same study found a varied response amongst species showing 'maximum development on dry sites', with some species increasing in abundance while others showed some minor changes in abundance but persisted at all sites.

This data suggest that 'wet' and 'dry' species show different responses to reductions in groundwater levels, with shallow rooting or moisture dependent species more reliant on surface or near surface expression of the perched groundwater systems, while deeper rooting species less reliant on saturation levels are able to access soil moisture when groundwater systems are lower or are able to tolerate fluctuating water levels more readily.

Analysis of data obtained from shallow groundwater piezometers in upland swamps in the Russell Vale East area indicates that the lower, central sections of upland swamps, which often support vegetation communities reliant on permanent to intermittent waterlogging, show groundwater levels above -0.5 metres below ground level (mbgl) more often than the drier margins (Table 2).

**Table 2 Analysis of data from shallow groundwater piezometers in upland swamps, showing the percentage of time groundwater levels are above -0.5 mbgl**

| Site | Swamp monitored | Vegetation community | Intake depth (mbgl) | Percentage of readings > -0.5 mbgl |
|---|---|---|---|---|
| **SP1** | – | Terrestrial | 0.615 | 2 |
| **SP2** | – | Terrestrial | 1.04 | 1 |
| **PB4A** | BCUS4 | MU42 Banksia Thicket | 1.61 | 58 |
| **PB4B** | BCUS4 | MU43 Tea-tree Thicket | 0.60 | 100 |
| **PB4C** | BCUS4 | MU43 Tea-tree Thicket | 0.62 | 66 |
| **PB4D** | BCUS4 | MU42 Banksia Thicket | 0.76 | 31 |
| **PCr1A** | CRUS1 | MU42 Banksia Thicket | 0.53 | 29 |
| **PCr1B** | CRUS1 | MU43 Tea-tree Thicket | 0.69 | 62 |
| **PCr1C** | CRUS1 | MU42 Banksia Thicket | 1.15 | 35 |
| **PCr1D** | CRUS1 | MU42 Banksia Thicket | 0.37 | 100 |
| **PCc2** | CCUS2 | MU44a Sedgeland | 1.60 | 3 |
| **PCc3** | CCUS3 | MU42 Banksia Thicket | 1.13 | 0 |
| **PCc4A** | CCUS4 | MU42 Banksia Thicket | 1.61 | 11 |
| **PCc4B** | CCUS4 | MU42 Banksia Thicket | 1.84 | 7 |
| **PCc4C** | CCUS4 | MU43 Tea-tree Thicket | 1.27 | 40 |
| **PCc4D** | CCUS4 | MU43 Tea-tree Thicket | 1.00 | 28 |
| **PCc5A** | CCUS5 | MU42 Banksia Thicket | 1.24 | 56 |
| **PCc5B** | CCUS5 | MU43 Tea-tree Thicket | 1.31 | 85 |
| **PCc5C** | CCUS5 | MU42 Banksia Thicket | 0.85 | 44 |
| **PCc5D** | CCUS5 | MU43 Tea-tree Thicket | 1.23 | 74 |

| Site | Swamp monitored | Vegetation community | Intake depth (mbgl) | Percentage of readings > -0.5 mbgl |
|---|---|---|---|---|
| **PCc6** | CCUS6 | MU42 Banksia Thicket | 1.17 | 3 |
| **PCc10A** | CCUS10 | MU43 Tea-tree Thicket | 0.60 | 87 |
| **PCc10B** | CCUS10 | MU42 Banksia Thicket | 0.98 | 36 |
| **PCc12A** | CCUS12 | MU42 Banksia Thicket | 0.71 | 42 |
| **PCc12B** | CCUS12 | MU42 Banksia Thicket | 0.27 | 100 |

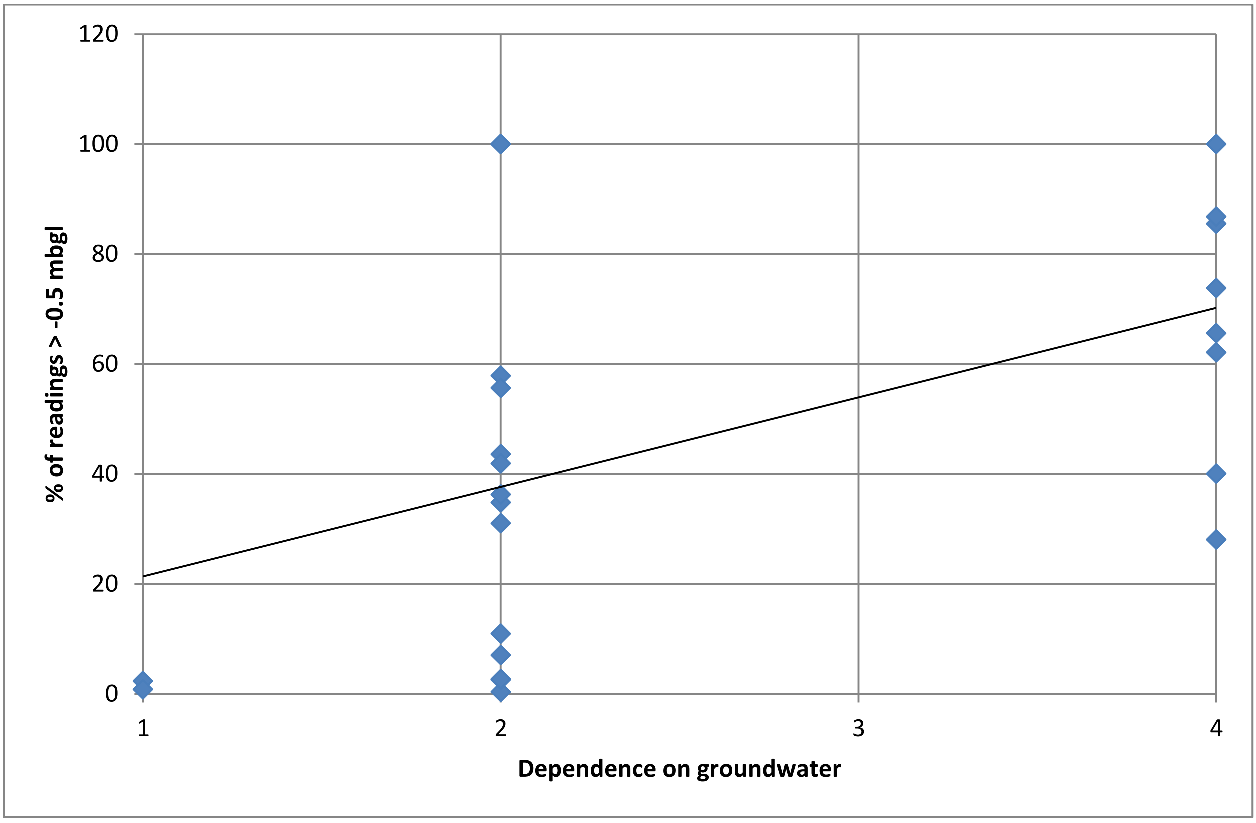
* Intake depth of less than 0.5 mbgl

Further analysis involving plotting groundwater levels against a measure of dependence on groundwater (using Keith et al. 2006) indicates there is a correlation between the percentage of time the groundwater levels are above --0.5 mbgl and the dependence of vegetation communities on groundwater levels. Each vegetation community was assigned a number based on their dependence on groundwater, as follows:

- 1 = terrestrial environments (soil piezometers)
- 2 = Banksia Thicket, Restioid Heath and Sedgeland
- 3 = Cyperoid Heath
- 4 = Tea-tree Thicket

Tea-tree Thicket shows greater levels of surface or near surface expression of groundwater levels than Banksia Thicket.  However, it interesting to note there are outliers in each group.   Outliers under group 2 (Banksia Thicket) occur as the depth of the piezometer is less than 0.5 mbgl.

**Graph 1 Groundwater levels (mbgl) against a measure of groundwater dependence**




This data indicates that vegetation communities within these swamps are driven by the underlying hydrology of these swamps. Where groundwater levels show less surface or near surface expression, vegetation communities tend to be drier and are less reliant on groundwater levels. In these instances surface water run-off and rainfall are likely to play a significant role in maintaining these swamps.

Hydrographs for each piezometer are provided in Appendix 1.

## 3.2 Explain methods of accurately measuring swamp boundaries

The complete methodology for mapping of upland swamps is outlined in Biosis (2012).

It is proposed that this methodology will be used for the ongoing monitoring of changes in the extent of upland swamps in relation to mining. Repeated light detection and ranging (LiDAR) measurements provide the opportunity to detect changes in extent over long periods using replicable and objective monitoring methods.

Recent comparisons of analogous LiDAR datasets indicate that there is an average 9 percent error in the data year on year. This error does not represent an actual transition or change, but is rather based on different collection methods and density of returns. This included 3 to 5 percent of the swamp being detected as swamp in year 1 but not in year 2 and approximately 3 to 7 percent not mapped as swamp in year one but mapped as swamp in year 2. This error usually occurs as small errors of less than a meter along the margins. When looking at the total area of the swamp, which averages out changes from one state to another, we have an average of a 0.7 percent change in area.

This data indicates that the use of repeated LiDAR mapping of upland swamps can be used to detect changes in the extent of upland swamps. LiDAR data has some inherent error, with errors of up to 10 percent of total area when considered any type of transition (swamp to woodland or woodland to swamp), but very low errors of less than 1 percent when considering total change in area.

Future monitoring would focus on measuring and detecting an ongoing decline in swamp extent using quantitative measures, as well as qualitative assessment of transitions from swamp to woodland with the results of remote sensing verified with ground truthing of these areas. The use of control sites will provide a baseline against which observed changes can be compared to determine whether they are a result of mining or an artefact of larger, landscape scale changes such as changes in long term rainfall trends.

## 3.3 Additional data for two swamps (CCUS24 and CRUS6)

The IRAP has requested subsidence predictions for two upland swamps, CCUS24 and CRUS6, identified by ongoing monitoring and improvements in the methodology used to identify upland swamps. Subsidence predictions were provided by SCT Operations and their letter report is included at Appendix 3.

To allow for all data to be provided in one place, and allow comparison between upland swamps, data for all upland swamps is presented in Table 3.

Data presented in Table 3 includes:

- Area of the swamp
- Overburden depth to panel width
- Subsidence parameters, including:
  - Maximum subsidence
  - Maximum tensile strain
  - Maximum compressive strain
  - Maximum tilt

It should be noted that values presented are the maximum values within the swamp, and do not reflect the degree of impact to the swamp. For this reason, Table 3 also contains calculations of:

- The area of the swamps within the 200 mm subsidence contour (hectares and percentage)
- The size of the catchment for each swamp
- The area of the swamp catchment within the 200 mm subsidence contour (hectares and percentage)

**Table 3 Area, subsidence predictions, and area of impact to swamps and their catchments for all upland swamps in the Russell Vale East area**

Figures in bold are greater than criteria outlined in DoP (2010), OEH (2012) and DoE (2014).

| Swamp | Area of swamp (ha) | 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 Depth to Panel Width | Max Tensile Strain (mm/m) | Max Comp Strain (mm/m) | Max Tilt (mm/m) | Area of swamp within 200mm (0.2m) subsidence contour (ha) | Area of swamp within 200mm (0.2m) subsidence contour (%) | Size of catchment area for the swamp (ha) | Area of catchment within 200mm subsidence (0.2m) contour (ha) | Area of catchment within 200mm subsidence (0.2m) contour (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **BCUS1** | 0.16 | < 0.2 | 0.1 | 270 | - | - | 0.5 | 1 | 2 | - | - | - | - | - |
| **BCUS2** | 0.89 | < 0.2 | 0.1 | 285 | - | - | 0.5 | 0.9 | 2 | - | - | - | - | - |
| **BCUS3** | 0.12 | < 0.2 | 0.1 | 265 | - | - | 0.5 | 1 | 2 | - | - | - | - | - |
| **BCUS4** | 2.46 | 1.0 | 1.5 | 295 | 150 | 1.97 | **6.8** | **13.6** | **23** | 2.23 | 1.14 | 51.38 | 15.01 | 12.13 |
| **BCUS5** | 0.96 | < 0.2 | 0.1 | 273 | - | - | 0.5 | 1 | 2 | - | - | - | - | - |
| **BCUS6** | 1.30 | < 0.2 | 0.1 | 308 | - | - | 0.4 | 0.9 | 1 | - | - | - | - | - |
| **BCUS11** | 0.26 | 1.4 | 1.5 | 335 | 150 | 2.23 | **6.1** | **12.2** | **20** | 0.26 | 100.00 | 1.14 | 1.14 | 100.00 |
| **CCUS1** | 4.81 | 0.6 | 1.5 | 285 | - | - | **7** | **14.1** | **23** | 0.16 | 9.99 | 7.96 | 3.64 | 45.80 |
| **CCUS2** | 1.21 | 1.8 | 2.0 | 285 | 150 | 1.90 | **9.4** | **18.8** | **31** | 1.21 | 1.21 | 100.00 | 4.08 | 4.08 |
| **CCUS3** | 0.55 | 1 | 1.5 | 300 | 125 | 2.40 | **6.7** | **13.4** | **22** | 0.55 | 0.55 | 100.00 | 3.26 | 2.49 |
| **CCUS4** | 1.77 | 1.4 | 2.0 | 290 | 150 | 1.93 | **9.2** | **18.5** | **31** | 1.77 | 1.75 | 98.48 | 16.33 | 4.89 |
| **CCUS5** | 3.45 | 1.2 | 1.5 | 272 | 131 | 2.08 | **7.3** | **14.7** | **24** | 3.45 | 0.51 | 14.71 | 10.10 | 5.27 |
| **CCUS6** | 2.05 | 2 | 2.0 | 285 | 125 | 2.28 | **9.4** | **18.8** | **31** | 2.05 | 1.69 | 82.41 | 12.16 | 5.93 |
| **CCUS7** | 1.32 | < 0.2 | 0.1 | 270 | - | - | 0.5 | 1 | 2 | - | - | - | - | - |
| **CCUS8** | 0.46 | < 0.2 | 0.1 | 270 | - | - | 0.5 | 1 | 2 | - | - | - | - | - |
| **CCUS9** | 0.76 | < 0.2 | 0.1 | 293 | - | - | 0.5 | 0.9 | 2 | - | - | - | - | - |
| **CCUS10** | 1.63 | 0.8 | 0.8 | 280 | 150 | 1.87 | **3.8** | **7.6** | **13** | 1.63 | 0.16 | 9.99 | 7.96 | 3.64 |
| **CCUS11** | 0.34 | 1.8 | 2.0 | 340 | 150 | 2.27 | **8.8** | **18** | **29** | 0.34 | 0.34 | 100.00 | 1.18 | 1.18 |
| **CCUS12** | 1.84 | 1.2 | 1.5 | 355 | 150 | 2.37 | **5.8** | **11.5** | **19** | 1.84 | 100.00 | 3.49 | 3.49 | 100.00 |
| **CCUS13** | 0.26 | < 0.2 | 0.1 | 335 | - | - | 0.4 | 0.8 | 1 | - | - | - | - | - |
| **CCUS14** | 0.37 | < 0.2 | 0.1 | 275 | - | - | 0.5 | 1 | 2 | - | - | - | - | - |
| **CCUS15** | 0.06 | < 0.2 | 0.1 | 325 | - | - | 0.4 | 0.8 | 1 | - | - | - | - | - |
| **CCUS16** | 0.87 | < 0.2 | 0.1 | 300 | - | - | 0.4 | 0.9 | 1 | - | - | - | - | - |
| **CCUS17** | 0.07 | < 0.2 | 0.1 | 325 | - | - | 0.4 | 0.8 | 1 | - | - | - | - | - |
| **CCUS18** | 0.05 | < 0.2 | 0.1 | 325 | - | - | 0.4 | 0.8 | 1 | - | - | - | - | - |
| **CCUS19** | 0.04 | < 0.2 | 0.1 | 325 | - | - | 0.4 | 0.8 | 1 | - | - | - | - | - |

| Swamp | Area of swamp (ha) | 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 Depth to Panel Width | Max Tensile Strain (mm/m) | Max Comp Strain (mm/m) | Max Tilt (mm/m) | Area of swamp within 200mm (0.2m) subsidence contour (ha) | Area of swamp within 200mm (0.2m) subsidence contour (%) | Size of catchment area for the swamp (ha) | Area of catchment within 200mm subsidence (0.2m) contour (ha) | Area of catchment within 200mm subsidence (0.2m) contour (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CCUS20** | 0.55 | < 0.2 | 0.1 | 290 | - | - | 0.5 | 0.9 | 2 | - | - | - | - | - |
| **CCUS21** | 0.05 | < 0.2 | 2.0 | 280 | - | - | **9.5** | **19** | **32** | 0 | 0 | 0 | 0 | 0 |
| **CCUS22** | 0.31 | < 0.2 | 0.1 | 317 | - | - | 0.4 | 0.9 | 1 | - | - | - | - | - |
| **CCUS23** | 1.44 | 0.2 | 1.5 | 310 | 125 | 2.48 | **6.5** | **13** | **22** | 0.02 | 1.31 | 7.04 | 0.18 | 2.61 |
| **CCUS24** | 0.08 | 1.0 | 1.0 | 370 | 150 | 2.48 | **4.0** | **8.0** | **14** | 0.08 | 100.00 | 0.54 | 0.54 | 100.00 |
| **CRUS1** | 9.84 | 1.4 | 1.5 | 300 | 150 | 2.00 | **6.7** | **13.4** | **22** | 0.84 | 8.50 | 29.12 | 2.52 | 8.64 |
| **CRUS2** | 3.12 | < 0.2 | 0.1 | 210 | - | - | 0.6 | 1.2 | 2 | - | - | - | - | - |
| **CRUS3** | 3.42 | < 0.2 | 0.1 | 295 | - | - | 0.5 | 0.9 | 2 | - | - | - | - | - |
| **CRUS6** | 0.49 | 2.0 | 2.0 | 375 | 150 | 2.48 | **8.0** | **16.0** | **27** | 0.49 | 100.00 | 2.99 | 2.99 | 100.00 |

## 3.4 Overall risk classification for each swamp

The IRAP has requested an overall risk classification for each swamp. Table 4 provides an overall risk classification for each swamp, with a discussion of potential impacts for swamps rated as being at medium or greater risk. A consolidated risk assessment for all upland swamps is provided in Table 5 (summarised from Broadleaf, 2015).

**Table 4 Summary of risks for each upland swamp**

| Location | Risk | Discussion |
|---|---|---|
| **BCUS4** | Medium | A small, upper section of BCUS4 overlies the longwall. Tilts and strains of sufficient magnitude to result in fracturing of underlying bedrock will occur over a small, upper section of the swamp. Fracturing of bedrock, and consequent drying of the swamp, has the potential to result in increased susceptibility to fire, reduction in baseflow provided by the swamp and detrimental effects on the swamp ecosystem.<br>However, the area where fracturing is predicted to occur supports communities that are not reliant on a perched water table, and are already fire prone. Tilts from Longwall 11 may result in diversion of flow around a section of MU43 Tea-tree Thicket, with potential for compositional change.<br>Overall risk to this swamp is assessed as medium. |
| **BCUS11** | Low | – |
| **CCUS1** | Medium | A very small (0.15 ha) area of this swamp will be subject to strains of sufficient magnitude to result in fracturing of bedrock and consequent impacts to the swamp ecosystem. Other risks are assessed as low or negligible.<br>Given the small percentage of the swamp that will be impacted (3.14%) the overall risk is assessed as medium. |
| **CCUS2** | Medium | This swamp overlies Longwalls 2 and 3. Subsidence will result in strains of sufficient magnitude to result in fracturing of the underlying bedrock. CCUS2 does not support vegetation communities reliant on waterlogging, with data from piezometers indicating that the perched groundwater table in this upland swamp rarely shows surface expression. Whilst some compositional change may occur, this is likely to be minor in nature. This swamp does not provide significant contributions to baseflow given the small catchment area.<br>Overall risk is assessed as medium. |
| **CCUS4** | High | CCUS4 overlies Longwall 6 and will experience strains of sufficient magnitude to result in fracturing of underlying bedrock, as well as potential for fracturing of the controlling rockbar at the base of this swamp. Fracturing of bedrock or controlling rockbar, and consequent drying of the swamp, has the potential to result in increased susceptibility to fire, reduction in baseflow provided by the swamp and detrimental effects on the swamp ecosystem. Whilst the outer margins of this swamp support vegetation communities that are not reliant on |

| Location | Risk | Discussion |
|---|---|---|
| | | waterlogging, the central axis of this swamp supports MU43 Tea-tree Thicket and MU44c Cyperoid Heath which are reliant on surface on near surface expression of the perched groundwater table. This may result in compositional change within this swamp and increase susceptibility to fire.<br>This may also result in localised impacts to the Giant Dragonfly, which relies on the perched water table during the species' larval stage. Whilst impacts to baseflow may occur, data from CCUS4 shows that this swamp only provides flow for short periods following rainfall, and does not provide a long term baseflow contribution.<br>Overall risk is assessed as high. |
| **CCUS5** | Low | – |
| **CCUS10** | Low | – |
| **CCUS11** | Low | – |
| **CCUS12** | Low | – |
| **CCUS24** | Negligible | – |
| **CRUS1** | Negligible | – |
| **CRUS3** | Negligible | – |
| **CRUS6** | Low | – |

**Table 5 Summary of risk assessment for upland swamps**

| Location | Identifier | Risk summary ... | Consequence | Impact | Cons | L'hood | Risk |
|---|---|---|---|---|---|---|---|
| BCUS4 | CS 11511 | Surface fracturing with cracking of bedrock beneath swamp | CS 11511 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| BCUS4 | CS 11521 | Surface fracturing with cracking of bedrock beneath swamp | CS 11521 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | C | Low |
| BCUS4 | CS 1153 | Surface fracturing with cracking of bedrock beneath swamp | CS 1153 Detrimental effects on swamp ecosystems | E | 2 | C | Medium |
| BCUS4 | CS 1154 | Surface fracturing with cracking of bedrock beneath swamp | CS 1154 Increased susceptibility to fire | E | 2 | C | Medium |
| BCUS4 | CS 1155 | Surface fracturing with cracking of bedrock beneath swamp | CS 1155 Reduction in base flow provided by swamp | V | 1 | A | Medium |
| BCUS4 | CT 121 | Tilting leading to changes to swamp water regimes | CT 121 Detrimental effect on BCUS4 ecosystems | E | 3 | C | Medium |
| BCUS11 | CS 11611 | Surface fracturing with cracking of bedrock beneath swamp | CS 11611 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| BCUS11 | CS 11621 | Surface fracturing with cracking of bedrock beneath swamp | CS 11621 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | C | Low |
| BCUS11 | CS 1163 | Surface fracturing with cracking of bedrock beneath swamp | CS 1163 Detrimental effects on swamp ecosystems | E | 1 | D | Negligible |
| BCUS11 | CS 1164 | Surface fracturing with cracking of bedrock beneath swamp | CS 1164 Increased susceptibility to fire | E | 1 | D | Negligible |
| CCUS1 | AS 11111 | Surface fracturing with cracking of bedrock beneath swamp | AS 11111 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| CCUS1 | AS 11121 | Surface fracturing with cracking of bedrock beneath swamp | AS 11121 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | C | Low |
| CCUS1 | AS 1113 | Surface fracturing with cracking of bedrock beneath swamp | AS 1113 Detrimental effects on swamp ecosystems | E | 2 | C | Medium |
| CCUS1 | AS 1114 | Surface fracturing with cracking of bedrock beneath swamp | AS 1114 Increased susceptibility to fire | E | 1 | D | Negligible |
| CCUS1 | AS 1115 | Surface fracturing with cracking of bedrock beneath swamp | AS 1115 Reduction in base flow provided by swamp | V | 1 | C | Low |
| CCUS2 | AS 11211 | Surface fracturing with cracking of bedrock beneath swamp | AS 11211 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| CCUS2 | AS 11221 | Surface fracturing with cracking of bedrock beneath swamp | AS 11221 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| CCUS2 | AS 1123 | Surface fracturing with cracking of bedrock beneath swamp | AS 1123 Detrimental effects on swamp ecosystems | E | 1 | D | Negligible |
| CCUS2 | AS 1124 | Surface fracturing with cracking of bedrock beneath swamp | AS 1124 Increased susceptibility to fire | E | 2 | C | Medium |
| CCUS2 | AS 1125 | Surface fracturing with cracking of bedrock beneath swamp | AS 1125 Reduction in base flow provided by swamp | V | 1 | D | Negligible |
| CCUS4 | BS 11111 | Surface fracturing with cracking of bedrock beneath swamp | BS 11111 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |

| Location | Identifier | Risk summary ... | Consequence | Impact | Cons | L'hood | Risk |
|---|---|---|---|---|---|---|---|
| CCUS4 | BS 11121 | Surface fracturing with cracking of bedrock beneath swamp | BS 11121 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | C | Low |
| CCUS4 | BS 1113 | Surface fracturing with cracking of bedrock beneath swamp | BS 1113 Detrimental effects on swamp ecosystems | E | 4 | A | High |
| CCUS4 | BS 1114 | Surface fracturing with cracking of bedrock beneath swamp | BS 1114 Increased susceptibility to fire | E | 2 | C | Medium |
| CCUS4 | BS 1115 | Surface fracturing with cracking of bedrock beneath swamp | BS 1115 Reduction in base flow provided by swamp | V | 1 | A | Medium |
| CCUS4 | BS 12111 | Surface fracturing with fracturing of controlling rockbars | BS 12111 Reduced quality of water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| CCUS4 | BS 12121 | Surface fracturing with fracturing of controlling rockbars | BS 12121 Reduced quality of water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| CCUS4 | BS 1213 | Surface fracturing with fracturing of controlling rockbars | BS 1213 Detrimental effects on swamp ecosystems | E | 4 | A | High |
| CCUS4 | BS 1214 | Surface fracturing with fracturing of controlling rockbars | BS 1214 Increased susceptibility to fire | E | 2 | C | Medium |
| CCUS4 | BT 121 | Tilting leading to changes to swamp water regimes | BT 121 Detrimental effects on CCUS4 ecosystems | E | 2 | C | Medium |
| CCUS5 | BS 11211 | Surface fracturing with cracking of bedrock beneath swamp | BS 11211 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| CCUS5 | BS 11221 | Surface fracturing with cracking of bedrock beneath swamp | BS 11221 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | C | Low |
| CCUS5 | BS 1123 | Surface fracturing with cracking of bedrock beneath swamp | BS 1123 Detrimental effects on swamp ecosystems | E | 1 | C | Low |
| CCUS5 | BS 1124 | Surface fracturing with cracking of bedrock beneath swamp | BS 1124 Increased susceptibility to fire | E | 1 | C | Low |
| CCUS5 | BS 1125 | Surface fracturing with cracking of bedrock beneath swamp | BS 1125 Reduction in base flow provided by swamp | V | 1 | D | Negligible |
| CCUS10 | CS 11111 | Surface fracturing with cracking of bedrock beneath swamp | CS 11111 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| CCUS10 | CS 11121 | Surface fracturing with cracking of bedrock beneath swamp | CS 11121 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | C | Low |
| CCUS10 | CS 1113 | Surface fracturing with cracking of bedrock beneath swamp | CS 1113 Detrimental effects on swamp ecosystems | E | 1 | D | Negligible |
| CCUS10 | CS 1114 | Surface fracturing with cracking of bedrock beneath swamp | CS 1114 Increased susceptibility to fire | E | 1 | D | Negligible |
| CCUS11 | CS 11211 | Surface fracturing with cracking of bedrock beneath swamp | CS 11211 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| CCUS11 | CS 11221 | Surface fracturing with cracking of bedrock beneath swamp | CS 11221 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | C | Low |
| CCUS11 | CS 1123 | Surface fracturing with cracking of bedrock beneath swamp | CS 1123 Detrimental effects on swamp ecosystems | E | 1 | D | Negligible |
| CCUS11 | CS 1124 | Surface fracturing with cracking of bedrock beneath swamp | CS 1124 Increased susceptibility to fire | E | 1 | D | Negligible |
| CCUS12 | CS 11311 | Surface fracturing with cracking of bedrock beneath swamp | CS 11311 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| CCUS12 | CS 11321 | Surface fracturing with cracking of bedrock beneath swamp | CS 11321 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |

| Location | Identifier | Risk summary … | Consequence | Impact | Cons | L'hood | Risk |
|---|---|---|---|---|---|---|---|
| CCUS12 | CS 1133 | Surface fracturing with cracking of bedrock beneath swamp | CS 1133 Detrimental effects on swamp ecosystems | E | 1 | C | Low |
| CCUS12 | CS 1134 | Surface fracturing with cracking of bedrock beneath swamp | CS 1134 Increased susceptibility to fire | E | 1 | D | Negligible |
| CCUS24 | CS 11411 | Surface fracturing with cracking of bedrock beneath swamp | CS 11411 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| CCUS24 | CS 11421 | Surface fracturing with cracking of bedrock beneath swamp | CS 11421 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| CCUS24 | CS 1143 | Surface fracturing with cracking of bedrock beneath swamp | CS 1143 Detrimental effects on swamp ecosystems | E | 1 | D | Negligible |
| CCUS24 | CS 1144 | Surface fracturing with cracking of bedrock beneath swamp | CS 1144 Increased susceptibility to fire | E | 1 | D | Negligible |
| CRUS1 | BS 11311 | Surface fracturing with cracking of bedrock beneath swamp | BS 11311 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| CRUS1 | BS 11321 | Surface fracturing with cracking of bedrock beneath swamp | BS 11321 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| CRUS1 | BS 1133 | Surface fracturing with cracking of bedrock beneath swamp | BS 1133 Detrimental effects on swamp ecosystems | E | 1 | D | Negligible |
| CRUS1 | BS 1134 | Surface fracturing with cracking of bedrock beneath swamp | BS 1134 Increased susceptibility to fire | E | 1 | D | Negligible |
| CRUS1 | BS 1135 | Surface fracturing with cracking of bedrock beneath swamp | BS 1135 Reduction in base flow provided by swamp | V | 1 | D | Negligible |
| CRUS3 | AS 11311 | Surface fracturing with cracking of bedrock beneath swamp | AS 11311 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | E | Negligible |
| CRUS3 | AS 11321 | Surface fracturing with cracking of bedrock beneath swamp | AS 11321 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | E | Negligible |
| CRUS3 | AS 1133 | Surface fracturing with cracking of bedrock beneath swamp | AS 1133 Detrimental effects on swamp ecosystems | E | 1 | D | Negligible |
| CRUS3 | AS 1134 | Surface fracturing with cracking of bedrock beneath swamp | AS 1134 Increased susceptibility to fire | E | 1 | D | Negligible |
| CRUS3 | AS 1135 | Surface fracturing with cracking of bedrock beneath swamp | AS 1135 Reduction in base flow provided by swamp | V | 1 | D | Negligible |
| CRUS6 | CS 11711 | Surface fracturing with cracking of bedrock beneath swamp | CS 11711 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | D | Negligible |
| CRUS6 | CS 11721 | Surface fracturing with cracking of bedrock beneath swamp | CS 11721 Reduced quality of surface water flowing into Cataract Reservoir | Q | 1 | C | Low |
| CRUS6 | CS 1173 | Surface fracturing with cracking of bedrock beneath swamp | CS 1173 Detrimental effects on swamp ecosystems | E | 1 | D | Negligible |
| CRUS6 | CS 1174 | Surface fracturing with cracking of bedrock beneath swamp | CS 1174 Increased susceptibility to fire | E | 1 | D | Negligible |

# 4. Response to comments from Office of Environment and Heritage

Biosis has been asked to provide a response to comments received from the NSW Office of Environment and Heritage (OEH) dated 2 September 2015 in response to the draft risk assessment.

> Recommendation 1 from the NSW Planning Assessment Commission (PAC) report recommends "*The establishment of a risk assessment panel, constituted by an independent Chair, Water NSW, the Dams Safety Committee, the Division of Resources and Energy and the proponent to oversee an integrated risk assessment, particularly focusing on links between subsidence and water (both groundwater and surface water) impacts of the proposal. This risk assessment, including associated work rerunning the groundwater modelling as recommended by Dr Mackie; and addressing the issues raised by the relevant agencies and experts (as highlighted by this report), needs to be completed before the application can be determined.*" In line with this, the IRAP's terms of reference, as stated in their response, was "*to address the impacts of underground mining on the quantity and quality of groundwater and surface water, and on environmental values associated with swamps. Wider environmental impacts of longwall mining are not considered in this review*."

Whilst some comments relate to Recommendation 1 and the terms of reference for the IRAP, other comments do not. These have not been discussed further herein.

It should be noted that where OEH make reference to the Independent Expert Scientific Committee (IESC) report they refer to the IESC advice that was provided to the Commonwealth Department of the Environment and NSW Department of Planning and Environment on 11 September 2014 and to the Planning and Assessment Commission on the 11 March 2015. These reports from the IESC have not considered the significant work completed since that time and which has informed the risk assessment. In addition, the assessment by the IESC did not take into consideration the diverse nature of upland swamps and their varying dependence, both between swamps and within swamps, on perched groundwater systems. All swamps are unique and should be assessed on an individual basis, as has been the approach for this risk assessment.

OEH makes reference to the 14 swamps identified as being at risk of negative environmental consequences, as identified in the initial risk assessment. DoP (2010) states that these criteria are a "*threshold for investigation – not a conclusion that the swamp will be impacted or suffer consequences*" (p. 120). In line with this, additional assessment was undertaken. To assume that all 14 swamps are at high risk of negative environmental consequences is unnecessarily conservative, and does not take into consideration the additional integrated analyses and assessment, such as detailed vegetation mapping and groundwater assessments (GeoTerra / GES, 2015).

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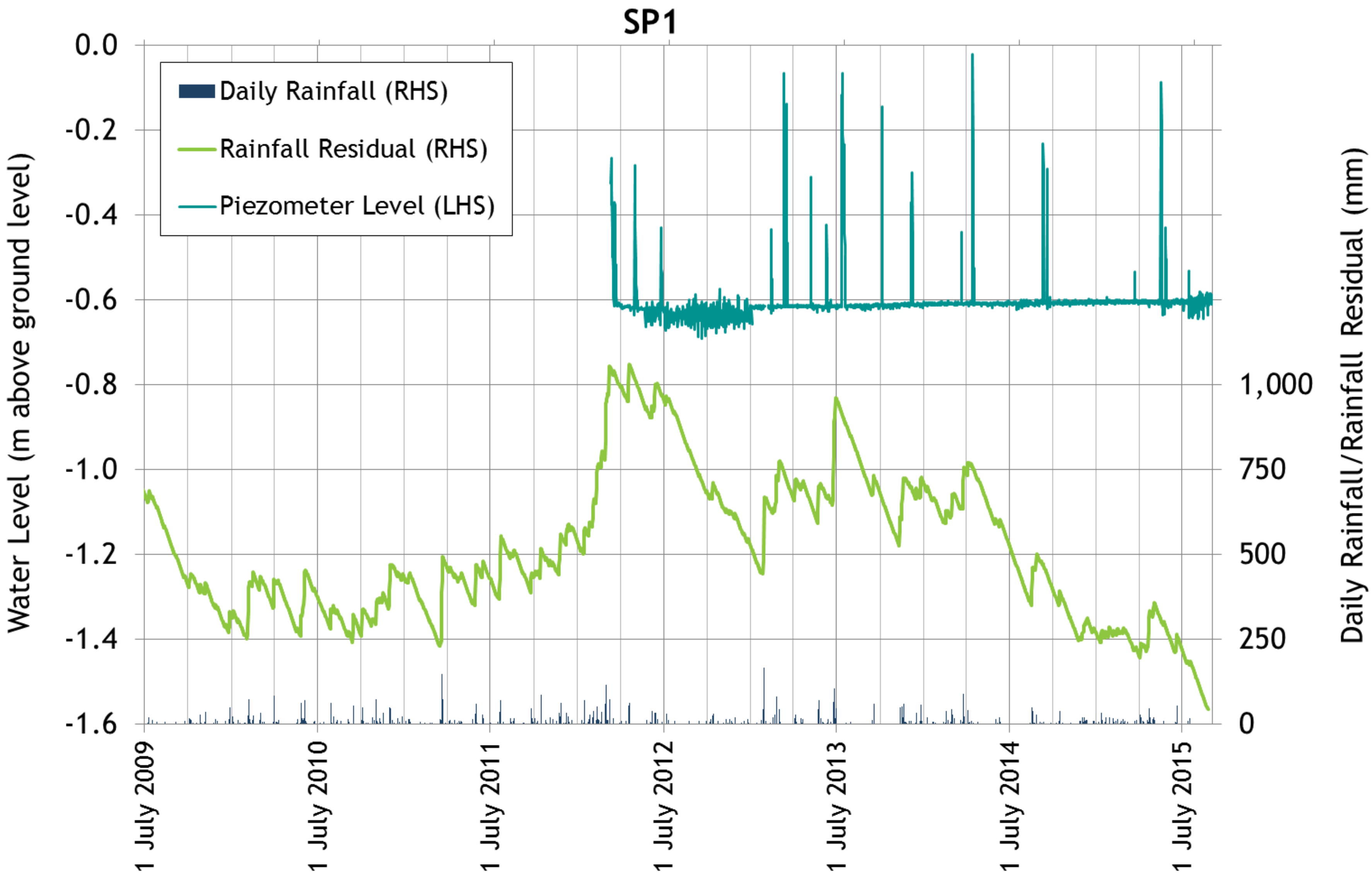
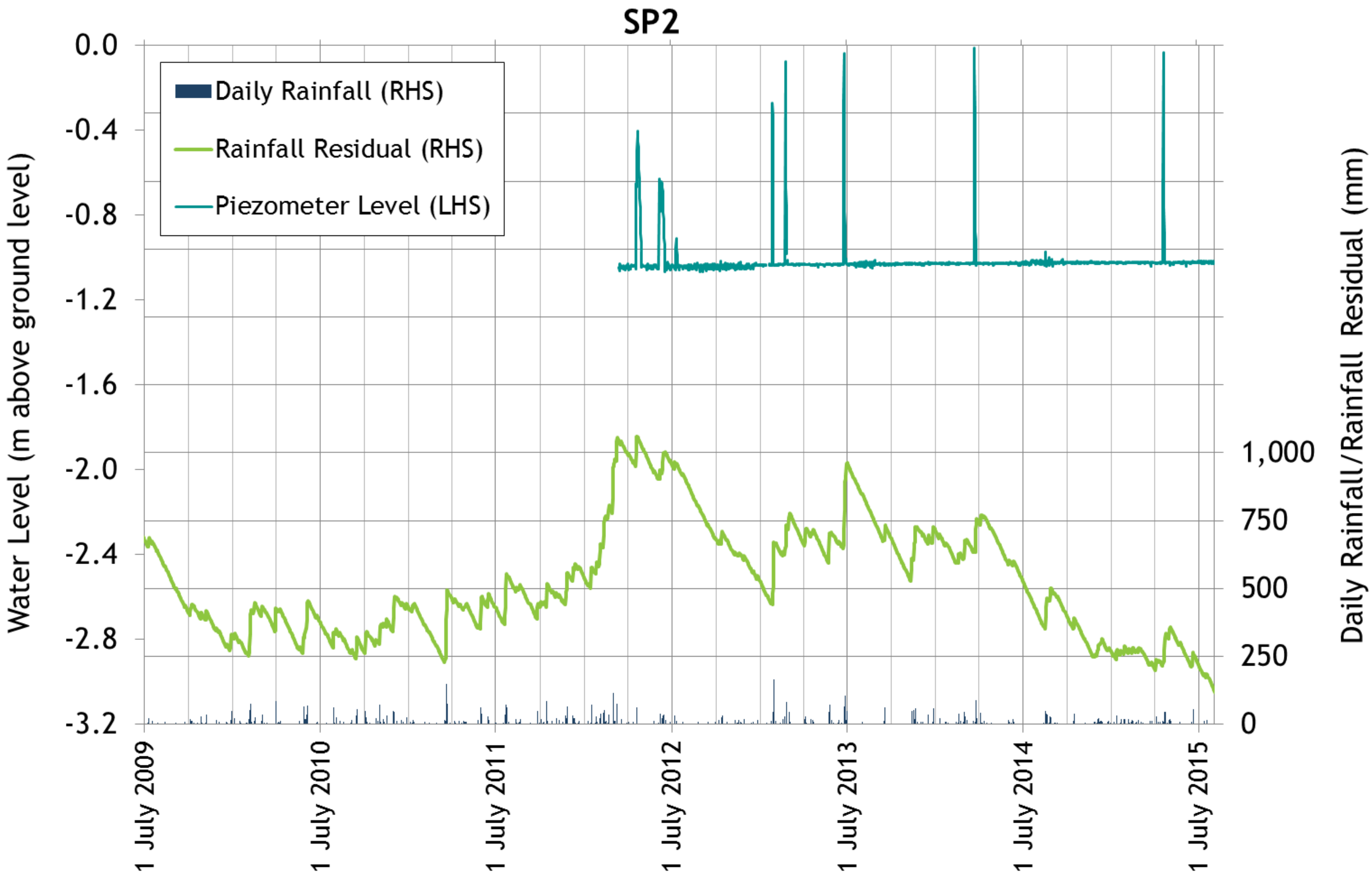
OEH 2012. Upland swamp environmental assessment guidelines. Guidance for the underground mining industry operating in the southern coalfield (Draft). NSW Office of Environment and Heritage.

# Appendix 1 – Swamp piezometer plots

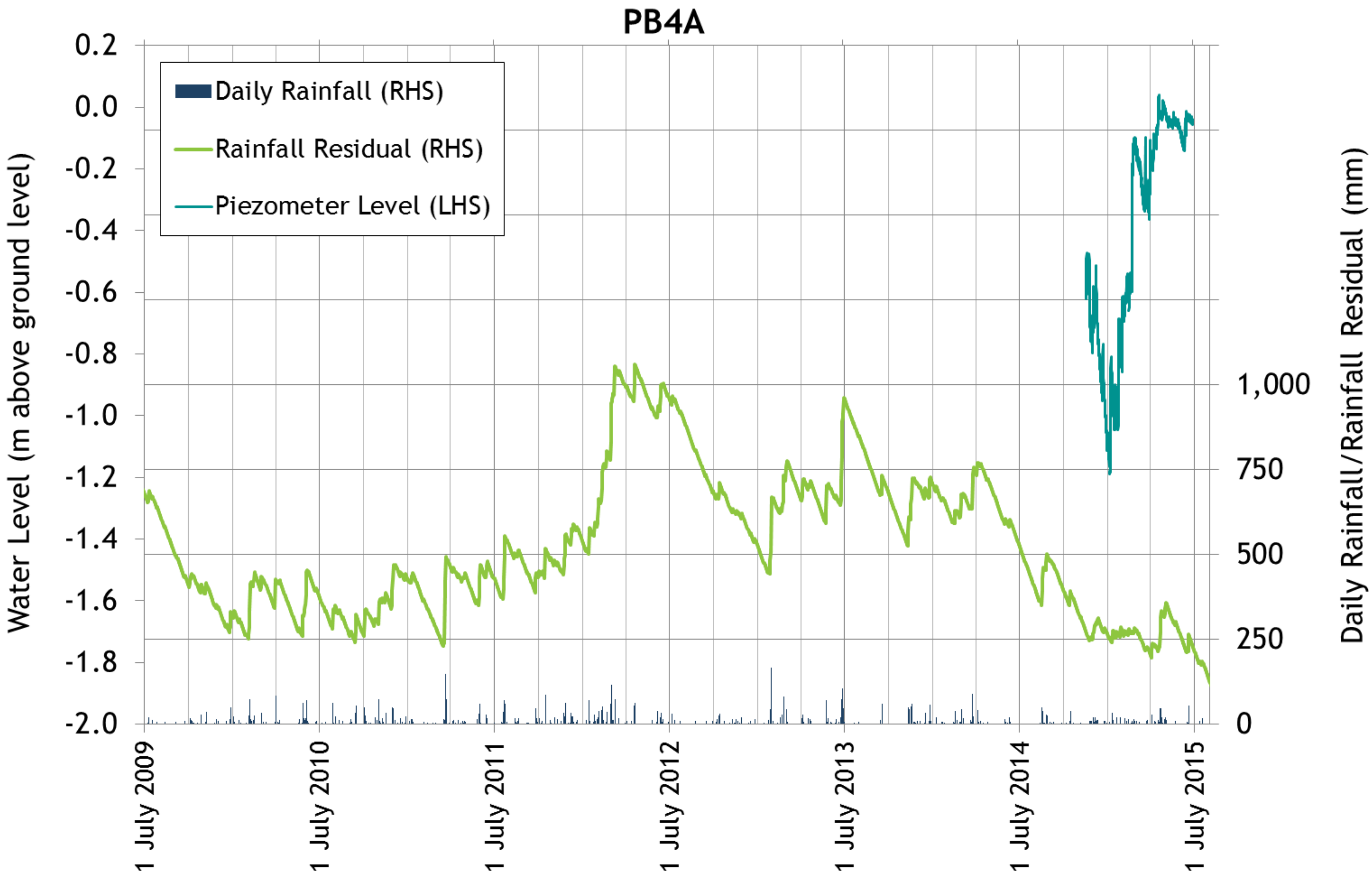
**Graph 2 Hydrograph – Piezometer SP1**



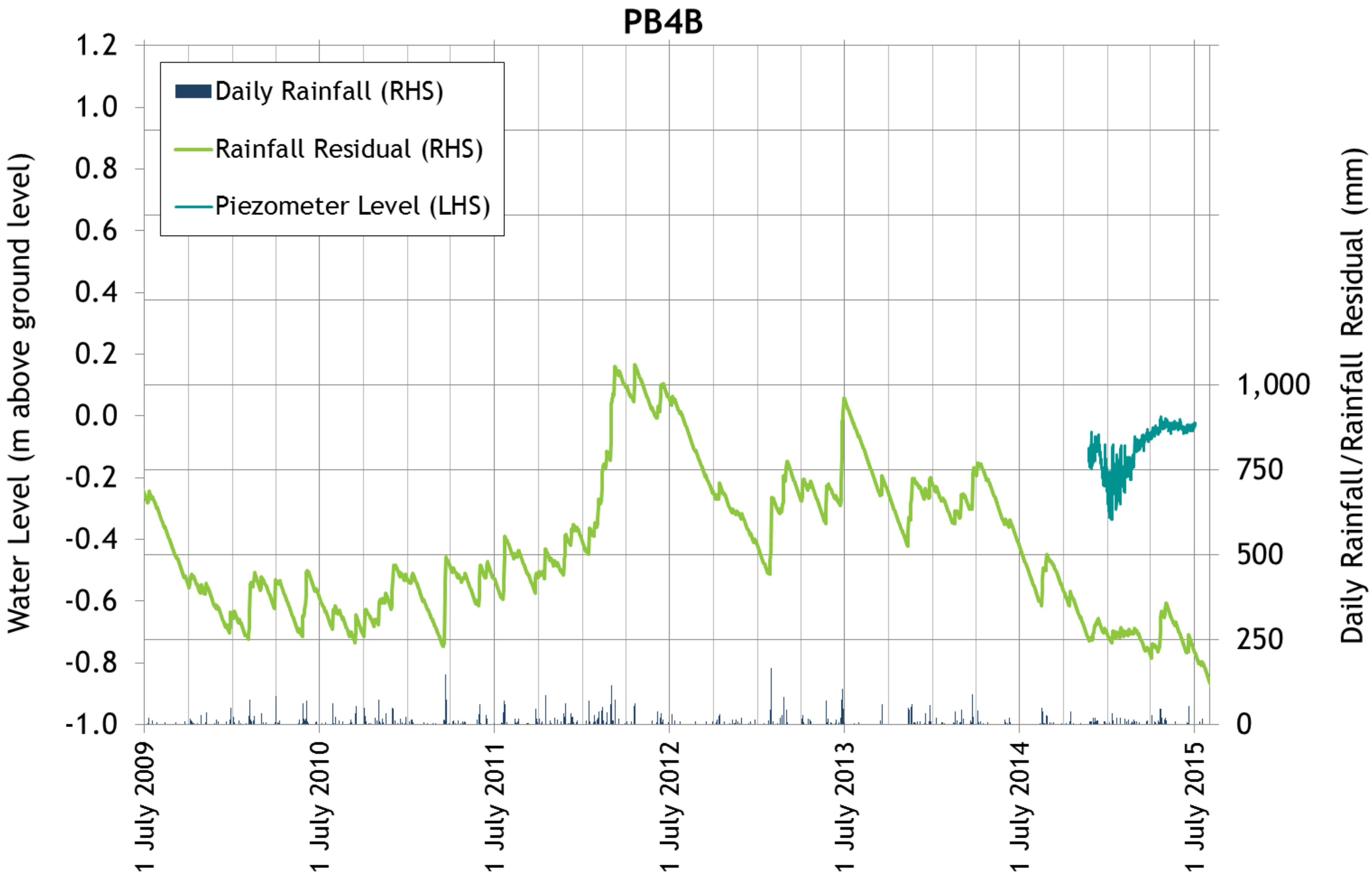
Graph 3 Hydrograph – Piezometer SP2



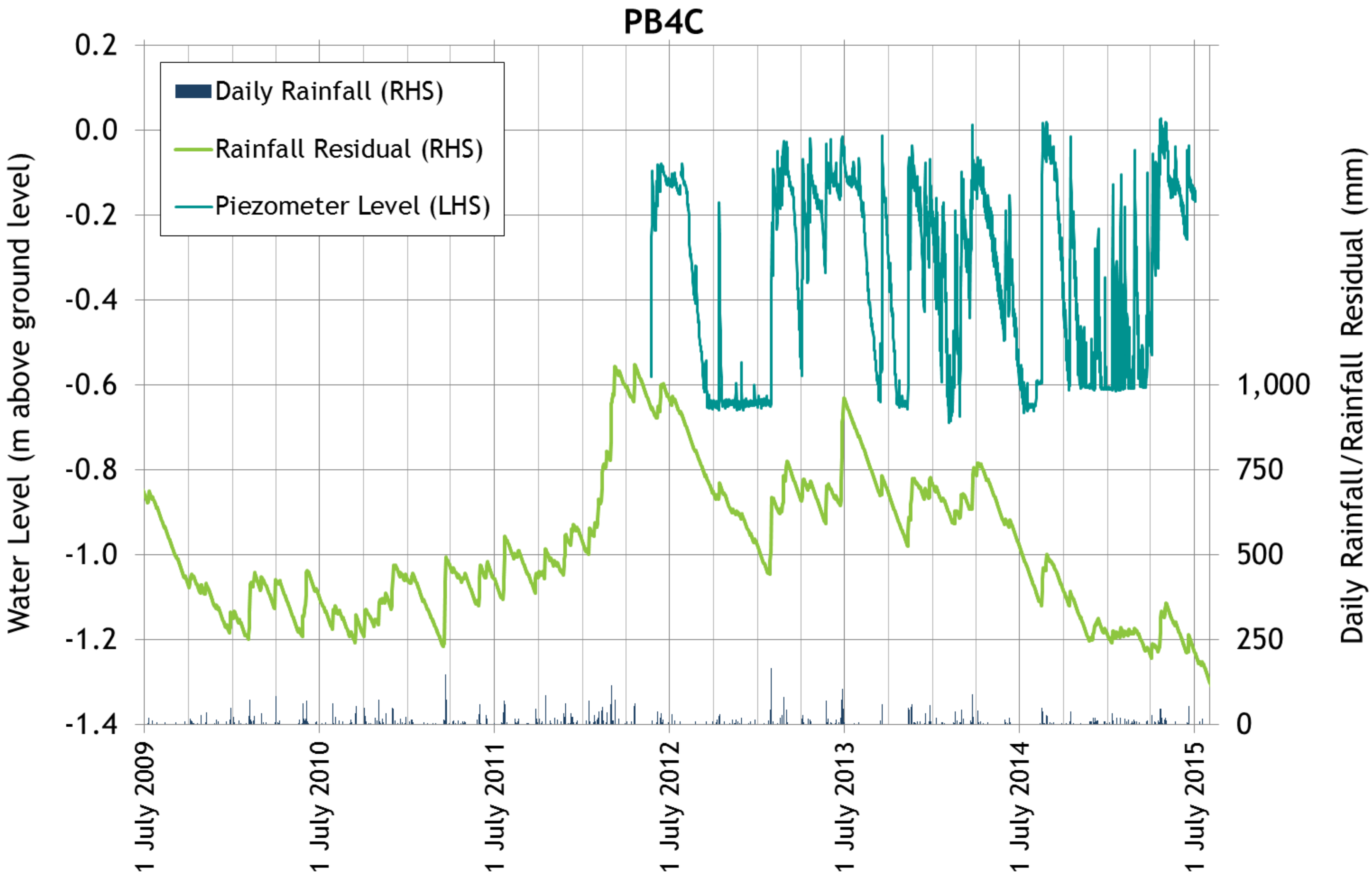
**Graph 4 Hydrograph – Piezometer PB4A**



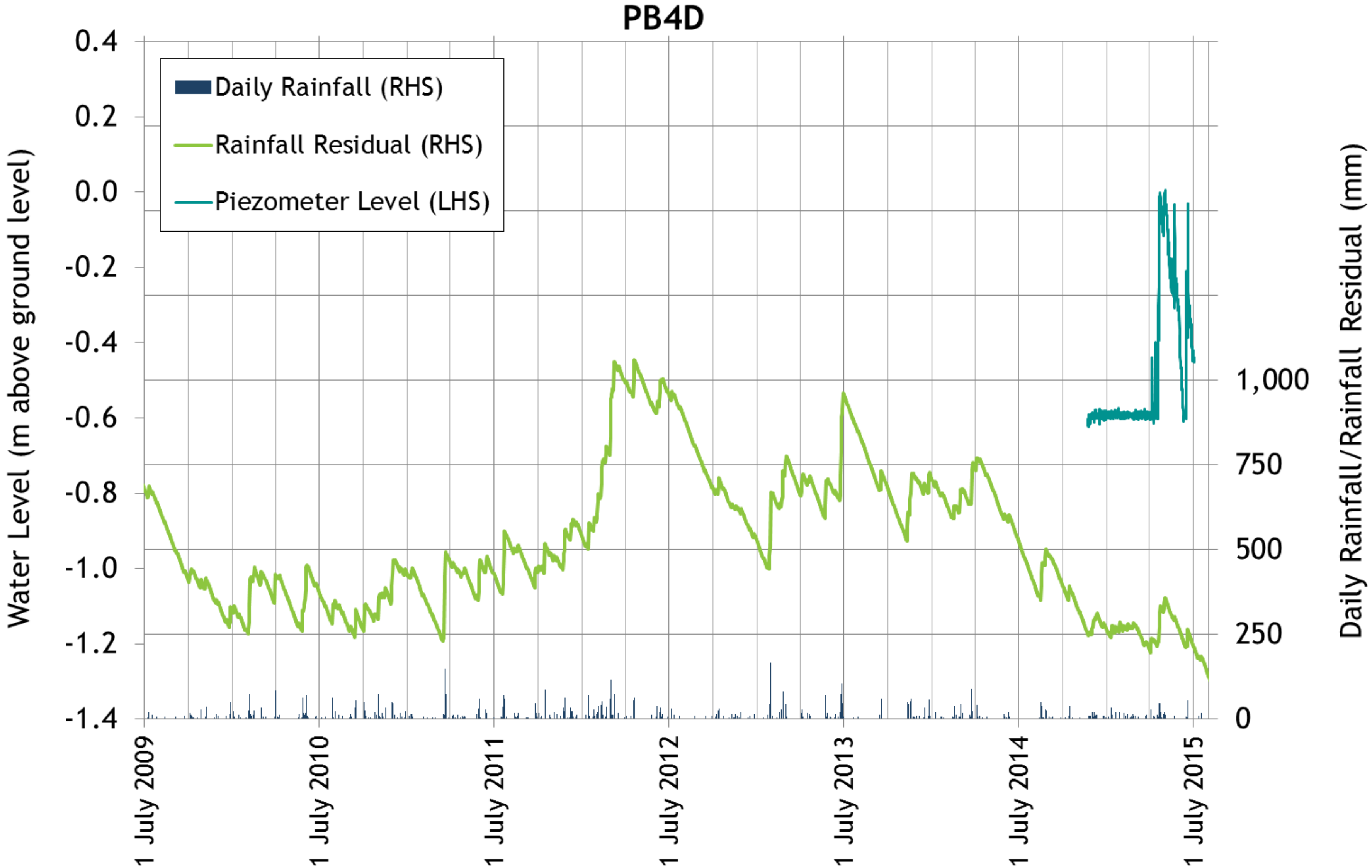
**Graph 5 Hydrograph – Piezometer PB4B**



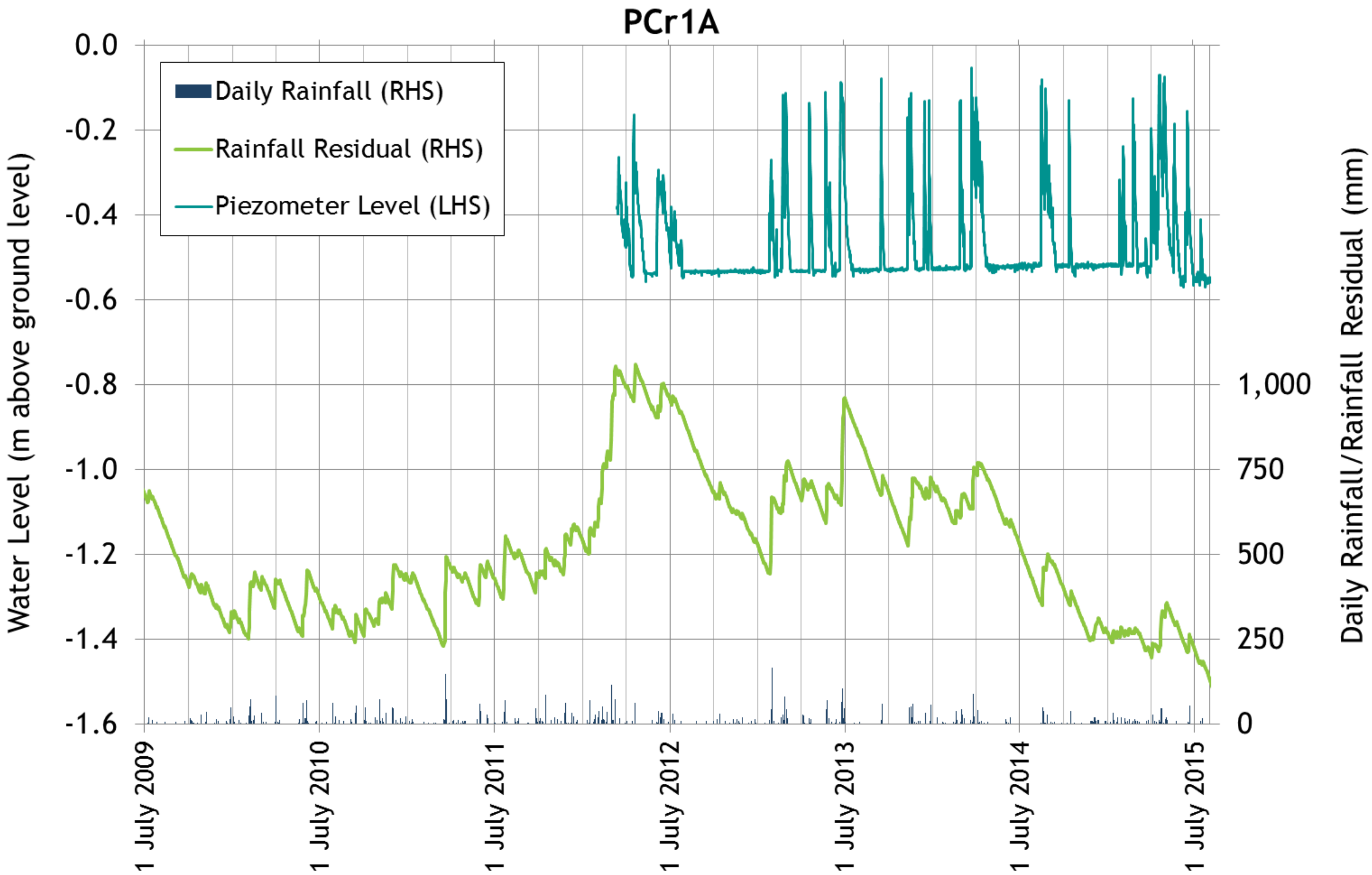
**Graph 6 Hydrograph – Piezometer PB4C**



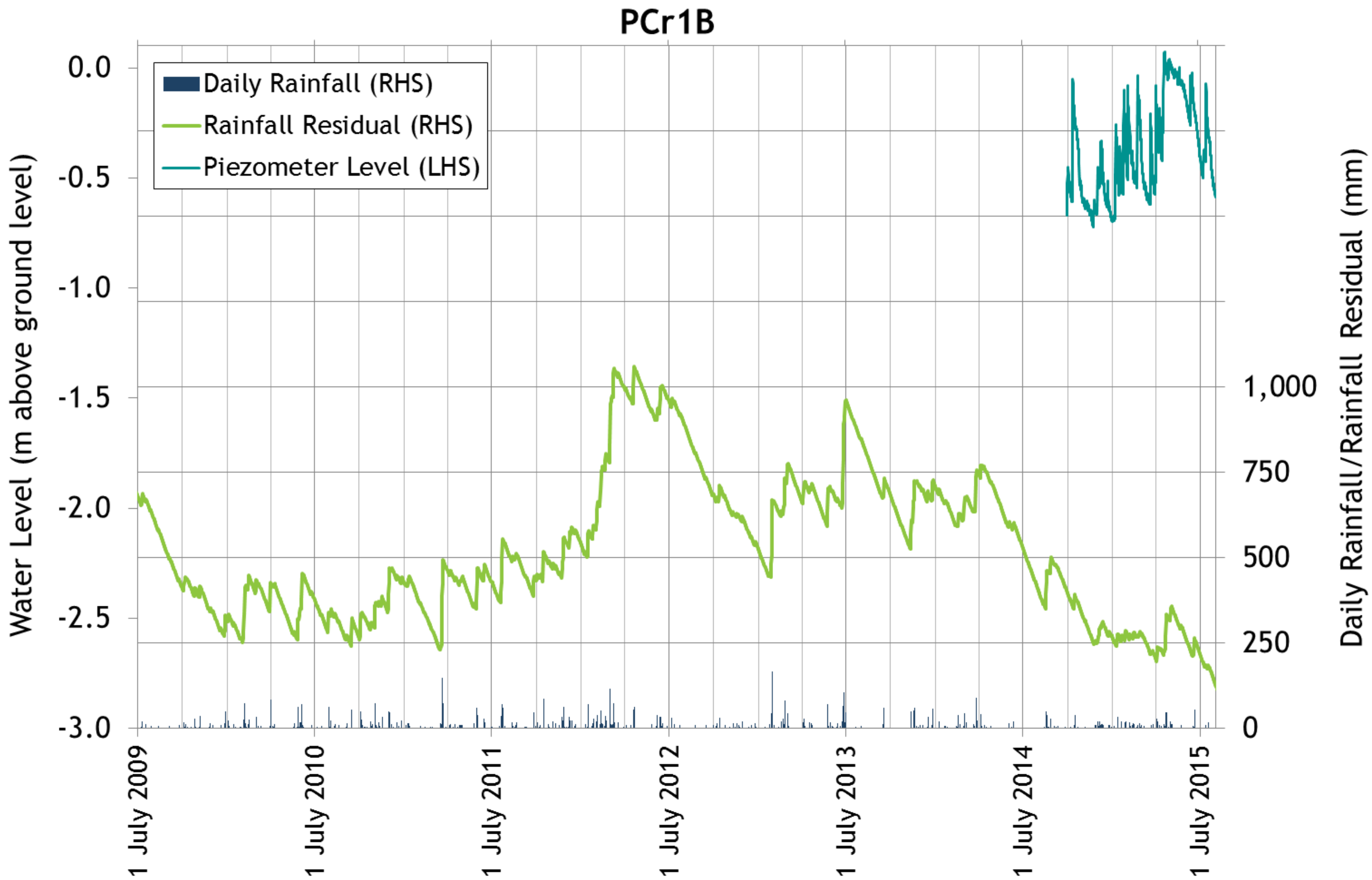
**Graph 7  Hydrograph – Piezometer PB4D**



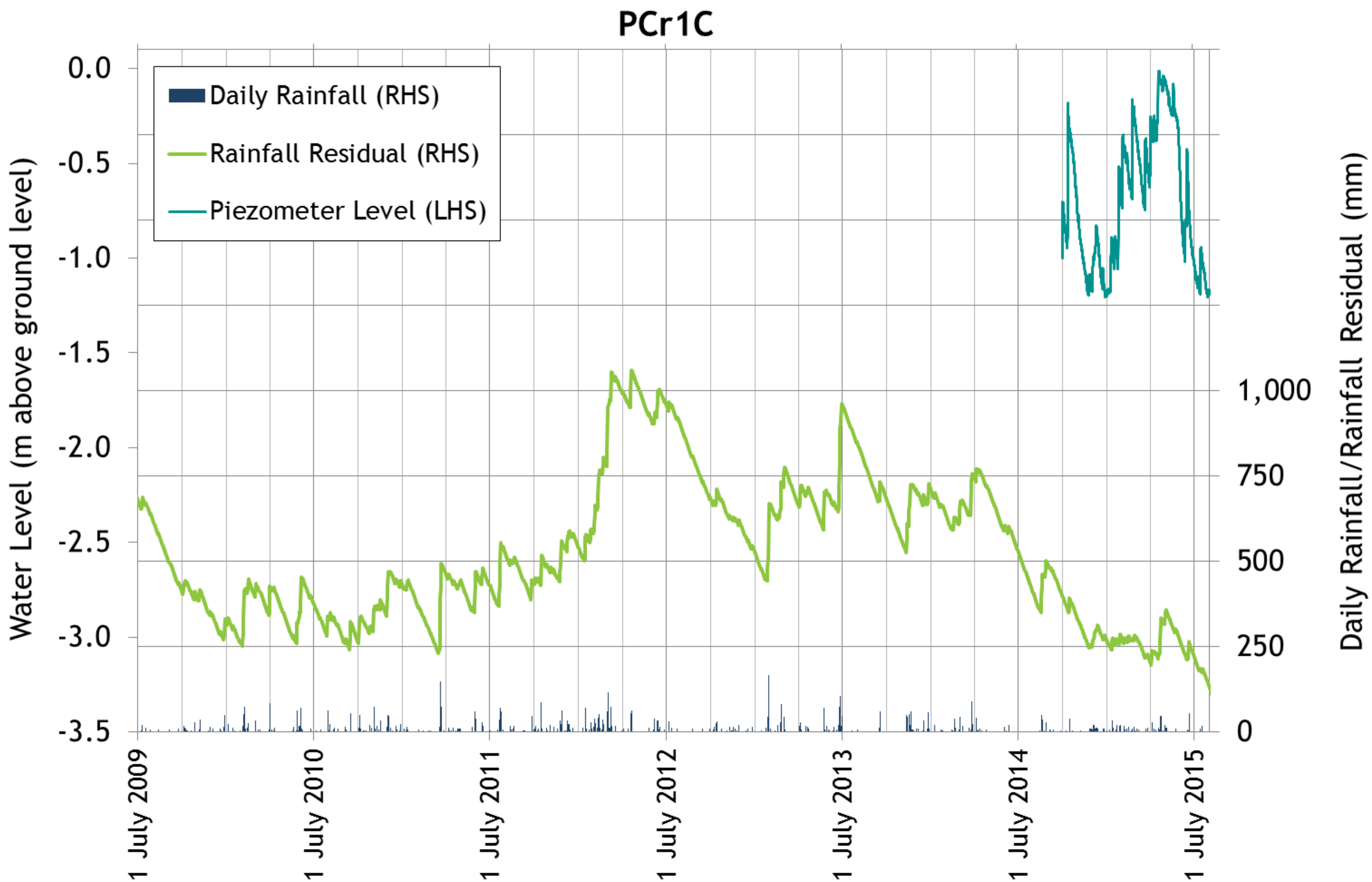
**Graph 8 Hydrograph – Piezometer PCr1A**



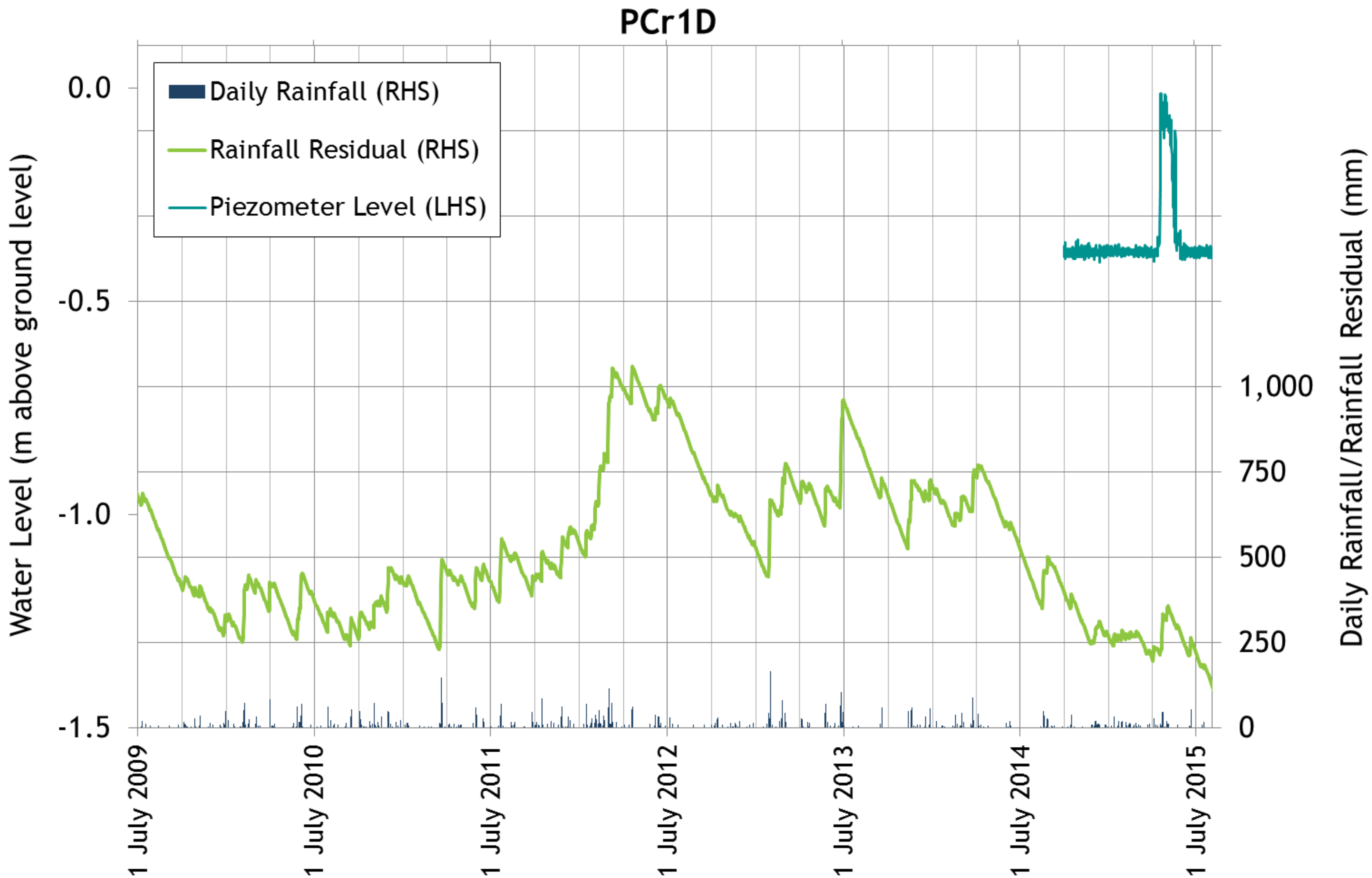
**Graph 9 Hydrograph – Piezometer PCr1B**



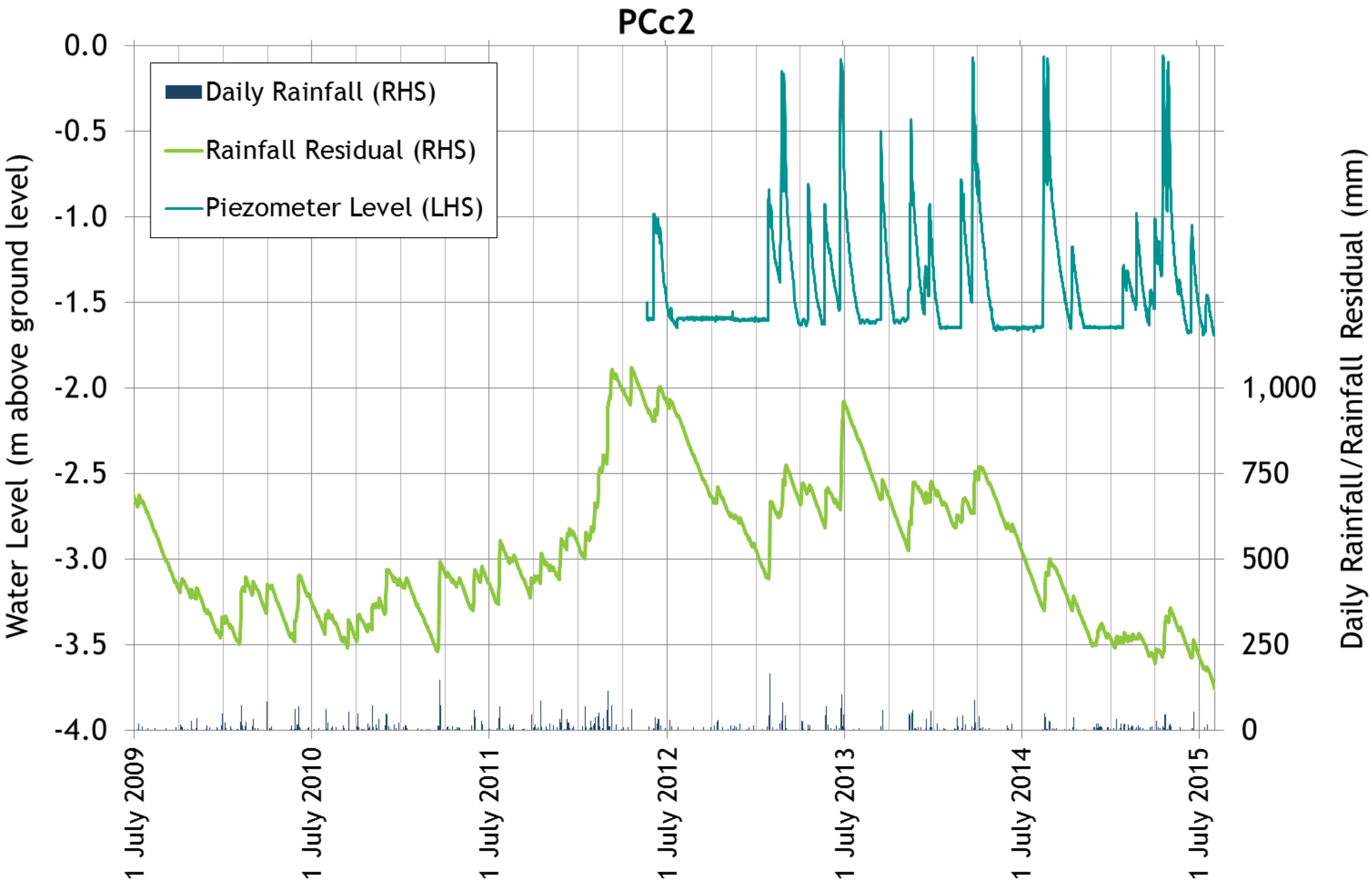
Graph 10 Hydrograph – Piezometer PCr1C



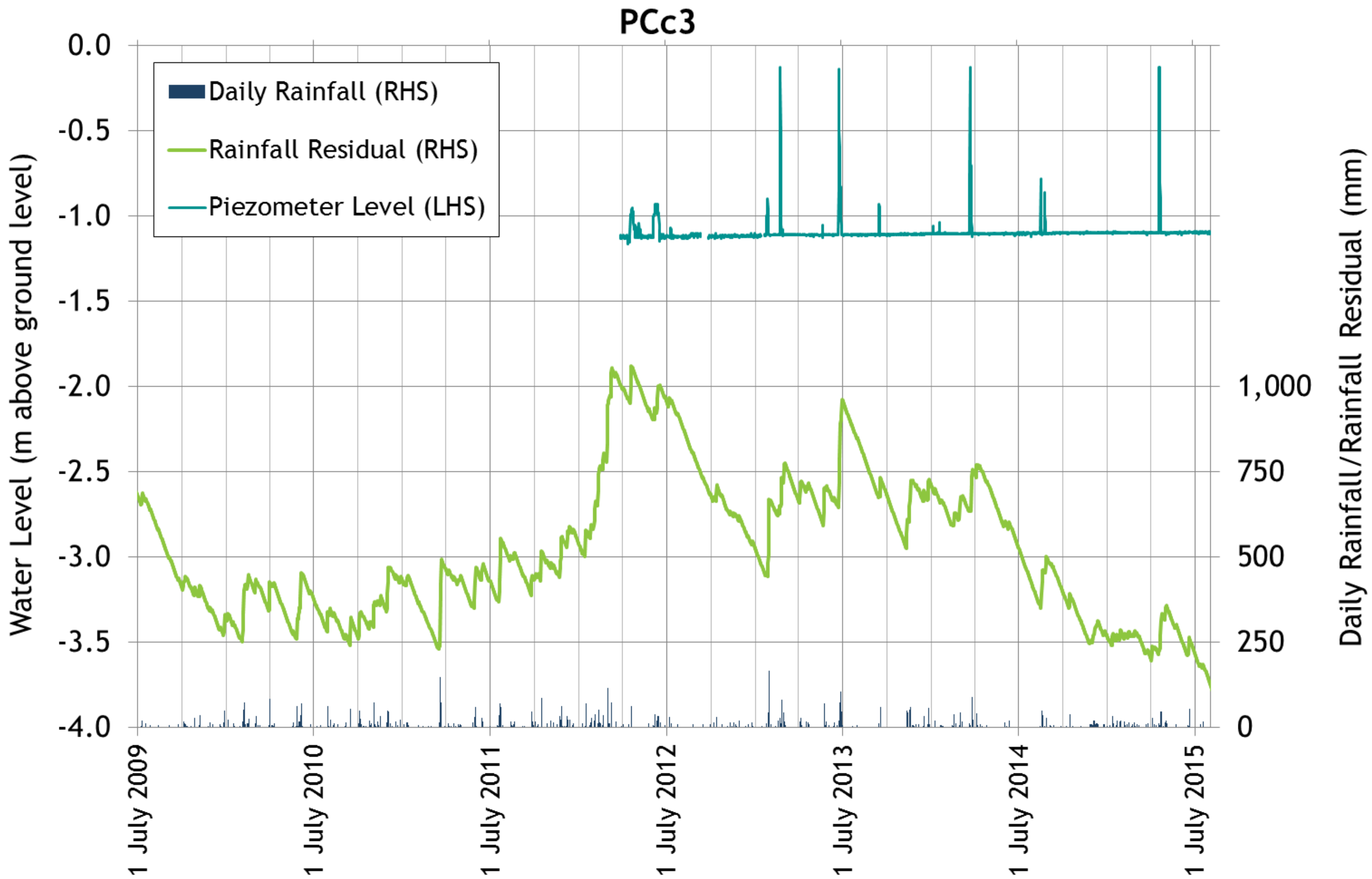
**Graph 11 Hydrograph – Piezometer PCr1D**



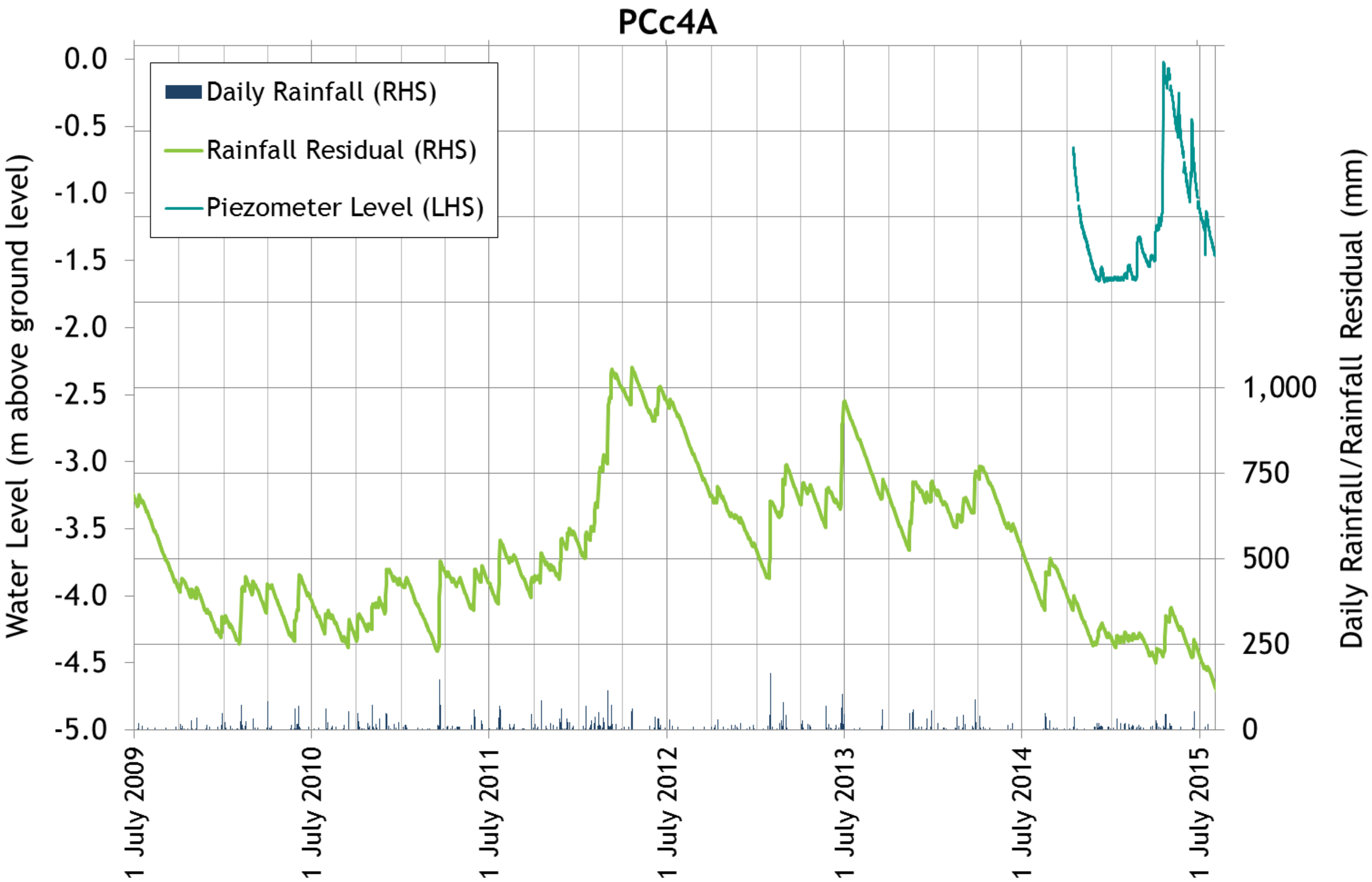
**Graph 12 Hydrograph – Piezometer PCc2**



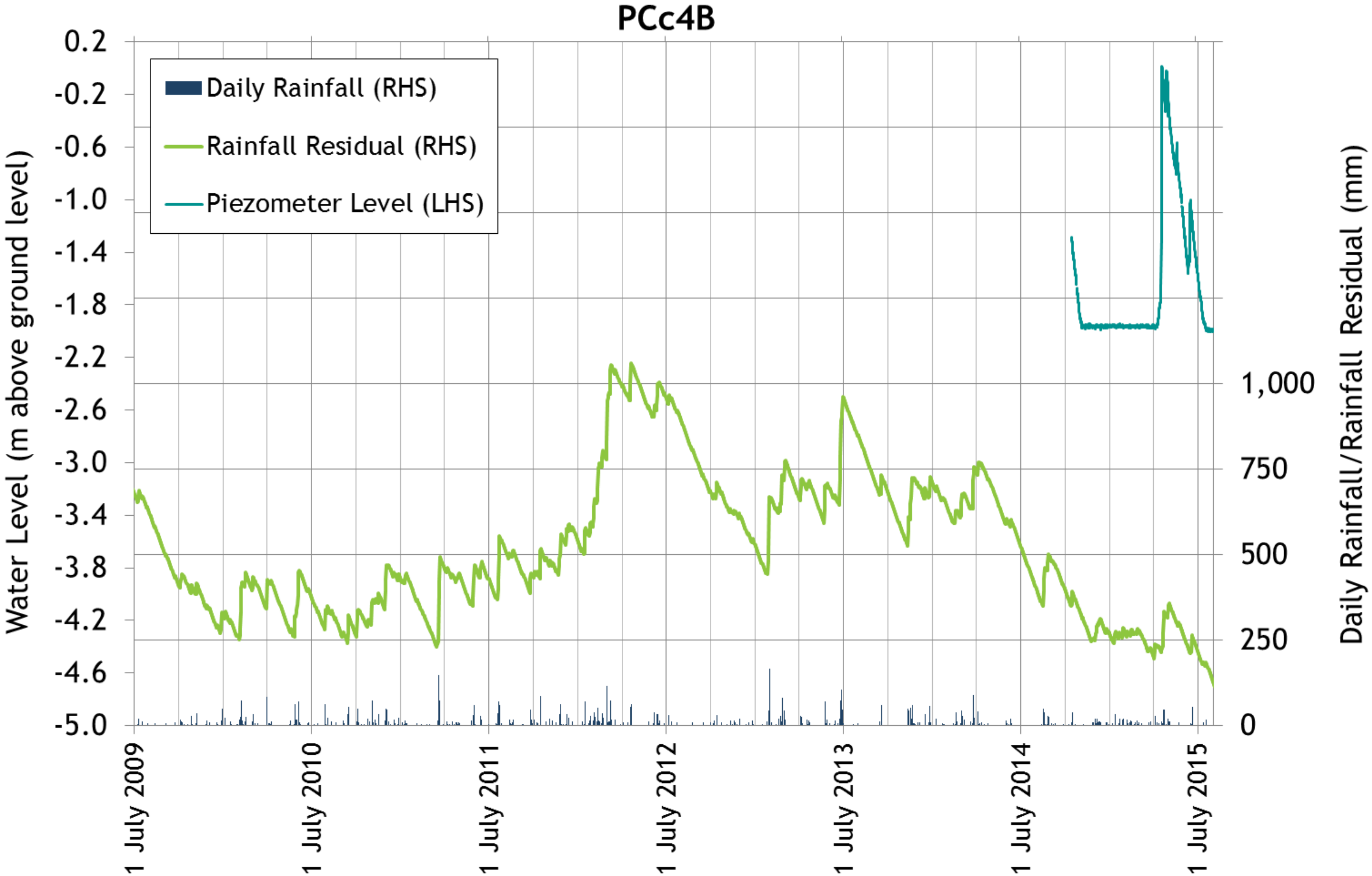
**Graph 13 Hydrograph – Piezometer PCc3**



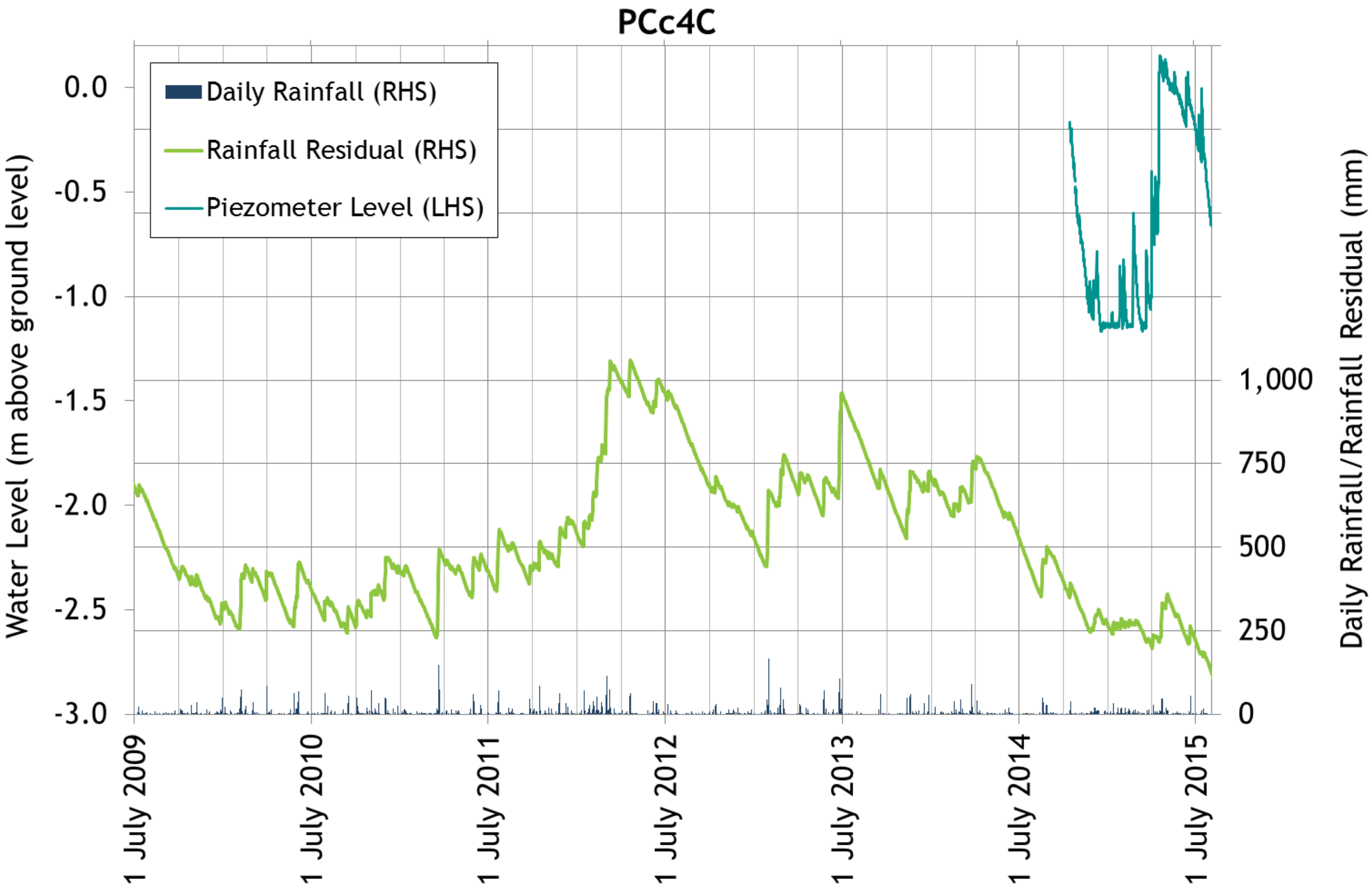
**Graph 14 Hydrograph – Piezometer PCc4A**



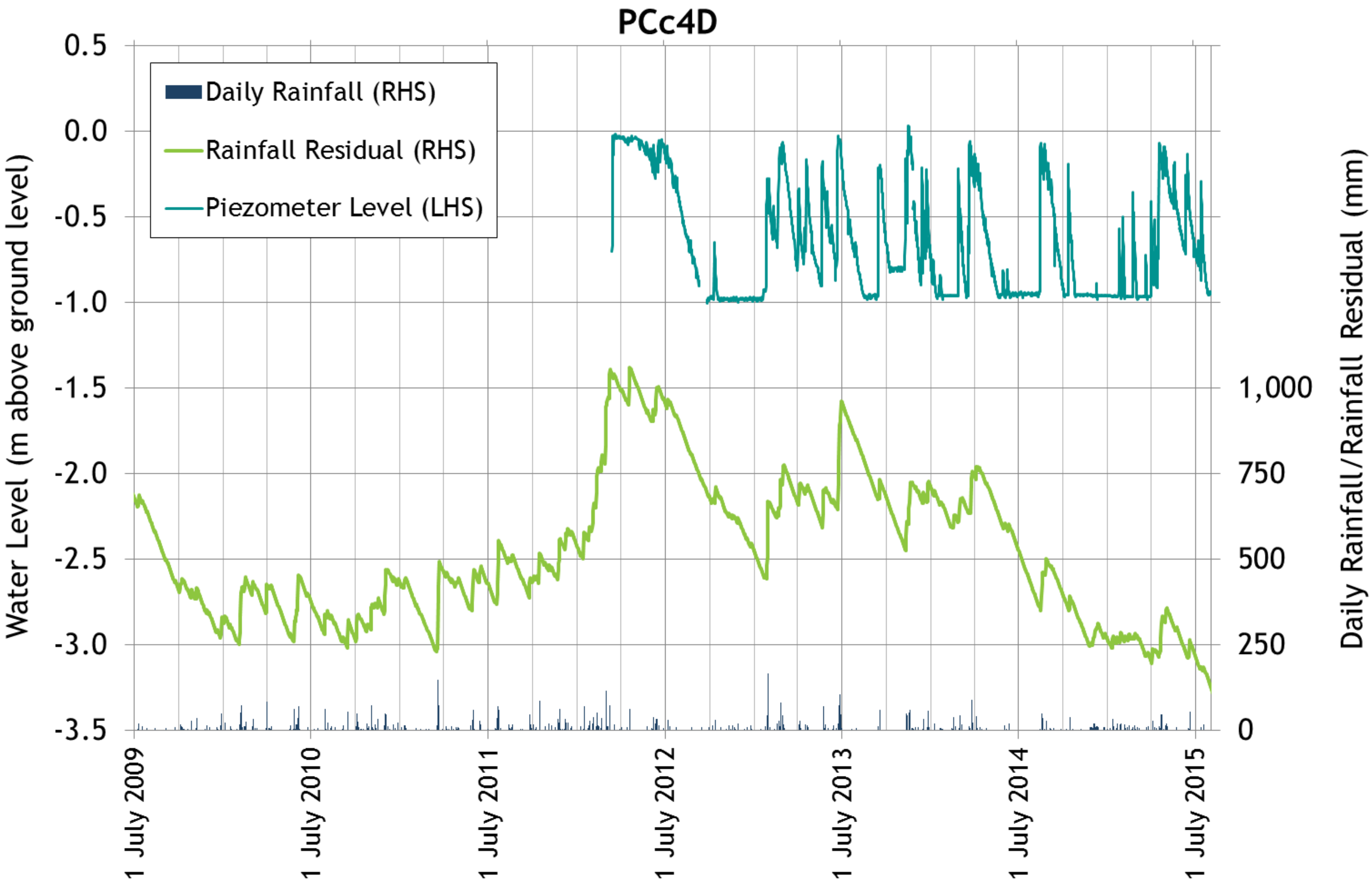
**Graph 15 Hydrograph – Piezometer PCc4B**



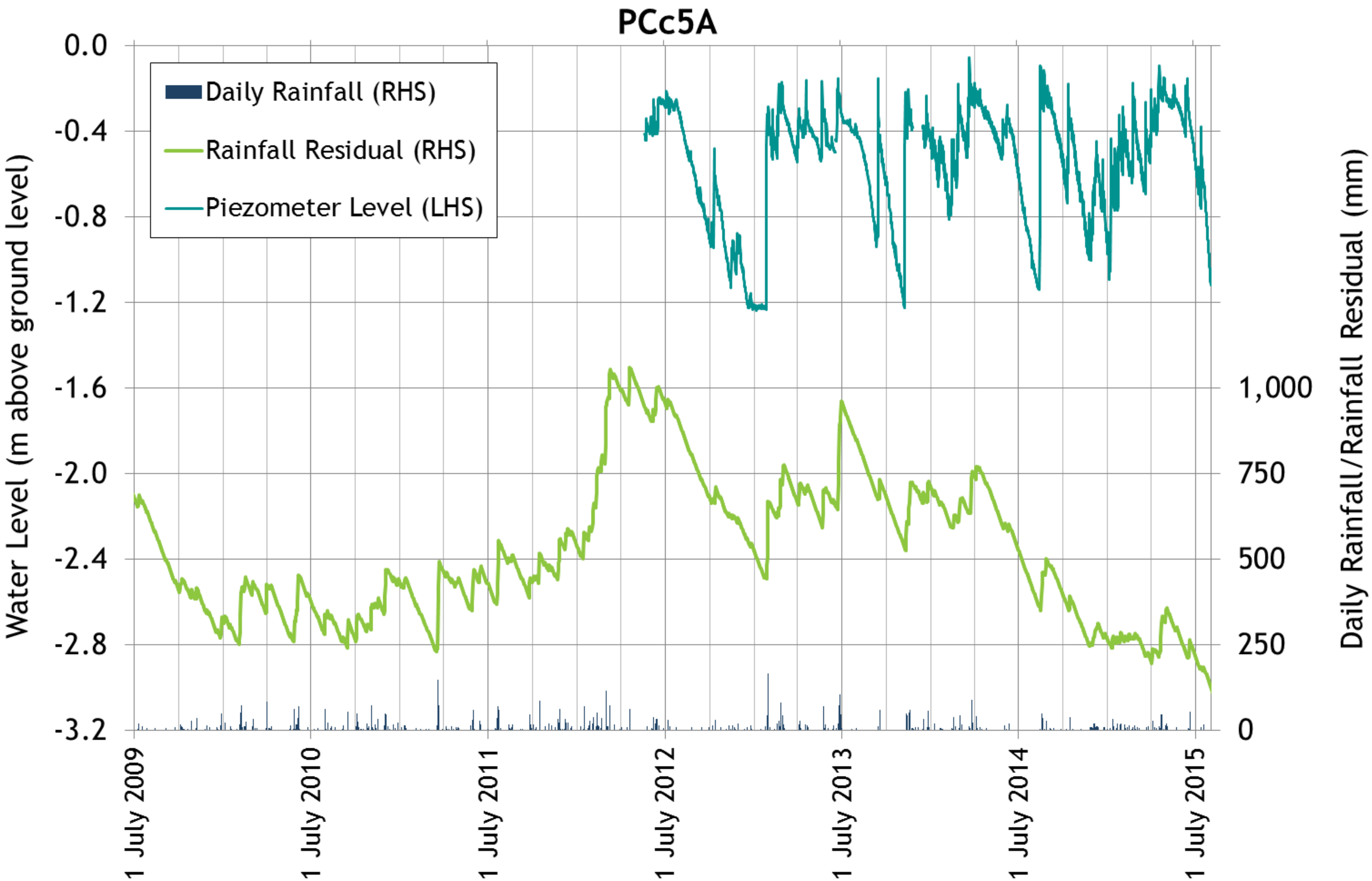
**Graph 16 Hydrograph – Piezometer PCc4C**



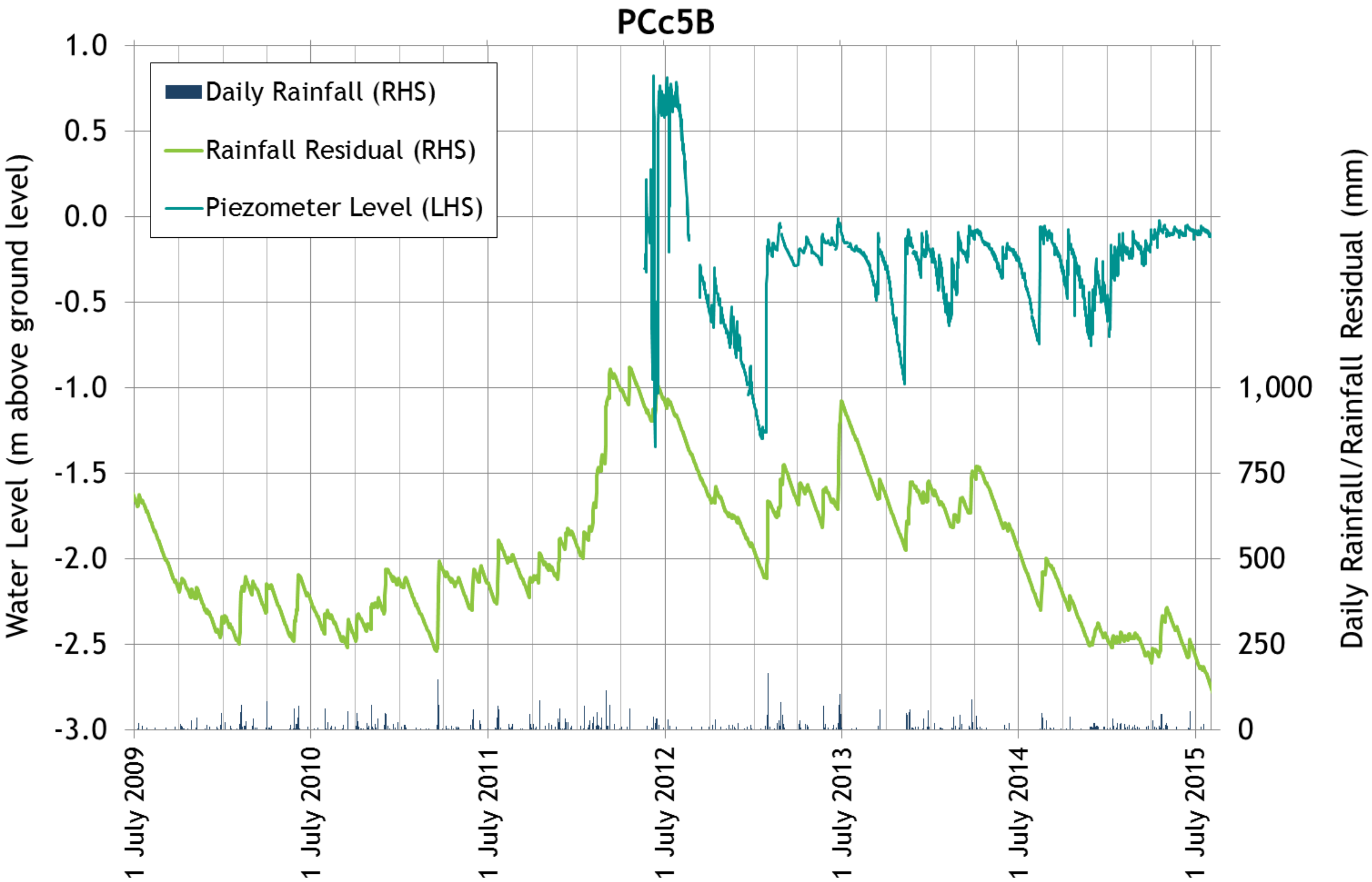
**Graph 17 Hydrograph – Piezometer PCc4D**



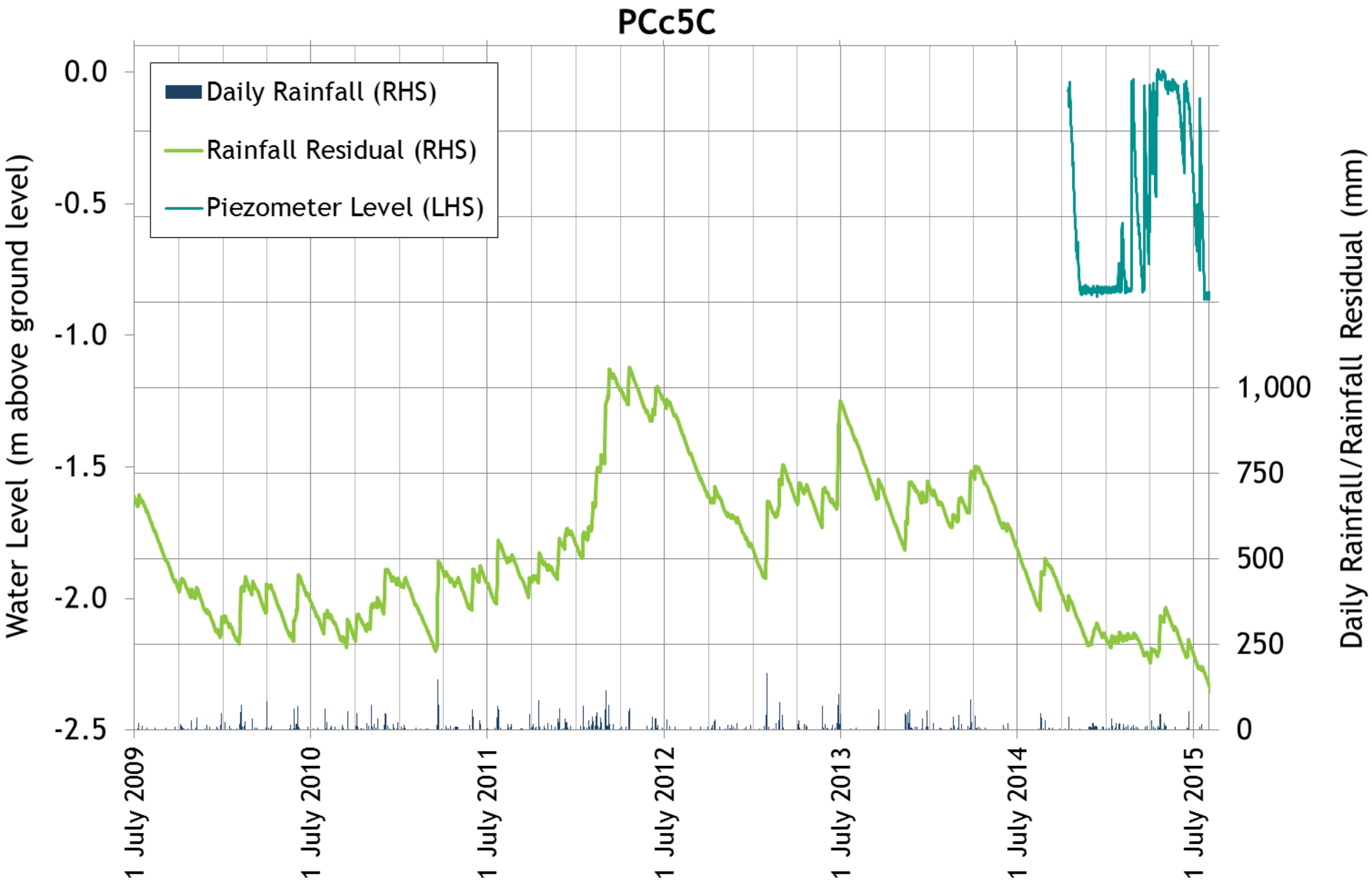
Graph 18 Hydrograph – Piezometer PCc5A



**Graph 19 Hydrograph – Piezometer PCc5B**

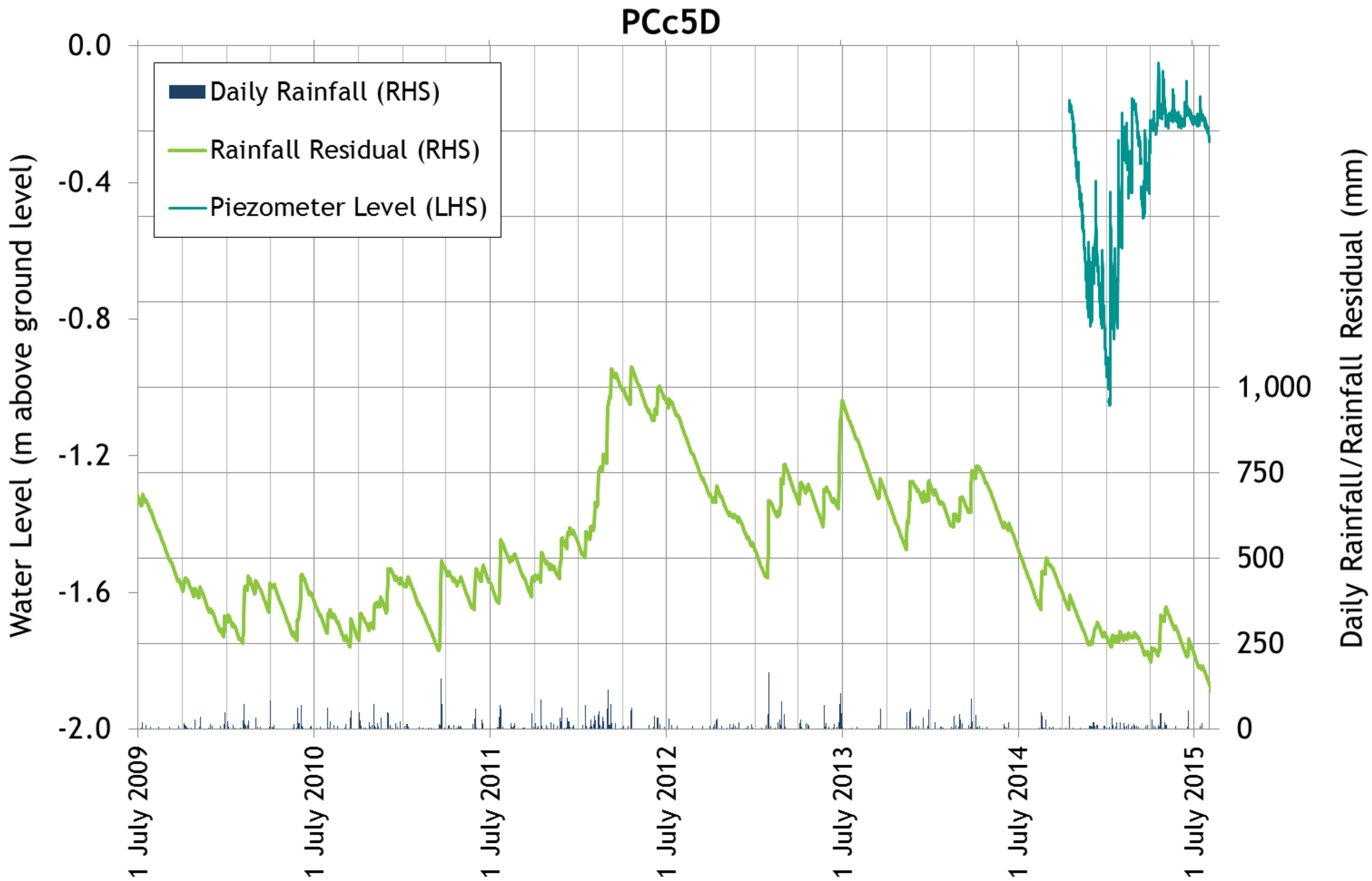


**Graph 20 Hydrograph – Piezometer PCc5C**

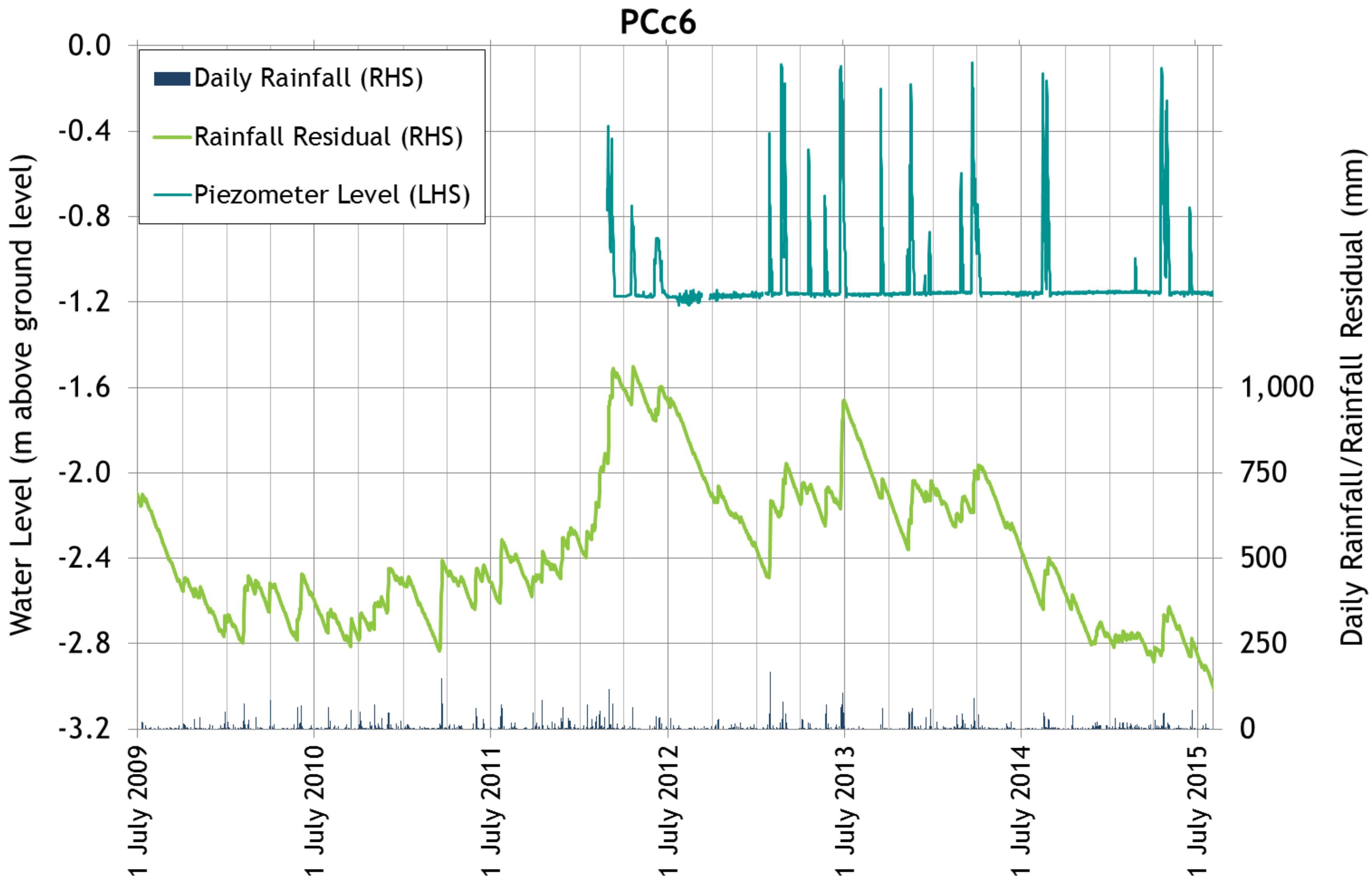


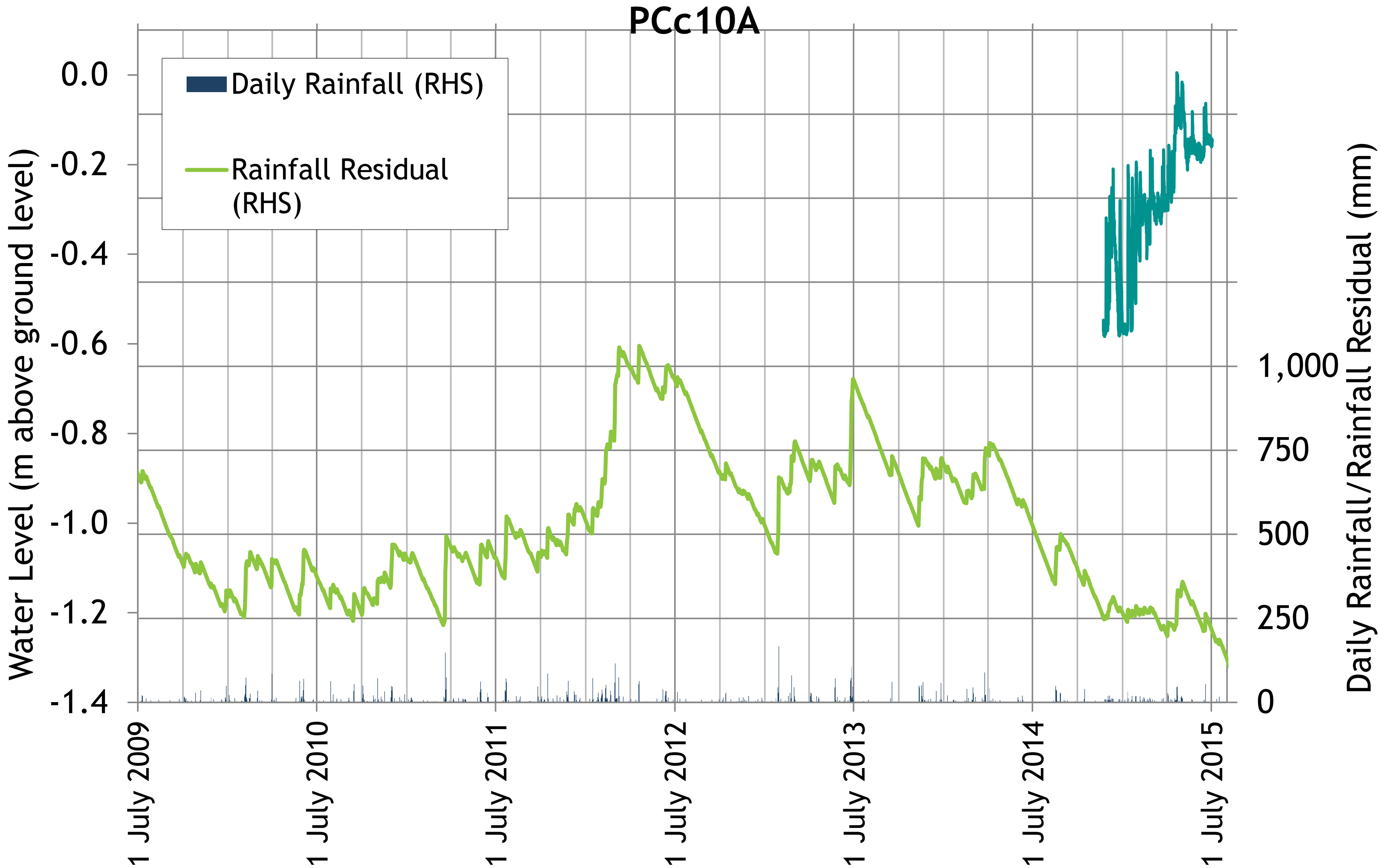
**Graph 21 Hydrograph – Piezometer PCc5D**



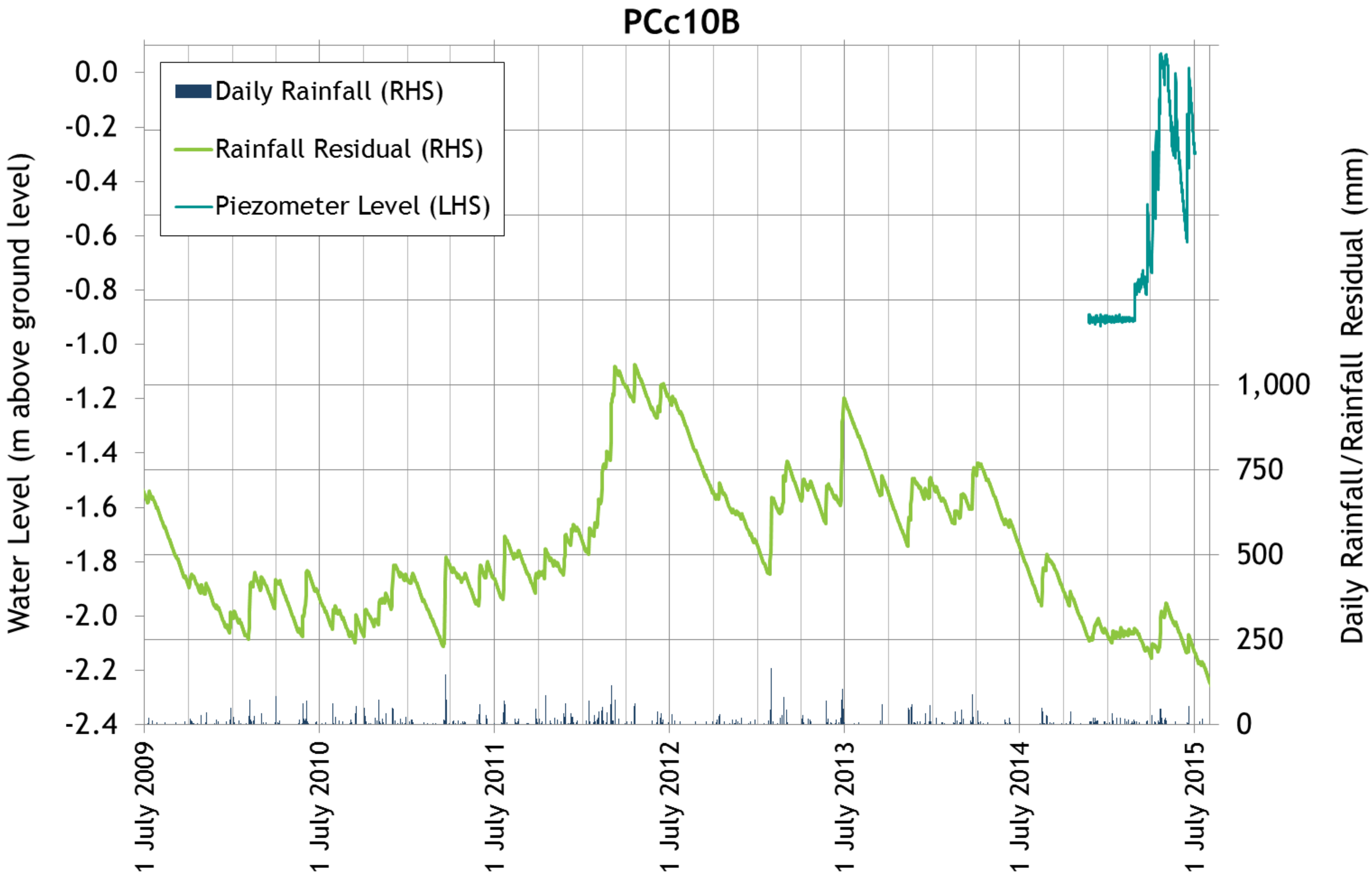
**Graph 22 Hydrograph – Piezometer PCc6**



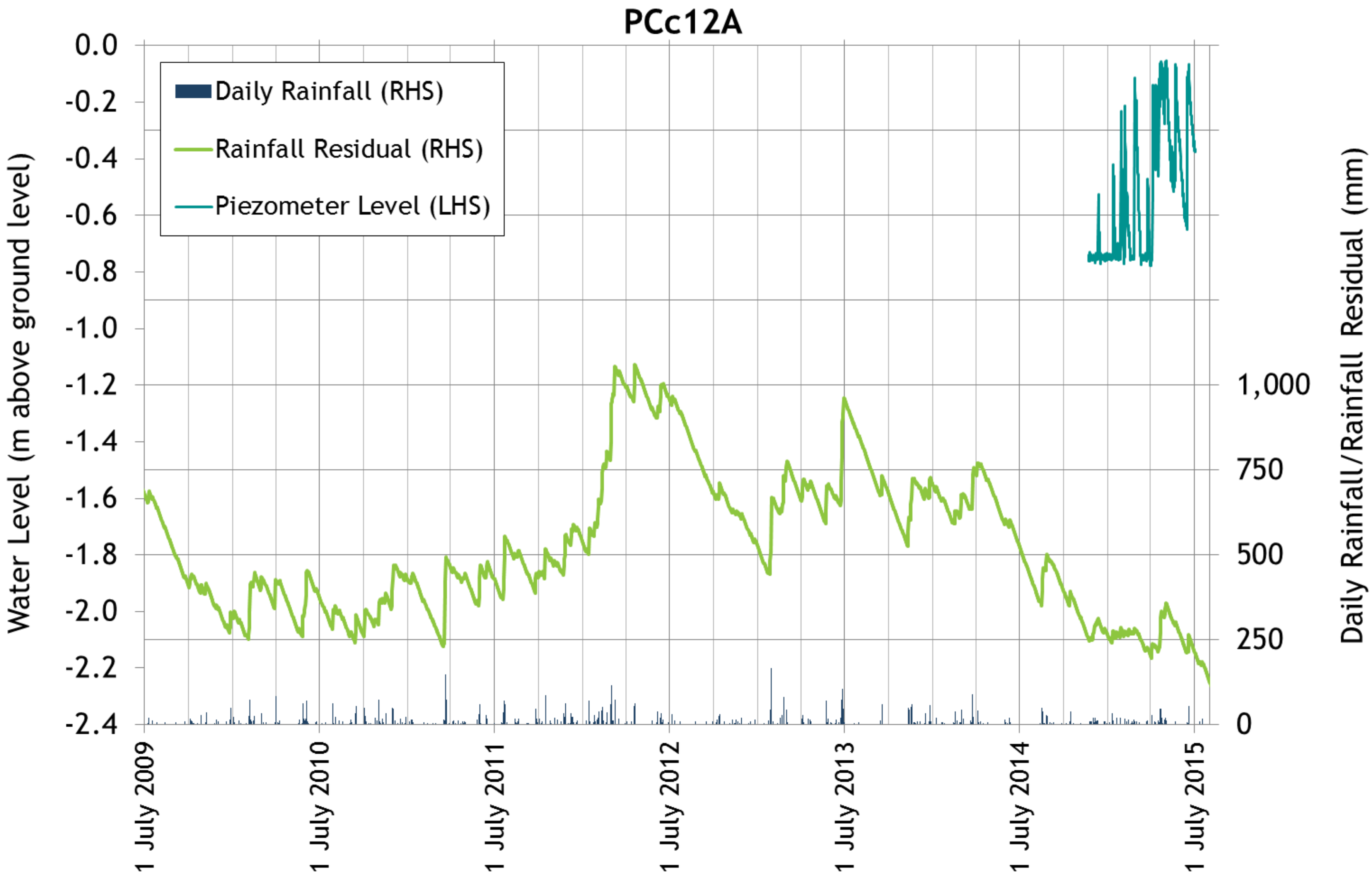
Graph 23 Hydrograph – Piezometer PCc10A



**Graph 24 Hydrograph – Piezometer PCc10B**



**Graph 25 Hydrograph – Piezometer PCc12A**



**Graph 26 Hydrograph – Piezometer PCc12B**

# Appendix 2 – Presentation to the Independent Risk Assessment Panel

# Wollongong Coal's Underground Expansion Project:

## Presentation to the Independent Risk Assessment Panel (IRAP)

Nathan Garvey, Senior Consultant Ecologist

3 September 2015

# Overview of the project

- 8 longwalls across 3 areas
- 40 upland swamps within 600 metres of the longwalls
- 11 upland swamps directly overly the longwalls
  - Area 1: CCUS2
  - Area 2: CCUS4, CCUS5, CRUS1
  - Area 3: BCUS4, BCUS11, CCUS10, CCUS11, CCUS12, CCUS24, CRUS6
- 2 additional swamps located in close proximity to longwalls
  - Area 1: CCUS1, CRUS3

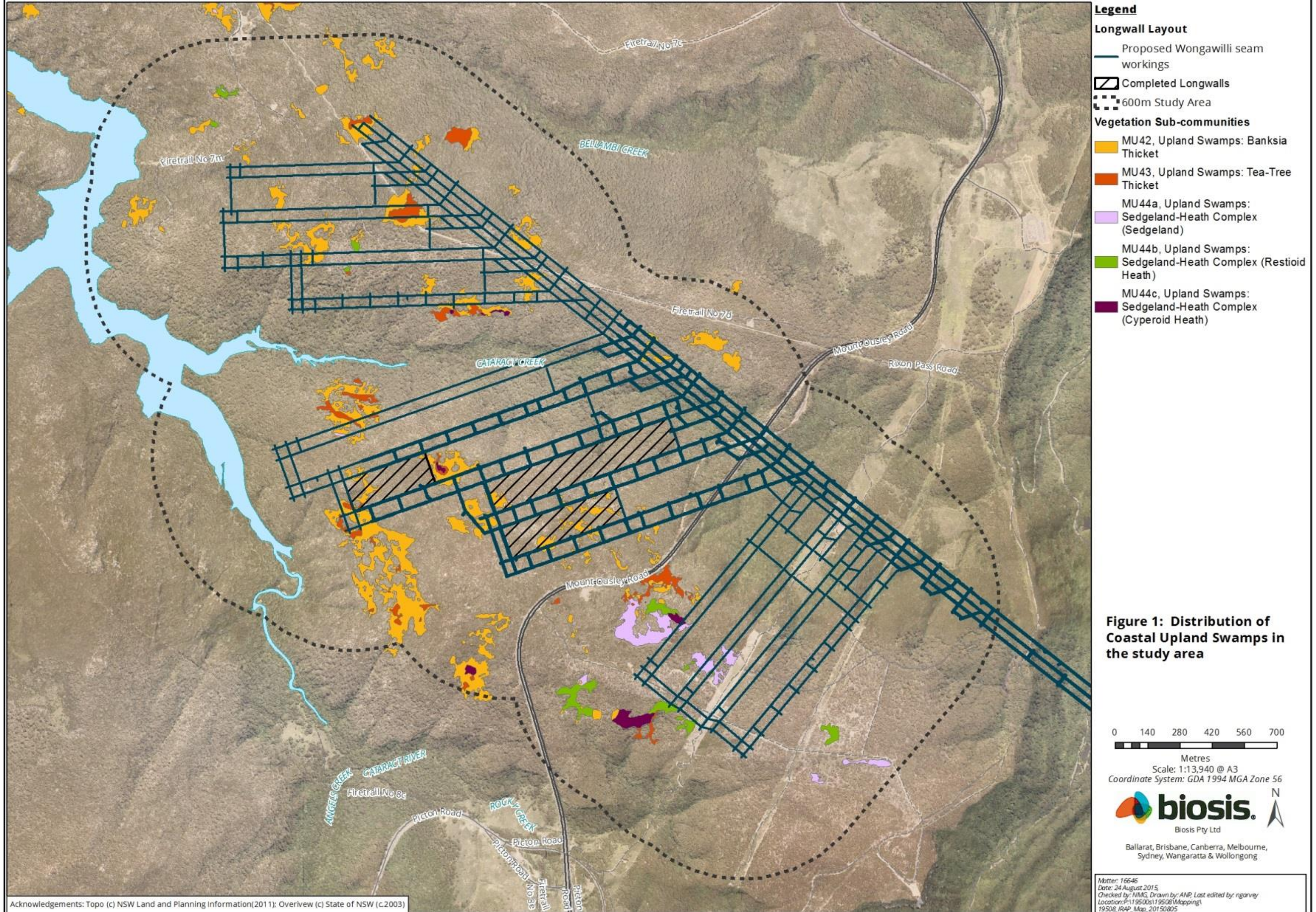



Figure 1: Distribution of Coastal Upland Swamps in the study area

# Measures to avoid and minimise impacts

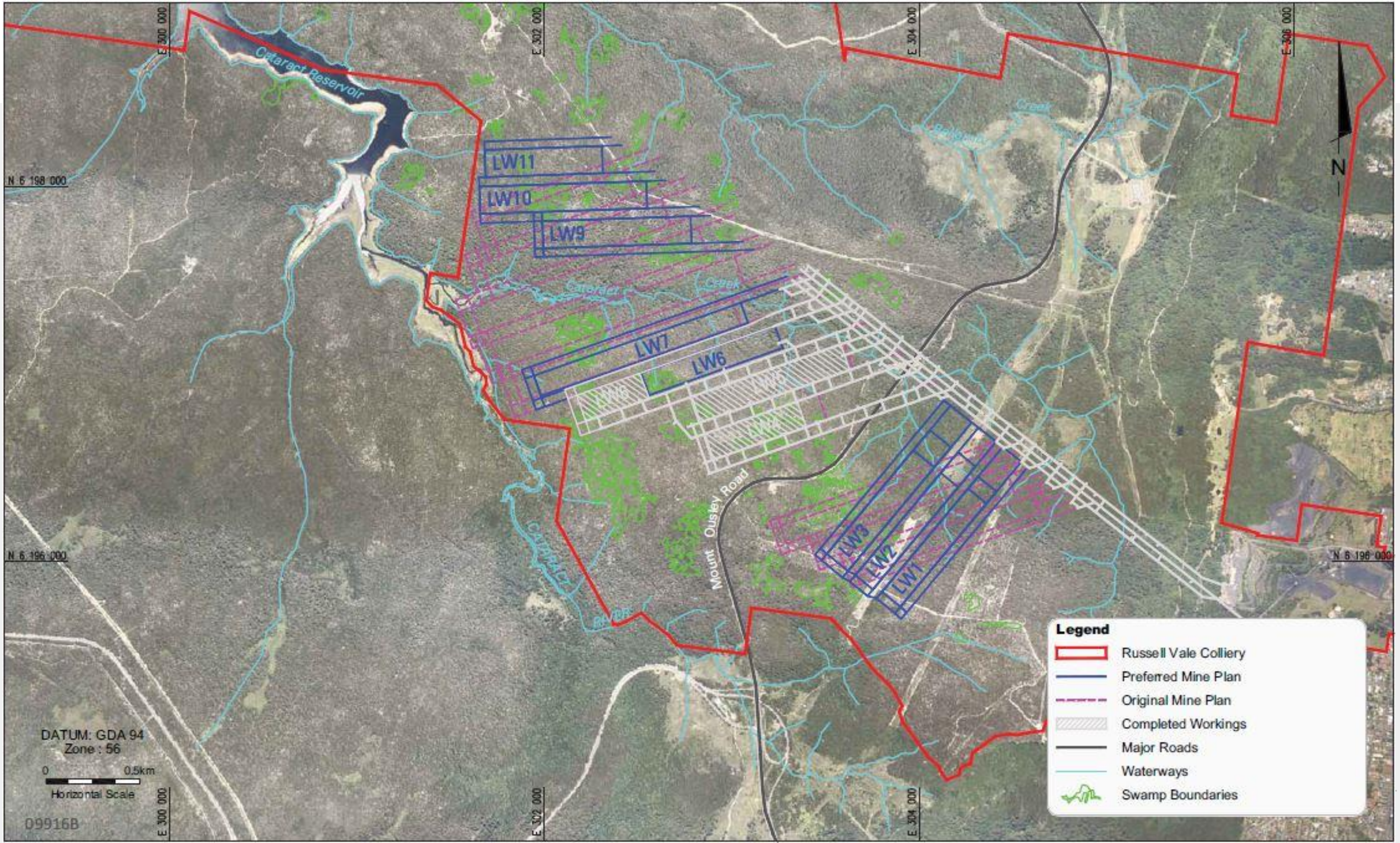
> Re-orientation of LWs 1 – 3 to avoid impacts to upland swamp CCUS1

> Restriction on the length of LWs 1 – 3 to avoid impacts to upland swamps CRUS3

> Reduction in the width of LW 7 and removal of LW8 to minimise impacts to upland swamp CCUS5

> Re-orientation of LW 9  to minimise impacts to upland swamp CCUS10



E 300 000
E 302 000
E 304 000
E 306 000
N 6 198 000
N 6 196 000
Cataract Reservoir
Cataract Creek
Cataract River
Bellambi Creek
Mount Ousley Road
LW11
LW10
LW9
LW7
LW6
LW3
LW2
LW1
N
DATUM: GDA 94
Zone : 56
0
0.5km
Horizontal Scale
Legend
Russell Vale Colliery
Preferred Mine Plan
Original Mine Plan
Completed Workings
Major Roads
Waterways
Swamp Boundaries
09916B

# Risk Assessment

## Factors of consideration

- Size of swamp and area mined beneath
- Catchment size and area mined beneath
- Presence of perched water table and impacts to water holding capacity
- Potential impacts to in-flow and through flow
- Vegetation communities and dependence on perched water table

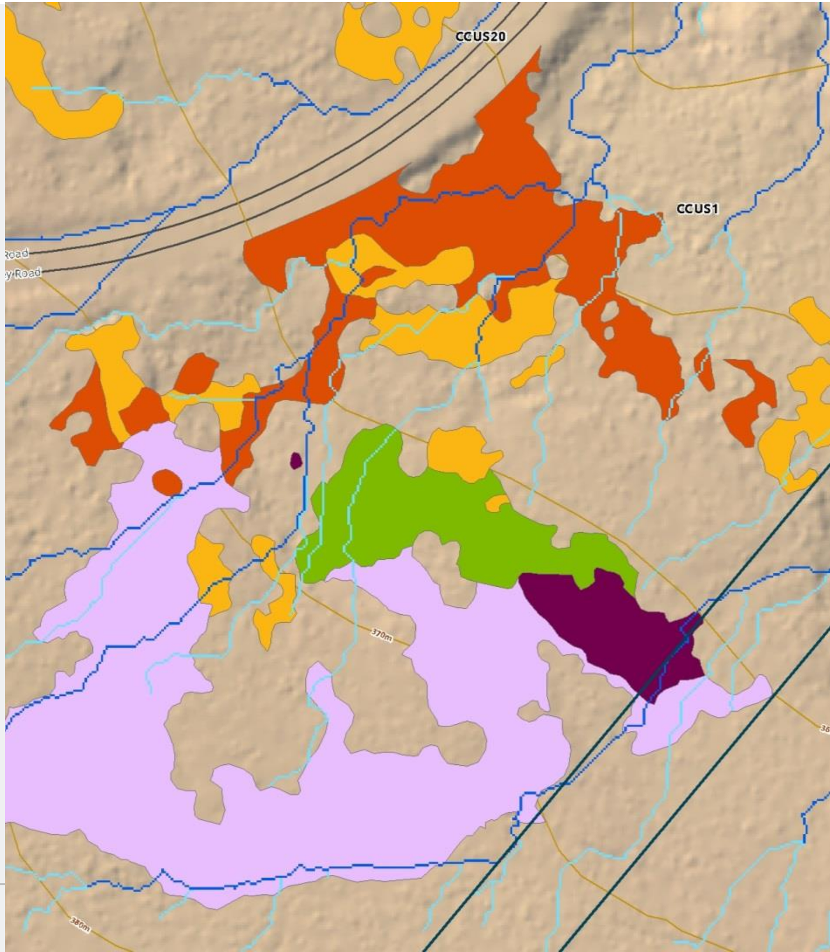
  

# Upland Swamp CCUS1

> Located over the pillar of LW3

> Water dependent sections located within 200mm subsidence zone or in areas

| | |
|---|---|
| Size of swamp | 4.81 ha |
| Area of swamps within 200mm subsidence zone | 0.15 ha |
| Area of swamps within 200mm subsidence zone | 3.14% |
| Size of catchment area (ha) | 18.13 ha |
| Area of catchment within 200mm subsidence zone (ha) | 1.63 ha |
| Area of catchment within 200mm subsidence zone (%) | 8.99% |
| Supports vegetation communities reliant on perched water table? | Yes |

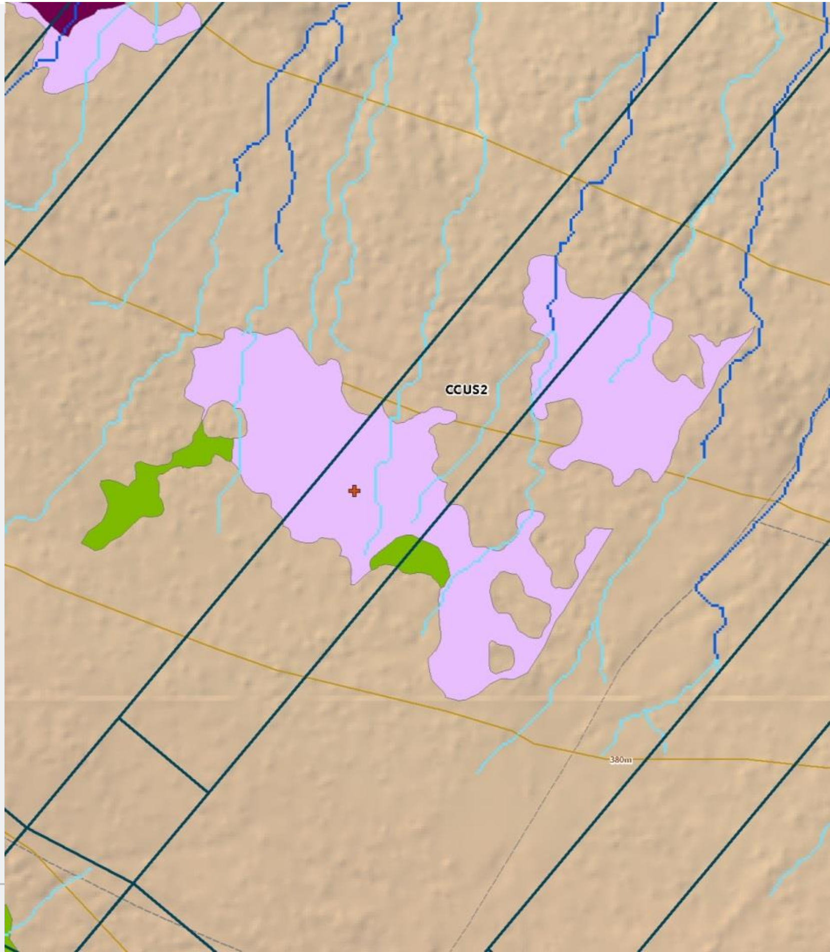


# Upland Swamp CCUS2

- Located over LWs 2 and 3
- Piezometer  indicates presence of perched water table
- No GW dependent communities
- No measurable outflow

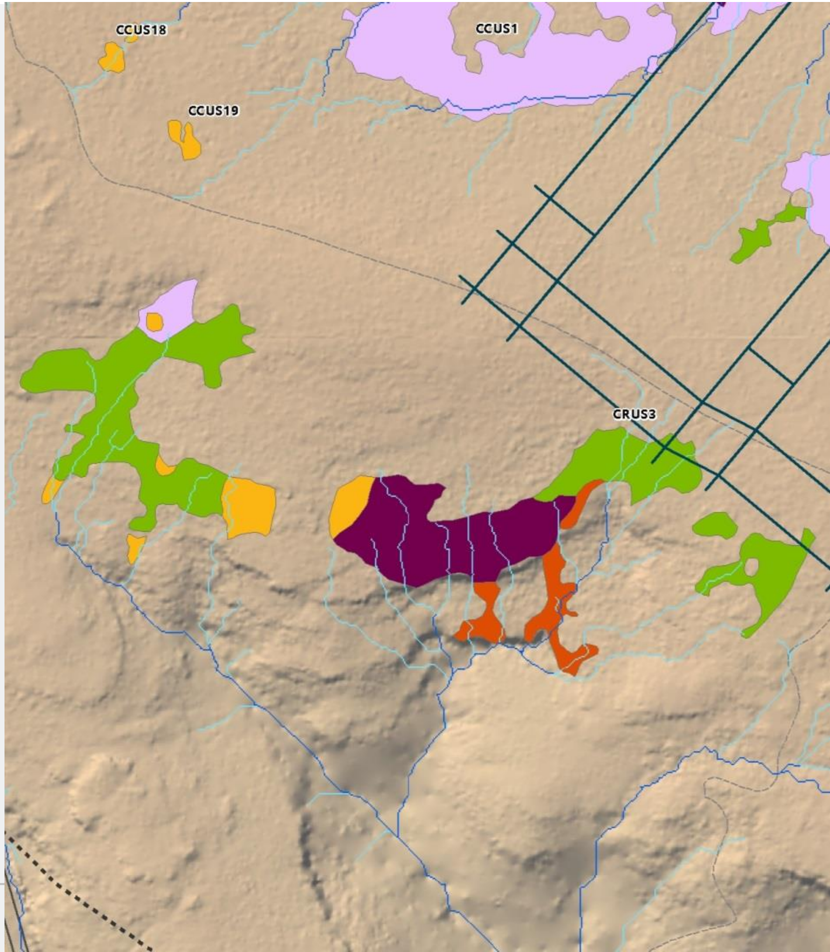
| | |
|---|---|
| Size of swamp | 1.21 ha |
| Area of swamps within 200mm subsidence zone | 1.21 ha |
| Area of swamps within 200mm subsidence zone | 100% |
| Size of catchment area (ha) | 4.08 ha |
| Area of catchment within 200mm subsidence zone (ha) | 4.08 ha |
| Area of catchment within 200mm subsidence zone (%) | 100% |
| Supports vegetation communities reliant on perched water table? | No |



# Upland Swamp CRUS3

- Located over pillar of LWs 2 and 3
- Entire swamp located outside 200mm subsidence zone

| | |
|---|---|
| Size of swamp | 3.42 ha |
| Area of swamps within 200mm subsidence zone | 0 ha |
| Area of swamps within 200mm subsidence zone | 0% |
| Size of catchment area (ha) | 12.62 ha |
| Area of catchment within 200mm subsidence zone (ha) | 0.62 ha |
| Area of catchment within 200mm subsidence zone (%) | 4.91% |
| Supports vegetation communities reliant on perched water table? | Yes |

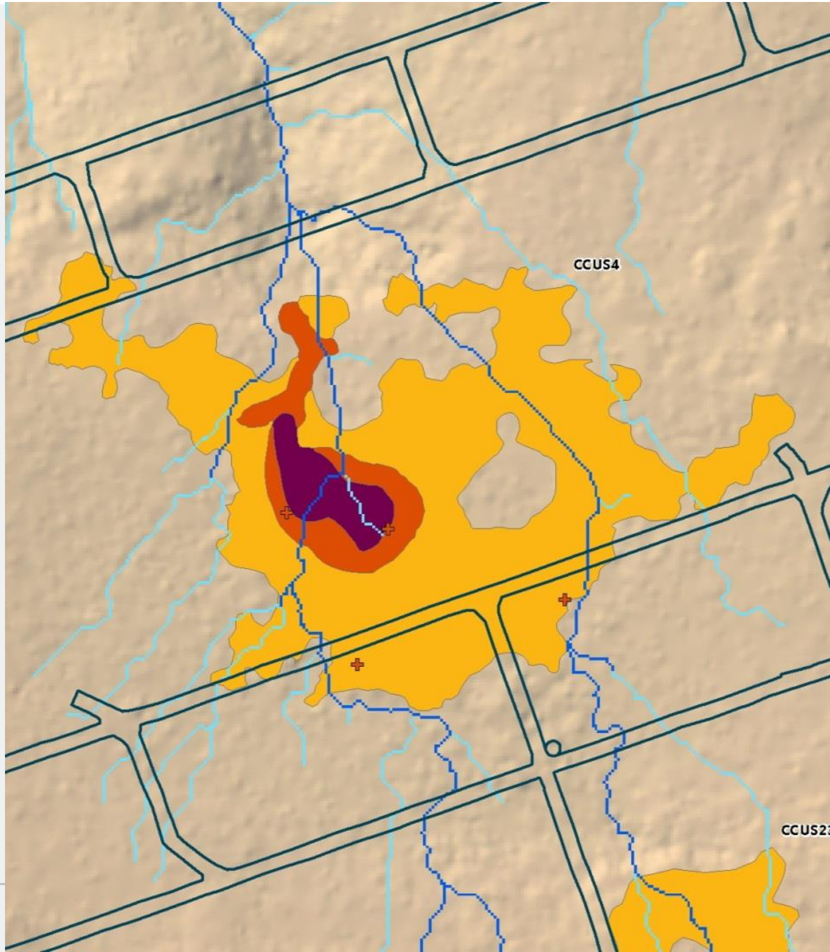


# Upland Swamp CCUS4

- Located over pillar of LW 6
- Piezometers indicate presence of a perched water table
- Minimal outflow, despite being wettest swamp
- Potential impacts due to subsidence induced drying

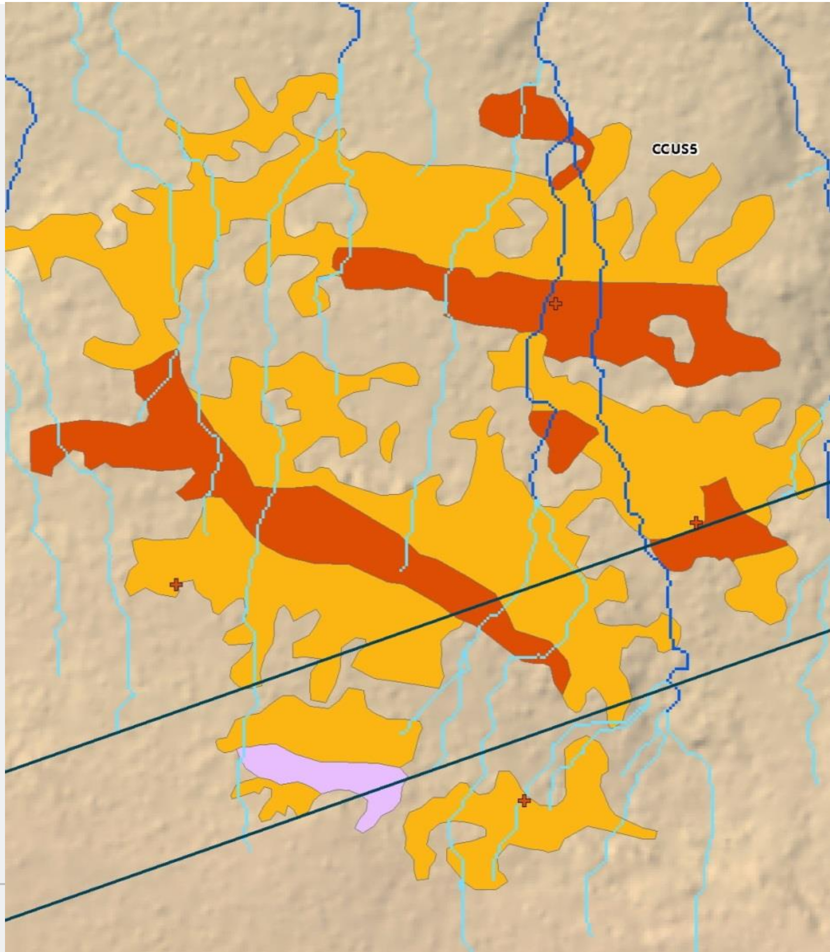
| | |
|---|---|
| Size of swamp | 1.77 ha |
| Area of swamps within 200mm subsidence zone | 1.75 ha |
| Area of swamps within 200mm subsidence zone | 98.48% |
| Size of catchment area (ha) | 16.33 ha |
| Area of catchment within 200mm subsidence zone (ha) | 4.89 ha |
| Area of catchment within 200mm subsidence zone (%) | 29.93 % |
| Supports vegetation communities reliant on perched water table? | Yes |



# Upland Swamp CCUS5

- Located over pillar of LW 7 with small upper section within longwall extent
- Piezometers indicate presence of a perched water table
- Water dependent sections located largely outside 200mm subsidence zone

| | |
|---|---|
| Size of swamp | 3.45 ha |
| Area of swamps within 200mm subsidence zone | 0.51 ha |
| Area of swamps within 200mm subsidence zone | 14.71 % |
| Size of catchment area (ha) | 10.10 ha |
| Area of catchment within 200mm subsidence zone (ha) | 5.27 ha |
| Area of catchment within 200mm subsidence zone (%) | 52.21 % |
| Supports vegetation communities reliant on perched water table? | Yes |

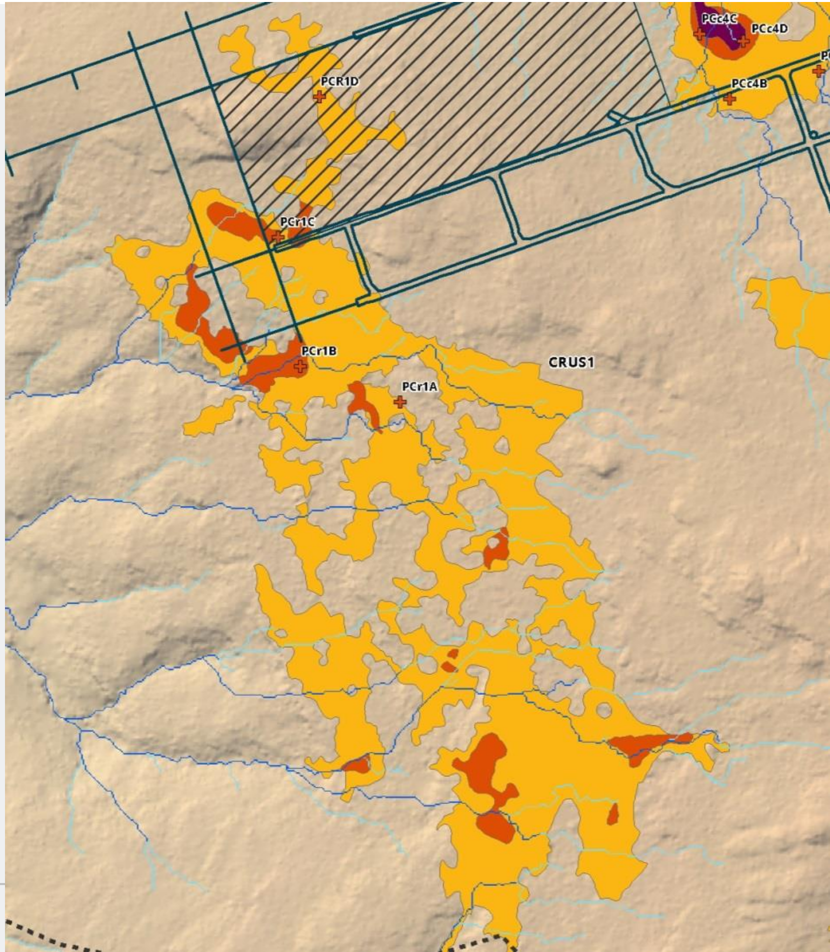


# Upland Swamp CRUS1

> Small upper section mined beneath by LW6 – no observed impacts

> No future mining beneath swamp

| | |
|---|---|
| Size of swamp | 9.84 ha |
| Area of swamps within 200mm subsidence zone | 0.84 ha |
| Area of swamps within 200mm subsidence zone | 8.50 % |
| Size of catchment area (ha) | 29.12 ha |
| Area of catchment within 200mm subsidence zone (ha) | 2.52 ha |
| Area of catchment within 200mm subsidence zone (%) | 8.64 % |
| Supports vegetation communities reliant on perched water table? | Yes |

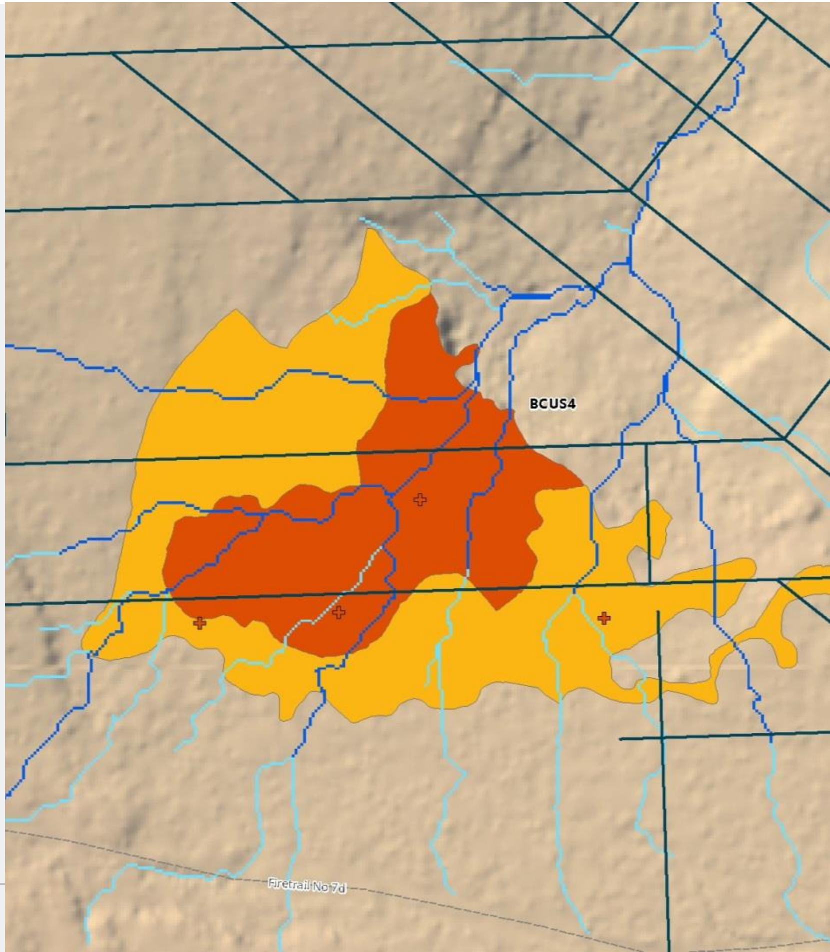


# Upland Swamp BCUS4

- Located over LW 10
- Piezometers indicate presence of a perched water table
- Known to support the Giant Dragonfly
- Impacts from tilt induced changes in flow regimes

| | |
|---|---|
| Size of swamp | 2.23 ha |
| Area of swamps within 200mm subsidence zone | 1.14 ha |
| Area of swamps within 200mm subsidence zone | 51.38 % |
| Size of catchment area (ha) | 15.01 ha |
| Area of catchment within 200mm subsidence zone (ha) | 12.13 ha |
| Area of catchment within 200mm subsidence zone (%) | 80.81 % |
| Supports vegetation communities reliant on perched water table? | Yes |

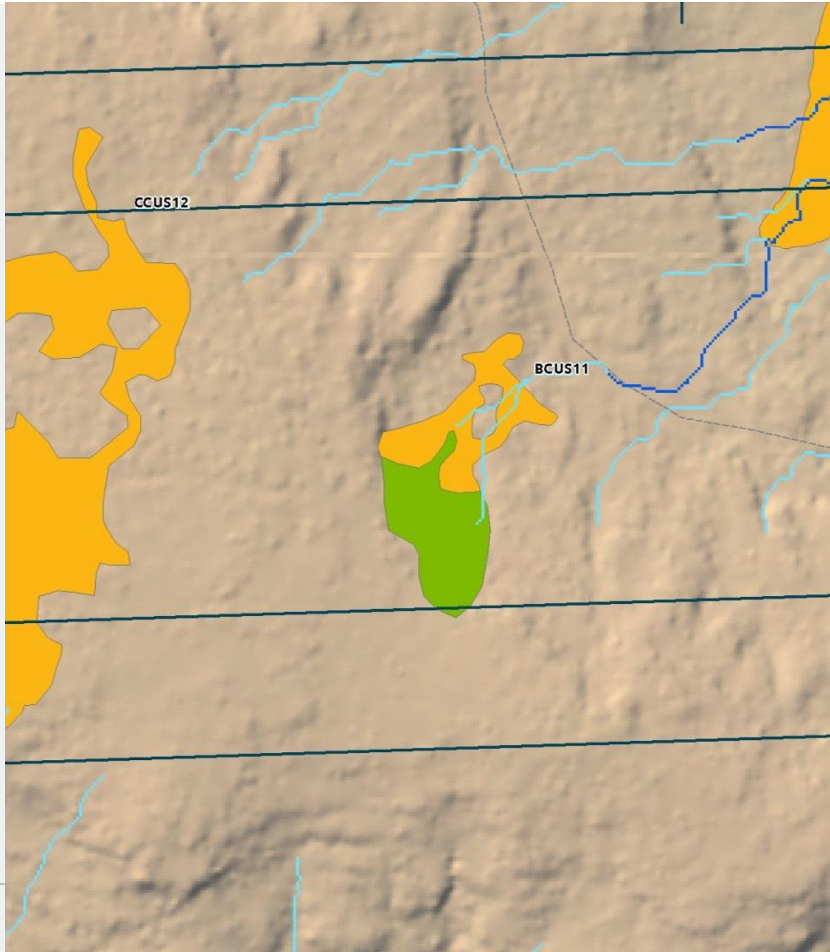


# Upland Swamp BCUS11

- > Located over LW 10
- > No piezometers installed
- > Soils dry.  Unlikely to support perched water table due to small catchment area

| | |
|---|---|
| Size of swamp | 0.26 ha |
| Area of swamps within 200mm subsidence zone | 1.14 ha |
| Area of swamps within 200mm subsidence zone | 100 % |
| Size of catchment area (ha) | 1.14 ha |
| Area of catchment within 200mm subsidence zone (ha) | 1.14 ha |
| Area of catchment within 200mm subsidence zone (%) | 100 % |
| Supports vegetation communities reliant on perched water table? | No |

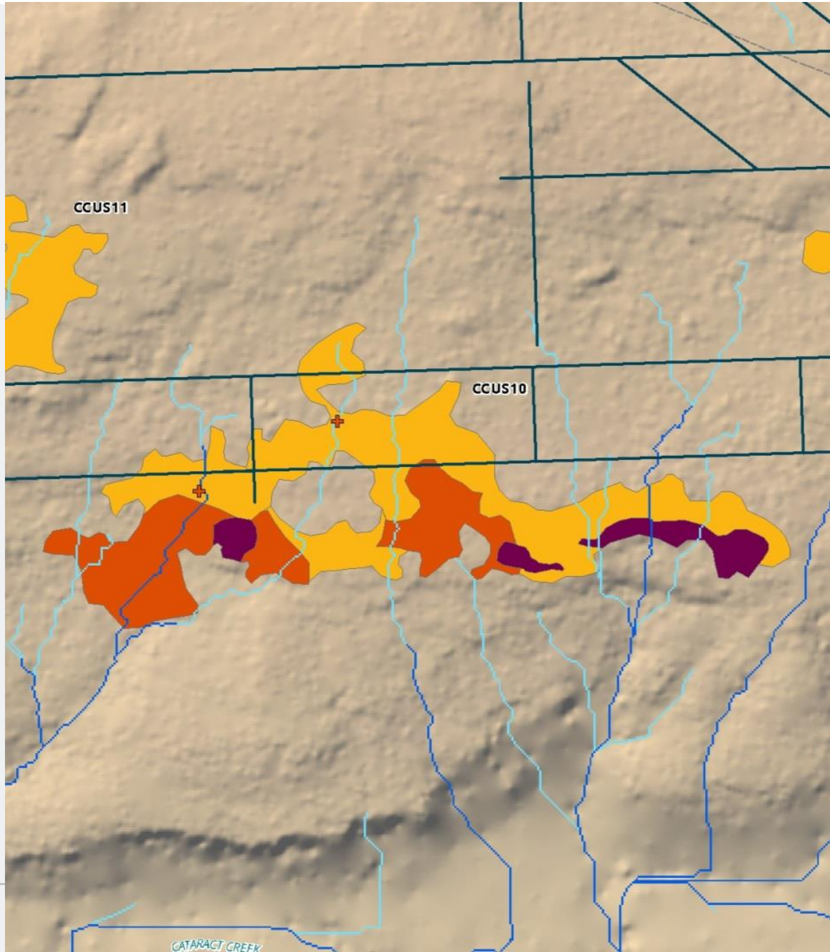


# Upland Swamp CCUS10

- Located over pillar of LW9 with small section located over the longwall
- Piezometers indicate upper section dry but lower section supports perched water table

| | |
|---|---|
| Size of swamp | 1.63 ha |
| Area of swamps within 200mm subsidence zone | 0.16 ha |
| Area of swamps within 200mm subsidence zone | 9.99 % |
| Size of catchment area (ha) | 7.96 ha |
| Area of catchment within 200mm subsidence zone (ha) | 3.64 ha |
| Area of catchment within 200mm subsidence zone (%) | 45.80 % |
| Supports vegetation communities reliant on perched water table? | Yes |

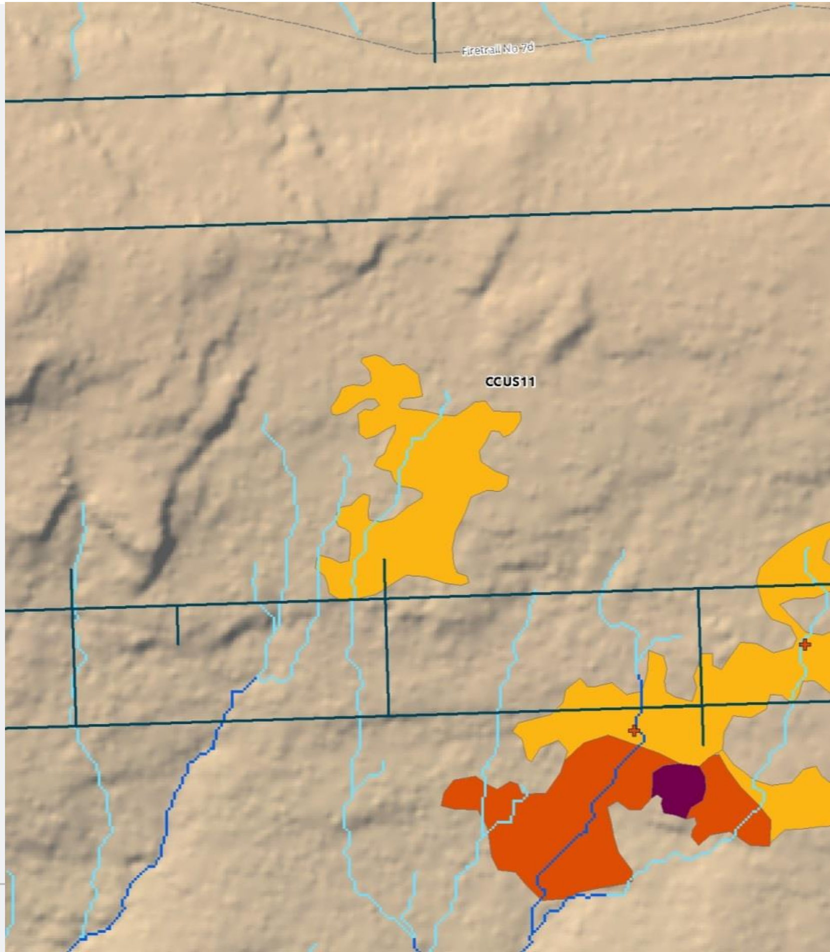


# Upland Swamp CCUS11

- Located over LW9
- No piezometers installed
- Soils dry. Unlikely to support perched water table due to small catchment area

| | |
|---|---|
| Size of swamp | 0.34 ha |
| Area of swamps within 200mm subsidence zone | 0.34 ha |
| Area of swamps within 200mm subsidence zone | 100 % |
| Size of catchment area (ha) | 1.18 ha |
| Area of catchment within 200mm subsidence zone (ha) | 1.18 ha |
| Area of catchment within 200mm subsidence zone (%) | 100 % |
| Supports vegetation communities reliant on perched water table? | No |



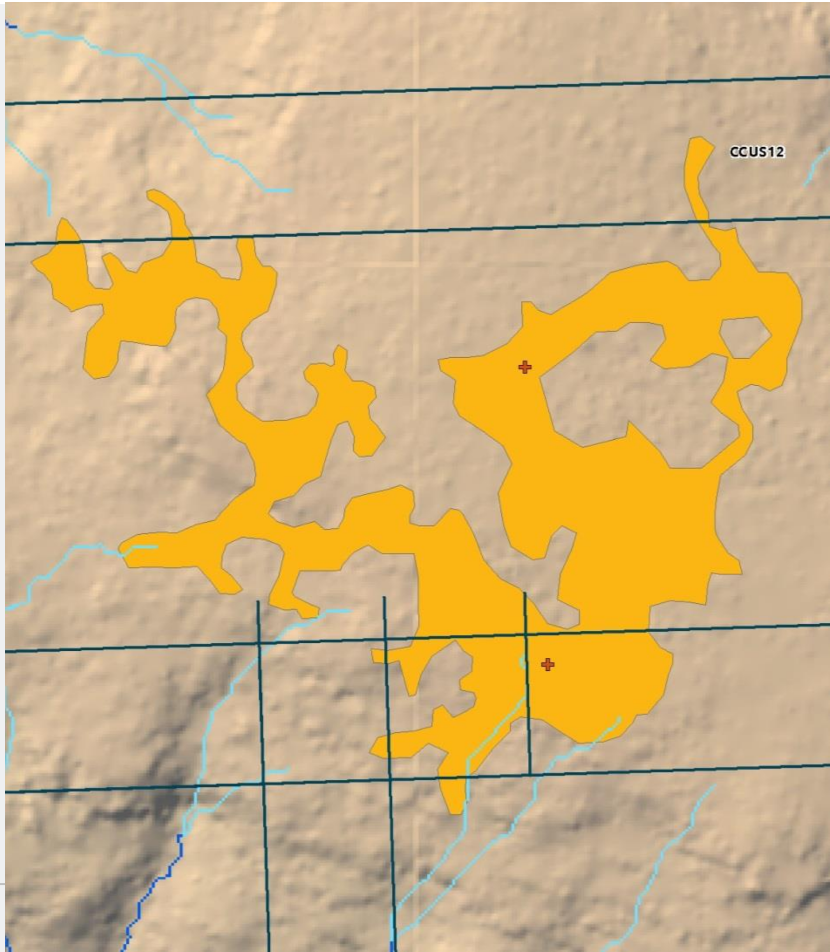

 

biosis

# Upland Swamp CCUS12

- Located over LW 10
- Piezometers indicate upper section dry but lower section supports perched water table occasionally inundated

| | |
|---|---|
| Size of swamp | 1.84 ha |
| Area of swamps within 200mm subsidence zone | 1.84 ha |
| Area of swamps within 200mm subsidence zone | 100 % |
| Size of catchment area (ha) | 3.49 ha |
| Area of catchment within 200mm subsidence zone (ha) | 3.49 ha |
| Area of catchment within 200mm subsidence zone (%) | 100 % |
| Supports vegetation communities reliant on perched water table? | No |

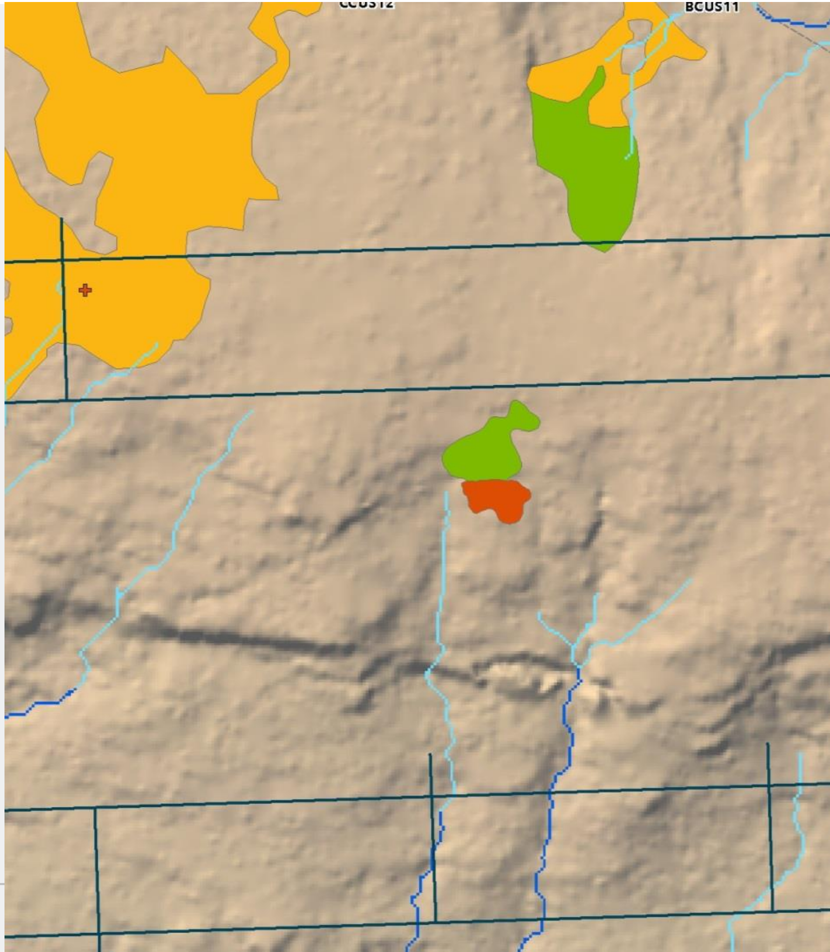


# Upland Swamp CCUS24

- Located over LW 9
- No piezometers installed
- Soils dry.  Unlikely to support perched water table due to extremely small catchment area

| | |
|---|---|
| Size of swamp | 0.08 ha |
| Area of swamps within 200mm subsidence zone | 0.08 ha |
| Area of swamps within 200mm subsidence zone | 100 % |
| Size of catchment area (ha) | 0.54 ha |
| Area of catchment within 200mm subsidence zone (ha) | 0.54 ha |
| Area of catchment within 200mm subsidence zone (%) | 100 % |
| Supports vegetation communities reliant on perched water table? | Yes |

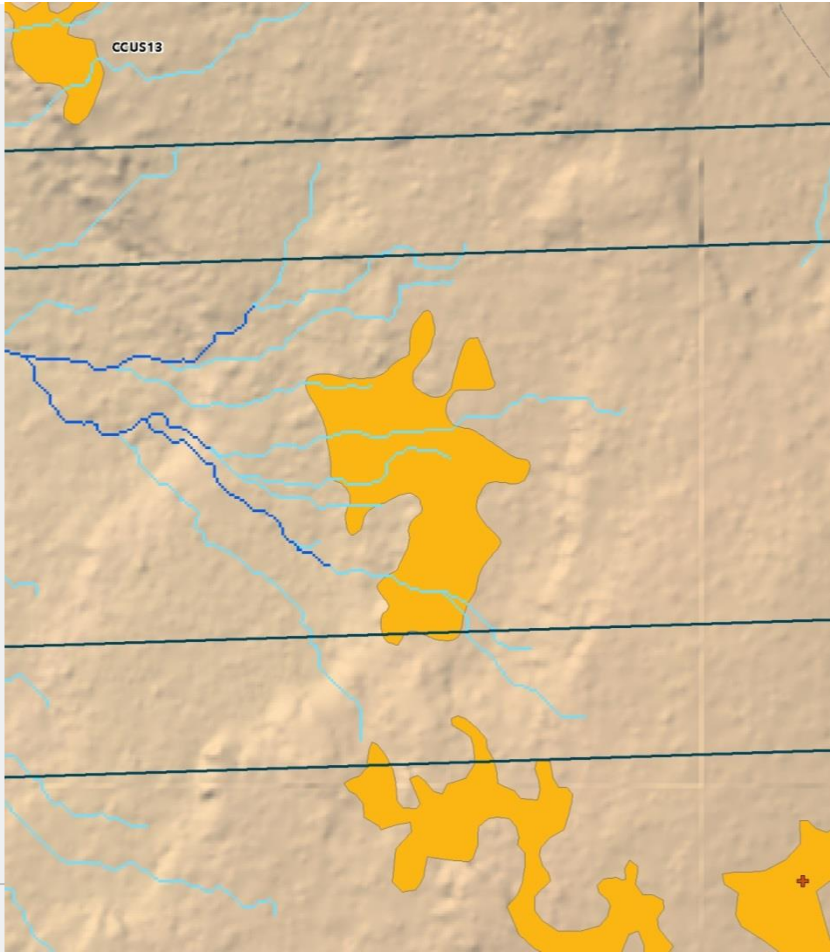


# Upland Swamp CRUS6

- Located over LW 11
- No piezometers installed
- Soils dry.  Unlikely to support perched water table due to small catchment area

| | |
|---|---|
| Size of swamp | 0.49 ha |
| Area of swamps within 200mm subsidence zone | 0.49 ha |
| Area of swamps within 200mm subsidence zone | 100 % |
| Size of catchment area (ha) | 2.99 ha |
| Area of catchment within 200mm subsidence zone (ha) | 2.99 ha |
| Area of catchment within 200mm subsidence zone (%) | 100 % |
| Supports vegetation communities reliant on perched water table? | No |



# Appendix 3 – Subsidence predictions for CCUS24 and CRUS6 (SCT Operations)

SCT Operations Pty Ltd
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www.sct.gs

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9 September 2015

David Clarkson
Group Environment Manager
Wollongong Coal
PO Box 924
Dapto NSW 2530

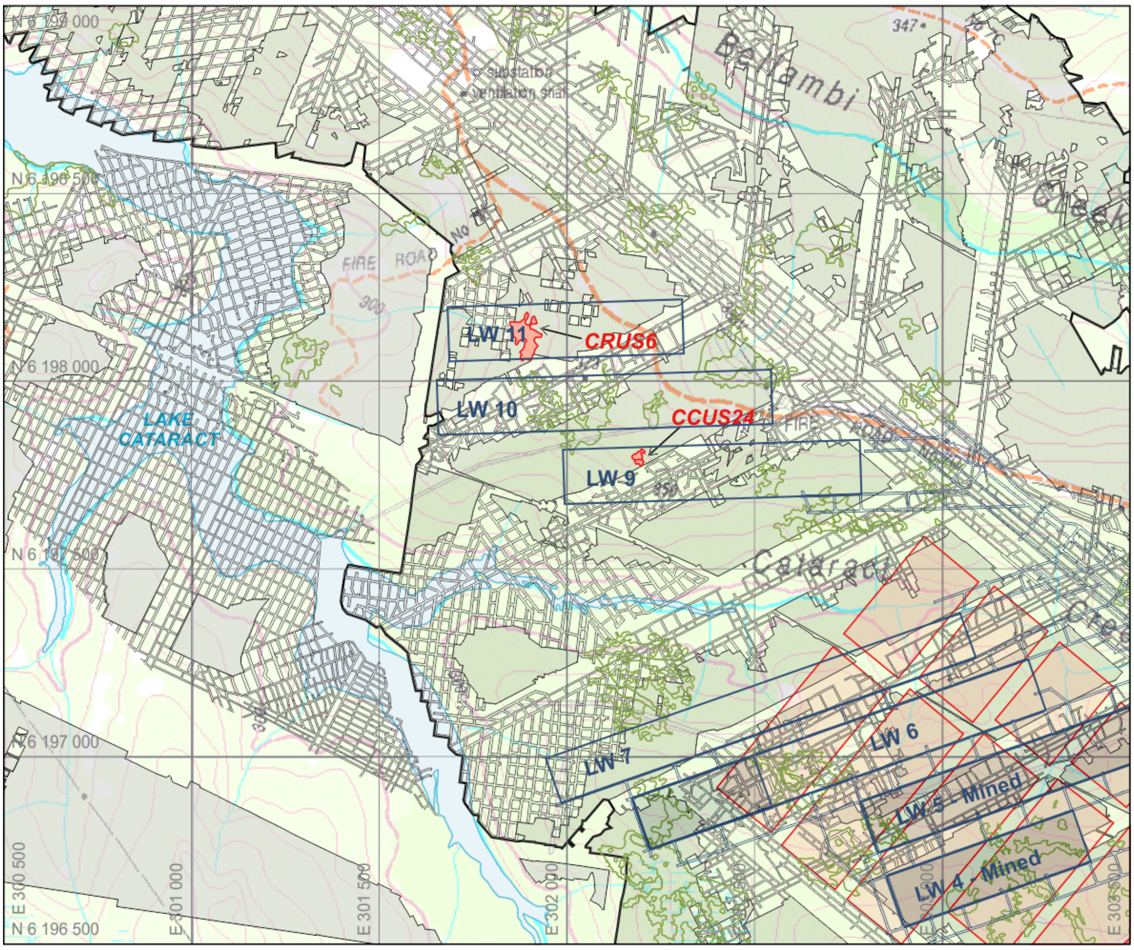
Dear Dave

**SUBSIDENCE PREDICTIONS FOR SWAMPS CCUS24 AND CRUS6**

As a result of improvements in technology since the original assessment, Biosis Pty Ltd has identified two upland swamps in the Russell Vale East area above Longwalls 9 and 11 additional to those identified in the original assessment for the Underground Expansion Project – Preferred Project Report. Subsidence predictions were not made for these two swamps during the subsidence assessment for this area because they were not known to exist. This letter report presents the subsidence predictions for these two additional swamps.

Figure 1 shows the locations of the two swamps relative to previous mining in the Bulli Seam and proposed mining of Longwalls 9 and 11.

Table 1 summarises the subsidence movements predicted at the location of each of these swamps. The relatively larger overburden depth at the site of these two upland swamps compared to the width of previous mining in the Bulli Seam means that previous mining is considered unlikely to have much of an impact on either upland swamp. At the completion of proposed mining in the Wongawilli Seam, there is potential for the overburden strata to be softened similar to that observed above Longwalls 4 and 5 leading to increased subsidence. A conservative approach has been taken to estimate the maximum subsidence and the associated strains and tilts, but even with a less conservative approach, it is considered likely that some perceptible cracking of the rock strata that forms the base of the swamp should be expected.




| | | | |
|---|---|---|---|
| Bulli Seam Previous Extraction Inc. Corrimal and old Bulli Colliery | Balgownie Seam Previous Extraction | Wongawill Seam Existing and Proposed Workings | Swamp Boundaries |

**Figure 1: Site Plan.**

**Table 1: Estimated Subsidence at the Completion of Mining in the Bulli Seam and at the Completion of Proposed Mining in the Wongawilli Seam**

| 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 Panel Width to Overburden Depth | Max Tensile Strain (mm/m) | Max Comp Strain (mm/m) | Max Tilt (mm/m) |
|---|---|---|---|---|---|---|---|---|
| **At Completion of Mining in Bulli Seam** | | | | | | | | |
| **CCUS24** | 0.3 | 0.3 | 340 | 190 | 0.5 | 1.3 | 2.6 | 4.3 |
| **CRUS6** | 0.1 | 0.1 | 345 | 100 | 0.3 | 0.4 | 0.9 | 1.5 |
| **At Completion of Mining in Wongawilli Seam** | | | | | | | | |
| **CCUS24** | 1.0 | 1.0 | 370 | 150 | 0.40 | 4 | 8 | 14 |
| **CRUS6** | 2.0 | 2.0 | 375 | 150 | 0.40 | 8 | 16 | 27 |

If you have any queries or require further clarification of any of these issues, please don't hesitate to contact me directly.

Regards

Ken Mills
Principal Geotechnical Engineer

# *APPENDIX B*

## *Integrated Risk Assessment*

## *Participants and IRAP Correspondence*

**Table A**
**Integrated Risk Assessment Contributors**

| Ref | Name | Title | Organisation |
|---|---|---|---|
| **IRAP** | | | |
| 1. | Professor Ismet Canbulat | IRAP Chair<br>Kenneth Finlay Chair of Rock Mechanics | UNSW Mining Engineering |
| 2. | Andrea Madden | Principal Hydrogeologist | WSP Parsons Brinkerhoff |
| 3. | Steve Perrens | Principal | Advisian |
| 4. | David Robertson | Director | Cumberland Ecology |
| 5. | Arthur A Waddington | Director | Mine Subsidence Engineering Consultants (MSEC) |
| **REGULATORS** | | | |
| 6. | David Kitto<br>Howard Reed<br>Sara Wilson | | DP&E |
| 7. | Bill Ziegler<br>Heather Middleton | | Dams Safety Committee (DSC) |
| 8. | Greg Kininmonth<br>Chris Hammersley | | Trade & Investment – Division of Resources and Energy (DRE) |
| 9. | Malcolm Hughes<br>Fiona Smith<br>Peter Dupen<br>Ross Wallace<br>Ravi Sundaram | | WaterNSW (formerly Sydney Catchment Authority) |
| 10. | James Dawson<br>Lachlan Wilmott<br>Martin Krogh<br>Gabrielle Pietrini | | Office of Environment & Heritage (OEH) |
| **WCL & SPECIALISTS** | | | |
| 11. | Rhys Brett | Business Development Manager | WCL |
| 12. | Dave Clarkson | Group Environment Manager | WCL |
| 13. | Dale Cooper | Director | Broadleaf Capital International |
| 14. | Dr Ken Mills | Principal Geotechnical Engineer | SCT Operations |
| 15. | Nathan Garvey | Senior Consultant Ecologist | Biosis |
| 16. | Andrew Dawkins | Principal Hydrogeologist | GeoTerra |
| 17. | Dianne Munro | Principal Environmental Scientist | Hansen Bailey |
| 18. | Andrew Wu | Environmental Engineer | Hansen Bailey |

To: Rhys Brett
Business Development Manager
Wollongong Coal
Email: rbrett@wcl.net.au
P: 02 4223 849
CC: Dianne Munro and David Clarkson

From: Independent Risk Assessment Panel

Date: 28 September 2015

REVIEW OF THE RISK ASSESSMENT CONDUCTED FOR THE RUSSELL VALE COLLIERY UNDERGROUND EXPANSION PROJECT

Dear Rhys,

The Independent Risk Assessment Panel (IRAP), which comprises Ismet Canbulat, Arthur Waddington, Andrea Madden, Steve Perrens and David Robertson, has conducted a review of the integrated risk assessment conducted by Wollongong Coal Limited (WCL) for the proposed Russell Vale Colliery Underground Expansion Project (UEP).

In line with the Terms of Reference provided by WCL, IRAP's review included the risks to Cataract Reservoir, groundwater, surface water and Upland Swamps during the extraction of Longwalls 1, 2, 3, 6, 7, 9, 10 and 11. As part of the review, the technical studies conducted by WCL provided the background information for the expected subsidence and associated potential impacts related to the extraction of the above mentioned longwall panels in the Russell Vale East area.

The review by IRAP consisted of two stages. In the first stage the risk assessment methodology that was developed by DF Cooper of Broadleaf and WCL was reviewed. IRAP provided comprehensive comments on the risk assessment methodology in a report, entitled "Russell Vale Colliery, Independent Risk Assessment Panel, Review of the Proposed Risk Assessment Methodology", dated 15 July 2015. WCL adapted the methodology in line with IRAP's recommendations and the adapted risk assessment methodology was approved by IRAP in a letter entitled "Review of the Risk Assessment Methodology Proposed for the Russell Vale Colliery Underground Expansion Project, dated 31 July 2015.

In the second stage, the risk assessment that was conducted by WCL was reviewed. The risk assessment was facilitated by DF Cooper of Broadleaf and the results were conveyed in a draft report entitled "Final report: Integrated risk assessment for the UEP Wollongong Coal, Russell Vale Underground Expansion Project", dated 14 August 2015. A risk register was also provided by Broadleaf in a separate report, entitled "Risk register: Integrated risk assessment for the UEP, Wollongong Coal, Russell Vale Underground Expansion Project", dated 14 August 2015 (Version 1). Detailed comments on the risk assessment and the associated documentation was provided by IRAP to WCL in a report, entitled "Russell Vale Colliery UEP IRAP Review of the Integrated Risk Assessment", dated 10 September 2015. IRAP comments have been addressed in the final risk assessment and the associated documents.

It is the IRAP's opinion that the risk assessment has been conducted by appropriately qualified experts in the fields of mine subsidence engineering, groundwater, surface water and ecology. It is understood that the WCL experts worked on the project together for a considerable period of time, which provided them the experience and the knowledge required to conduct the "integrated" risk assessment, which aims to ensure that the risks associated with underground mining on the quantity and quality of groundwater and surface water as well as upland swamps have been assessed and appropriate controls are identified.

Following an extensive review of the risk assessment and the relevant documentation, it is the opinion of IRAP that the risk assessment is 'integrated' and has been based upon an approach that is sufficiently detailed and at an appropriate level to evaluate the risks to the swamps, streams, groundwater and the waters of Cataract Reservoir.

Yours Sincerely

Ismet Canbulat
On Behalf of the Independent Risk Assessment Panel