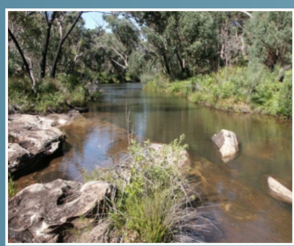
METROPOLITAN COAL LONGWALLS 311-316

WATER MANAGEMENT PLAN






Peabody

METROPOLITAN COAL

LONGWALLS 311-316

WATER MANAGEMENT PLAN

Revision Status Register

Section/Page/ Annexure	Revision Number	Amendment/Addition	Distribution	DPHI Approval Date
All	WMP-R01-A	Original	DPHI, NSW DCCEEW-Water, BCS, WaterNSW and DSNSW	-
All	WMP-R01-B	Updated to reflect amendments to the Longwalls 311-316 longwall layout and to address agency comments	DPHI, NSW DCCEEW-Water, BCS, WaterNSW and DSNSW	-
All	WMP-R01-C	Updated to reflect Longwall 311 Approval	DPHI	-

November 2024

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

TABLE OF CONTENTS (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

TABLE OF CONTENTS (Continued)

LIST OF FIGURES (Continued)

LIST OF APPENDICES

1 INTRODUCTION

The Metropolitan Colliery (Metropolitan Coal Mine) is owned and operated by Metropolitan Collieries Pty Ltd (Metropolitan Coal), which is a wholly owned subsidiary of Peabody Energy Australia Pty Ltd (Peabody). The Metropolitan Coal Mine is located adjacent to the township of Helensburgh (Figure 1), approximately 30 kilometres (km) north of Wollongong in New South Wales (NSW).

Metropolitan Coal was granted approval for the Metropolitan Coal Project (the Project) under section 75J of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) on 22 June 2009. A copy of the Project Approval is available on the Peabody website (http://www.peabodyenergy.com).

The Project comprises the continuation, upgrade and extension of underground coal mining operations (Longwalls 20-27 and Longwalls 301-317) and surface facilities at the Metropolitan Coal Mine. Longwalls 311-316 are situated to the west of Longwalls 301-310 and define the next mining sub-domain within the Project underground mining area (Figure 2). Longwall 317 will be subject to future Extraction Plans.

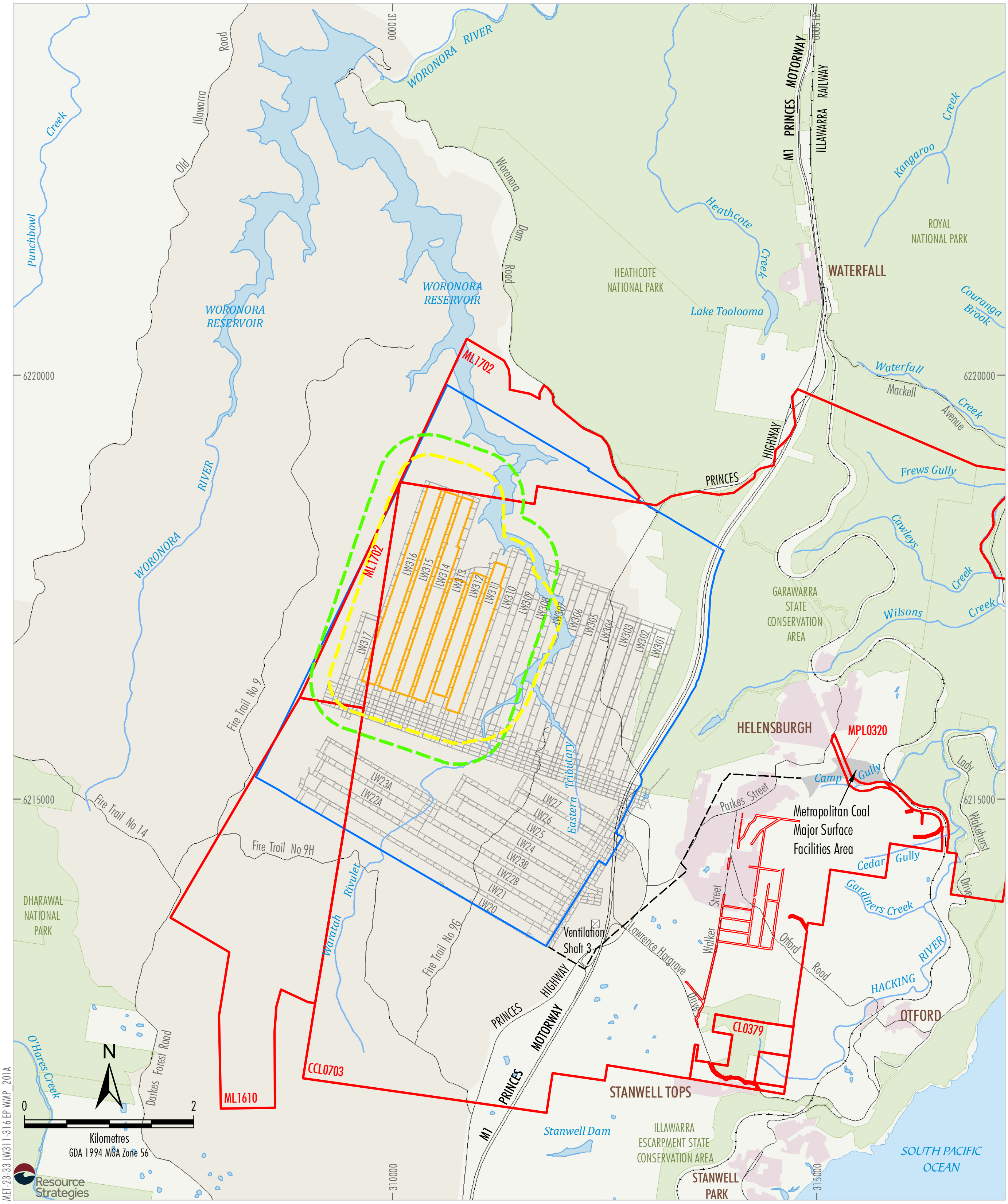
1.1 PURPOSE AND SCOPE

In accordance with Condition 6, Schedule 3 of the Project Approval, this Water Management Plan (WMP) has been prepared as a component of the Metropolitan Coal Longwalls 311-316 Extraction Plan to manage the potential environmental consequences of the Extraction Plan on watercourses (including the Woronora Reservoir), aquifers and catchment yield. The relationship of this WMP to the Metropolitan Coal Environmental Management Structure and to the Metropolitan Coal Longwalls 311-316 Extraction Plan is shown on Figure 3.

This WMP includes post-mining monitoring and management of water resources and watercourses for Longwalls 20-22, 23-27, 301-303, 304, 305-307 and 308-310, subject to the previously approved Metropolitan Coal Longwalls 308-310 WMP. Consistent with the recommended approach in the then NSW Department of Planning and Environment (DPE) (now known as the Department of Planning, Housing and Infrastructure[1] [DPHI]) (2022) *Extraction Plan Guideline*, the Longwalls 308-310 WMP will be superseded by this document following the completion of Longwall 310.

In accordance with Condition 6, Schedule 3 of the Project Approval, this WMP has been prepared by Metropolitan Coal, with assistance from SLR Consulting Australia Pty Ltd (SLR Consulting), ATC Williams Pty Ltd (ATC Williams), Associate Professor Barry Noller (The University of Queensland) and Mine Subsidence Engineering Consultants Pty Ltd (MSEC).

[1] The former Department of Planning and Environment (DPE) was renamed to the Department of Planning, Housing and Infrastructure (DPHI) on 1 January 2024. References to DPE have been retained throughout the remainder of this document.



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 311-316 Secondary Extraction
- Longwalls 311-316 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 311-316 Secondary Extraction
- Existing Underground Access Drive (Main Drift)

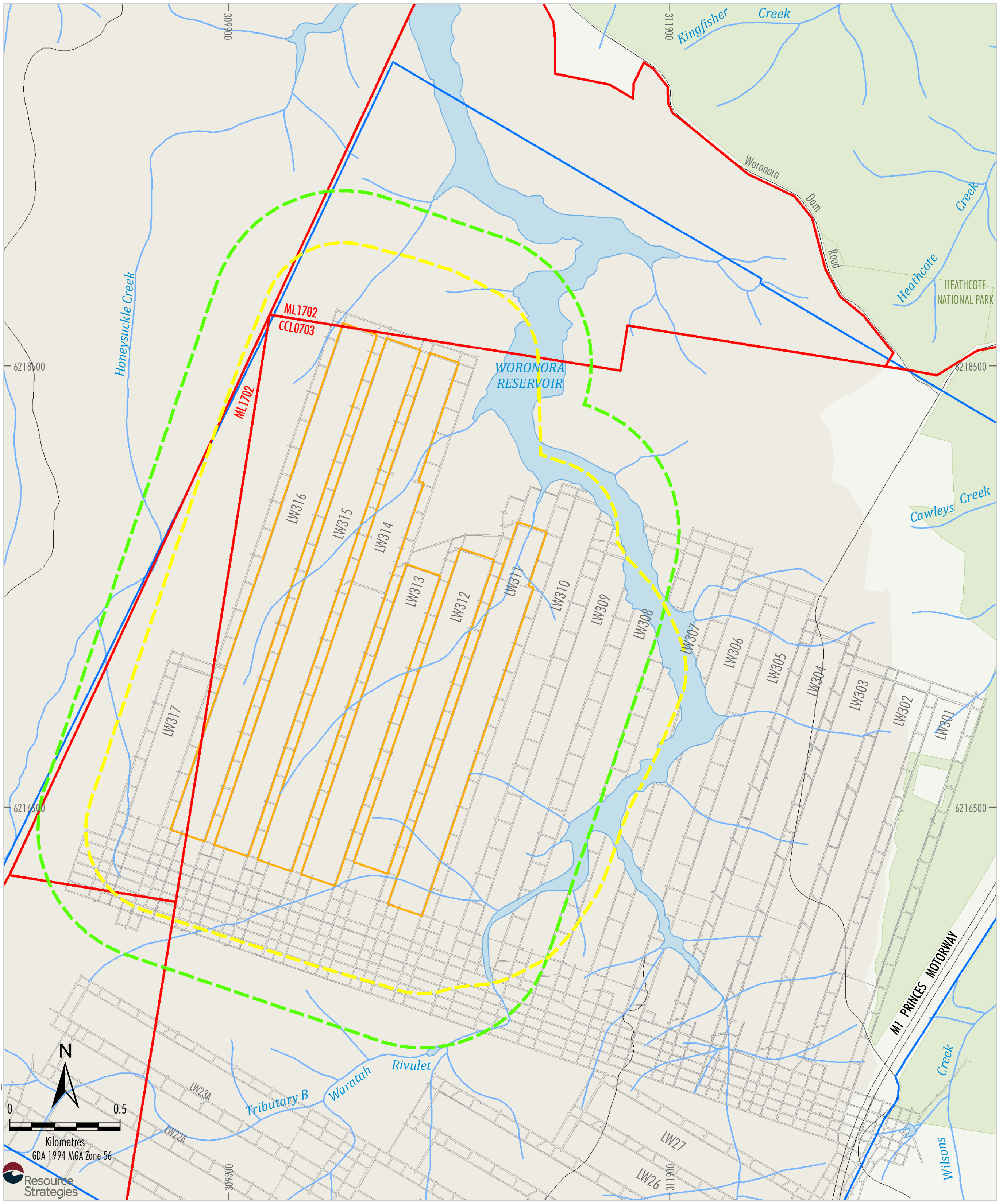
Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2023); MSEC (2024)

Peabody

METROPOLITAN COAL

Longwalls 311-316 and Project Underground Mining Area

Figure 1



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 311-316 Secondary Extraction
- Longwalls 311-316 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 311-316 Secondary Extraction

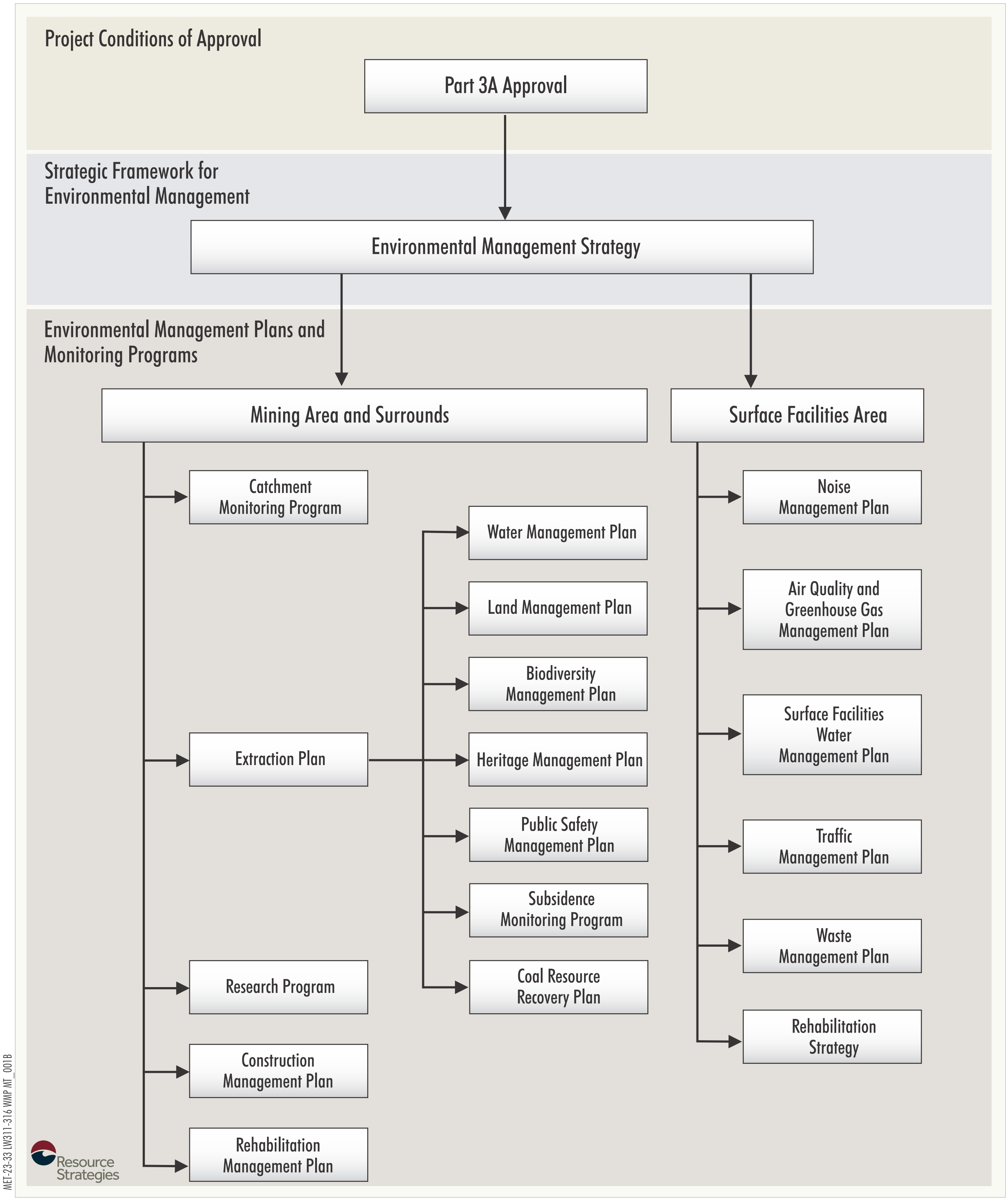
Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2023); MSEC (2024)

Peabody

METROPOLITAN COAL

Longwalls 311-316 Layout

Figure 2



Peabody
METROPOLITAN COAL

Environmental Management Structure

Figure 3

1.2 STRUCTURE OF THE WATER MANAGEMENT PLAN

The remainder of the WMP is structured as follows:

Section 2:	Describes the review and update of the WMP.
Section 3:	Outlines the statutory requirements applicable to the WMP.
Section 4:	Provides a summary of the water management information obtained since Project Approval.
Section 5:	Provides a revised assessment of the potential subsidence impacts and environmental consequences for Longwalls 311-316.
Section 6:	Details the performance measures and indicators that will be used to assess the Project.
Section 7:	Details the available baseline data.
Section 8:	Describes the monitoring programs and provides the detailed Trigger Action Response Plans (TARPs).
Section 9:	Describes the management measures that will be implemented.
Section 10:	Provides a Contingency Plan to manage any unpredicted impacts and their consequences.
Section 11:	Describes the program to collect baseline data for future Extraction Plans.
Section 12:	Describes the annual review and improvement of environmental performance.
Section 13:	Outlines the management and reporting of incidents.
Section 14:	Outlines the management and reporting of complaints.
Section 15:	Outlines the management and reporting of non-compliances with statutory requirements.
Section 16:	Lists the references cited in this WMP.

2 WATER MANAGEMENT PLAN REVIEW AND UPDATE

In accordance with Condition 4, Schedule 7 of the Project Approval, this WMP will be reviewed within three months of the submission of:

- an audit under Condition 8, Schedule 7;
- an incident report under Condition 6, Schedule 7;
- an annual review under Condition 3, Schedule 7; and
- if necessary, revised to the satisfaction of the Director-General (now Secretary) of the DPE, to ensure the WMP is updated on a regular basis and to incorporate any recommended measures to improve environmental performance.

The WMP will also be reviewed within three months of approval of any Project modification and if necessary, revised to the satisfaction of the DPE.

The revision status of this WMP is indicated on the title page of each copy. The distribution register for controlled copies of the WMP is described in Section 2.1.

2.1 DISTRIBUTION REGISTER

In accordance with Condition 10, Schedule 7 of the Project Approval 'Access to Information', Metropolitan Coal will make the WMP publicly available on the Peabody website.

Metropolitan Coal recognises that various regulators have different distribution requirements, both in relation to whom documents should be sent and in what format.

An Environmental Management Plan and Monitoring Program Distribution Register has been established in consultation with the relevant agencies and infrastructure owners that indicates:

- to whom the Metropolitan Coal plans and programs, such as the WMP, will be distributed;
- the format (i.e. electronic or hard copy) of distribution; and
- the format of revision notification.

Metropolitan Coal will make the Distribution Register publicly available on the Peabody website.

Metropolitan Coal will be responsible for maintaining the Distribution Register and for ensuring that the notification of revisions is sent by email or post as appropriate.

In addition, Metropolitan Coal employees with local computer network access will be able to view the controlled electronic version of this WMP on the Metropolitan Coal local area network. Metropolitan Coal will not be responsible for maintaining uncontrolled copies beyond ensuring the most recent version is maintained on Metropolitan Coal's computer system and the Peabody website.

3 STATUTORY REQUIREMENTS

Metropolitan Coal's statutory obligations are contained in:

(i) the conditions of the Project Approval;

(ii) relevant licences and permits, including conditions attached to mining leases; and

(iii) other relevant legislation.

These are described below.

3.1 ENVIRONMENTAL PLANNING & ASSESSMENT ACT APPROVAL

Condition 6(f), Schedule 3 of the Project Approval requires the preparation of a WMP as a component of Extraction Plan(s) for second workings. Condition 6(f), Schedule 3 states:

> ***SECOND WORKINGS***
>
> ***Extraction Plan***
>
> *6. The Proponent shall prepare and implement an Extraction Plan for all second workings in the mining area to the satisfaction of the Director-General. This plan must:*
>
> *…*
>
> *(f) include a:*
>
> *…*
>
> - *Water Management Plan, which has been prepared in consultation with OEH[2], SCA[3] and NOW[4], to manage the environmental consequences of the Extraction Plan on watercourses (including the Woronora Reservoir), aquifers and catchment yield;*

In addition, Condition 2, Schedule 7 and Condition 7, Schedule 3 of the Project Approval outline management plan requirements that are applicable to the preparation of the WMP. Table 1 indicates where each component of the conditions is addressed within this WMP.

[2] The Office of Environment and Heritage (OEH) is now the Department of Planning and Environment – Biodiversity, Conservation and Science Directorate (BCS).

[3] The Sydney Catchment Authority (SCA) is now WaterNSW.

[4] The NSW Office of Water (NOW) is now the Department of Planning and Environment – Water (DPE – Water).

Table 1
Management Plan Requirements

Project Approval Condition	WMP Section
Condition 2, Schedule 7	
2. The Proponent shall ensure that the management plans required under this approval are prepared in accordance with any relevant guidelines, and include:	
a) detailed baseline data;	Section 7
b) a description of:	
• the relevant statutory requirements (including any relevant approval, licence or lease conditions);	Section 3
• any relevant limits or performance measures/criteria;	Section 6
• the specific performance indicators that are proposed to be used to judge the performance of, or guide the implementation of, the project or any management measures;	Section 6
c) a description of the measures that would be implemented to comply with the relevant statutory requirements, limits, or performance measures/criteria;	Sections 3, 6, 8, 9 and 10
d) a program to monitor and report on the:	Sections 8, 9 and 12
• impacts and environmental performance of the project;	
• effectiveness of any management measures (see c above);	
e) a contingency plan to manage any unpredicted impacts and their consequences;	Section 10
f) a program to investigate and implement ways to improve the environmental performance of the project over time;	Sections 8 and 12
g) a protocol for managing and reporting any;	
• incidents;	Section 13
• complaints;	Section 14
• non-compliances with statutory requirements; and	Section 15
• exceedances of the impact assessment criteria and/or performance criteria; and	Section 10
h) a protocol for periodic review of the plan.	Sections 2 and 12
Condition 7, Schedule 3	
7. In addition to the standard requirements for management plans (see condition 2 of schedule 7), the Proponent shall ensure that the management plans required under condition 6(f) above include:	
a) a program to collect sufficient baseline data for future Extraction Plans;	Section 11
b) a revised assessment of the potential environmental consequences of the Extraction Plan, incorporating any relevant information that has been obtained since this approval;	Sections 4 and 5
c) a detailed description of the measures that would be implemented to remediate predicted impacts; and	Section 9
d) a contingency plan that expressly provides for adaptive management.	Section 10

3.2 LICENCES, PERMITS AND LEASES

In addition to the Project Approval, all activities at or in association with the Metropolitan Coal Mine will be undertaken in accordance with the following licences, permits and leases which have been issued or are pending issue:

- The conditions of mining leases issued by the NSW Division of Resources and Geoscience (DRG) (now Mining, Exploration and Geoscience [MEG]), under the NSW *Mining Act 1992* (e.g. Consolidated Coal Lease [CCL] 703, Mining Lease [ML] 1610, ML 1702, Coal Lease 379 and Mining Purpose Lease 320).
- The conditions of Environment Protection Licence (EPL) No. 767 issued by the NSW Environment Protection Authority (EPA) under the NSW *Protection of the Environment Operations Act 1997*. Revision of the EPL will be required prior to the commencement of Metropolitan Coal activities that differ from those currently licensed.
- The prescribed conditions of specific surface access leases within CCL 703 for the installation of surface facilities as required.
- Water Access Licences (WALs) issued by the NSW Department of Industry – Water (now DPE – Water) under the NSW *Water Management Act 2000,* including WAL 36475 under the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2023* and WAL 25410 under the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2023.*
- Mining and workplace health and safety related approvals granted by the Resources Regulator and WorkCover NSW.
- Supplementary approvals obtained from WaterNSW for surface activities within the Woronora Special Area (e.g. fire road maintenance activities).

3.3 OTHER LEGISLATION

Metropolitan Coal will conduct the Project consistent with the Project Approval and any other legislation that is applicable to an approved Part 3A Project under the EP&A Act.

The following Acts may be applicable to the conduct of the Project (Helensburgh Coal Pty Ltd [HCPL], 2008)[5]:

- *Biodiversity Conservation Act 2016;*
- *Biosecurity Act 2015;*
- *Contaminated Land Management Act 1997;*
- *Crown Land Management Act 2016;*
- *Dams Safety Act 2015;*
- *Dangerous Goods (Road and Rail Transport) Act 2008;*
- *Energy and Utilities Administration Act 1987;*
- *Fisheries Management Act 1994;*

---

5 The list of potentially applicable Acts has been updated to reflect changes to the Acts that were in force at the time of submission of the Metropolitan Coal Project Environmental Assessment (Project EA) (HCPL, 2008).

- *Mining Act 1992;*
- *National Parks and Wildlife Act 1974;*
- *Protection of the Environment Operations Act 1997;*
- *Rail Safety (Adoption of National Law) Act 2012;*
- *Roads Act 1993;*
- *Water Act 1912;*
- *Water Management Act 2000;*
- *Water NSW Act 2014;*
- *Work Health and Safety Act 2011;* and
- *Work Health and Safety (Mines and Petroleum Sites) Act 2013.*

Relevant licences or approvals required under these Acts will be obtained as required.

4 RELEVANT WATER MANAGEMENT INFORMATION OBTAINED SINCE PROJECT APPROVAL

4.1 SURFACE WATER

Streams occurring within 600 metres (m) of Longwalls 20-22, 23-27, 301-303, 304, 305-307 and/or 308-310 secondary extraction include the Waratah Rivulet and its tributaries (such as Tributary A and B), the Eastern Tributary and its tributaries, and small first and second order streams including those that drain into the Woronora Reservoir (Figure 4).

The Waratah Rivulet and Eastern Tributary are the subject of Project performance measures, as described in Section 6. The locations of pools on the Waratah Rivulet and the Eastern Tributary are shown on Figure 5. The Preferred Project Report (HCPL, 2009) indicated that valley closure values of greater than (>) 200 millimetres (mm) were predicted for a number of pools/rock bars on the Waratah Rivulet, Eastern Tributary and other streams. 'Negligible consequence' for a watercourse was considered by the Project Approval to mean, *'no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases'*, and was assumed to be achieved in circumstances where predicted valley closure was less than (<) 200 mm.

Subsidence impacts to a number of pools on the Eastern Tributary occurred during the mining of Longwalls 26 and 27 at predicted valley closure values of < 200 mm.

The Independent Expert Panel for Mining in the Catchment (IEPMC)[6] Initial Report recommended that the concept of restricting predicted valley closure to a maximum of 200 mm to avoid significant environmental consequences be revised for watercourses (IEPMC, 2018). Metropolitan Coal agreed that the 200 mm valley closure concept required revision in relation to the Eastern Tributary, noting that the unexpected impacts are particular to the Eastern Tributary and not the Waratah Rivulet. Restricting predicted valley closure to 200 mm has been a successful design tool for mining in the vicinity of the Waratah Rivulet.

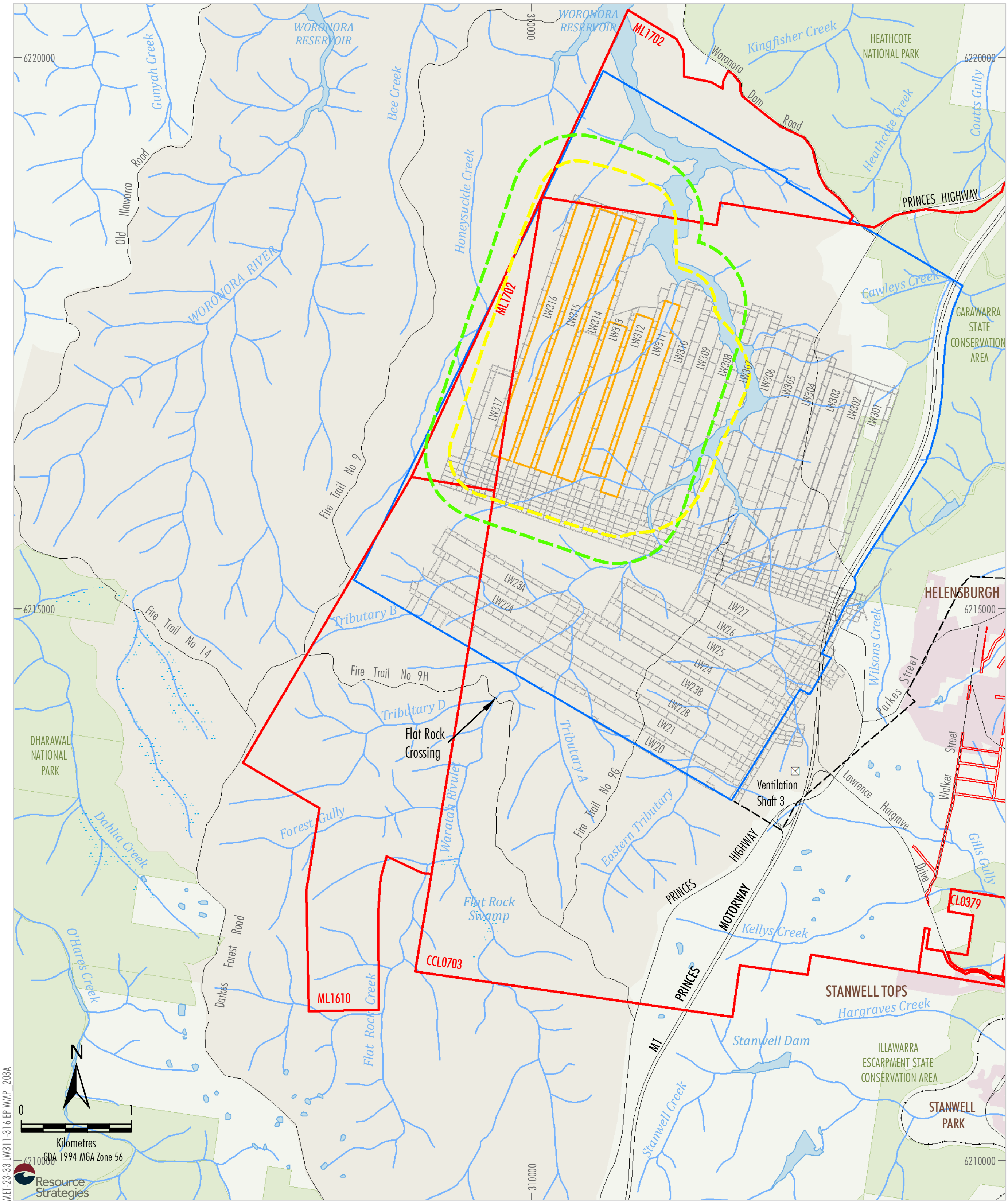
The negligible environmental consequences performance measure for watercourses, as described above, applied specifically for the Waratah Rivulet along the portion of the '*Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P)'*. This section of the Waratah Rivulet includes Pool T to Rock Bar W, located to the south-east of Longwalls 311-316.

The restriction of predicted valley closure to 200 mm has been a successful design tool on the Waratah Rivulet, with no impacts to pools and rock bars along the Waratah Rivulet at predicted total valley closure of < 200 mm. Pool P to Rock Bar W have not exceeded the negligible environmental consequence performance measure for the Waratah Rivulet. Predicted total valley closure for Pool P to Rock Bar W was < 200 mm for the extraction of Longwalls 20-27, 301-303, 304, 305-307 and did not increase for Longwalls 308-310.

Pool A to Pool O (a total of 16 pools) are located upstream of Pool P, and are therefore not subject to the Waratah Rivulet negligible environmental impact performance measure. It is noted that the majority of these pools were predicted to experience maximum predicted total closure of > 200 mm. However, of these pools, only two (Pools G1 and N) have experienced subsidence impacts that would have resulted in an exceedance of the negligible environmental impact performance measure. Impacts that have occurred at these pools have been the result of mining directly beneath the Waratah Rivulet or in close proximity (< 100 m) to the rock bars, at predicted total valley closure > 200 mm.

---

6 The IEPMC was established in November 2017 by the NSW Government to provide expert advice to the DPE on the impact of mining activities in the Greater Sydney Water Catchment Special Areas, with a particular focus on risks to the quantity of water in the catchment.



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 311-316 Secondary Extraction
- Longwalls 311-316 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 311-316 Secondary Extraction
- Existing Underground Access Drive (Main Drift)

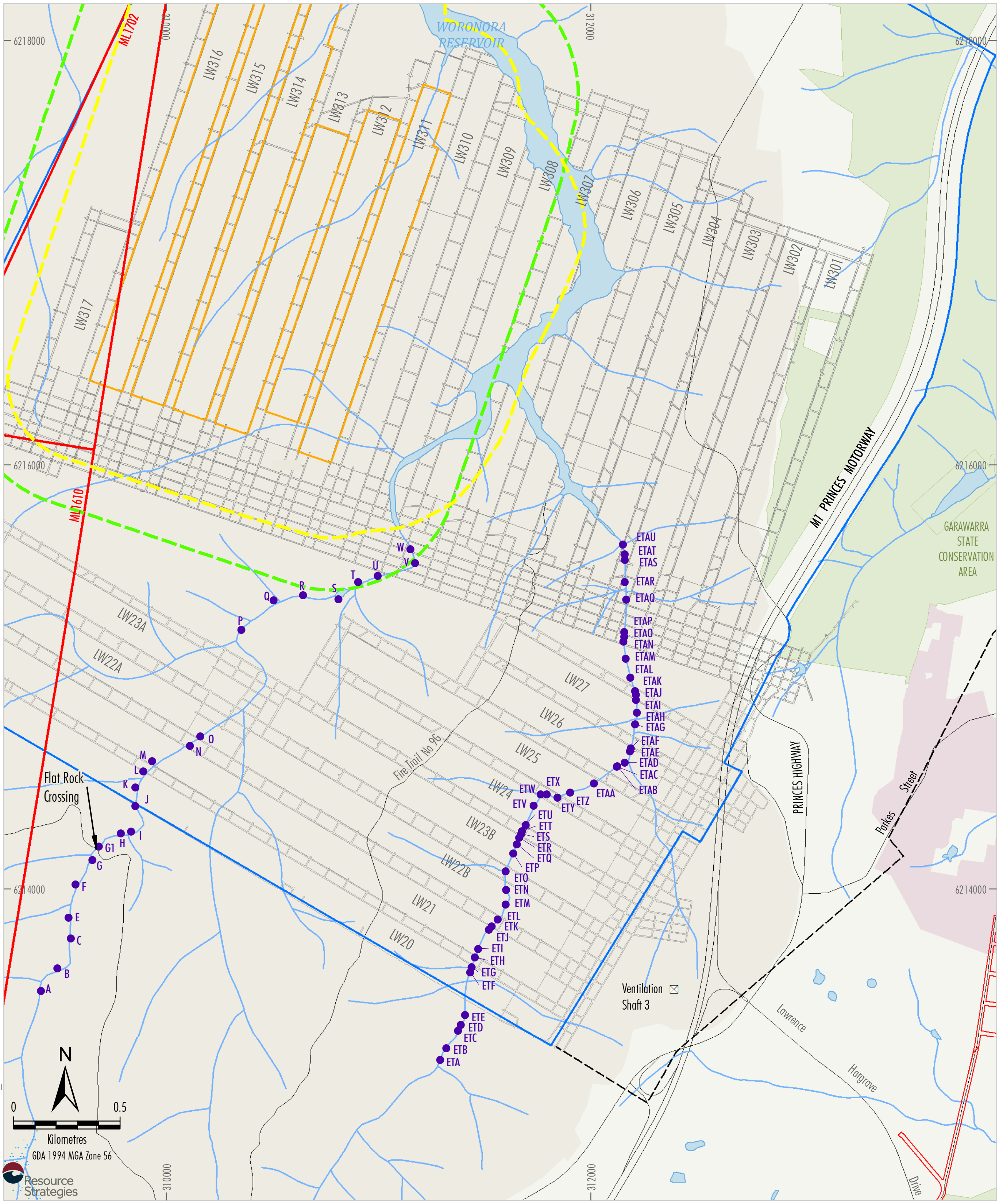
Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2023); MSEC (2024)

Peabody

METROPOLITAN COAL

Streams within the Project Underground Mining Area and Surrounds

Figure 4



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 311-316 Secondary Extraction
- Longwalls 311-316 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 311-316 Secondary Extraction
- Existing Underground Access Drive (Main Drift)
- Pool

Note: The streams are based on mapping by the Lands Department (2006). More detailed and accurate mapping of the streams is provided in Water Management Plan Appendices 1 to 4.

Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2023); MSEC (2024)

Peabody

METROPOLITAN COAL

Waratah Rivulet and Eastern Tributary Pools

Figure 5

Although subsidence impacts were observed at a number of pools on the Eastern Tributary at predicted total valley closure values of < 200 mm during the mining of Longwalls 26 and 27, restricting predicted total valley closure to 200 mm is no longer applied for the Eastern Tributary.

A geotechnical study of the Waratah Rivulet investigated the geological characteristics of the stream bed, with the aim of identifying any characteristics that would make the Waratah Rivulet more susceptible to subsidence movements (similar to the Eastern Tributary). The study focussed on Pool P to Rock Bar W on the Waratah Rivulet, and compared these sites to Pool ETAM on the Eastern Tributary, which has experienced subsidence movements due to historical mining.

The geotechnical study identified a thick unit (approximately 25 m) of thinly bedded sandstone along the Eastern Tributary at the location of Pool ETAM. The thinly bedded sandstone is considered to be of lower strength, and more weathered than adjoining thickly bedded sandstone units and therefore more prone to impact from valley closure movements. In addition, a higher frequency of seam level faults and surface lineaments have been identified in the vicinity of the Eastern Tributary. The thinly bedded units identified along the Waratah Rivulet were limited to less than 5 m thickness and the frequency of seam level faults and surface lineaments was considerably less.

Based on the results of the assessment, the geological features identified along the Eastern Tributary are considered to be unique, compared to the Waratah Rivulet. The Eastern Tributary is therefore more likely to be susceptible to subsidence movements. Restricting valley closure to 200 mm therefore continues to be an appropriate design tool for the Waratah Rivulet. Further discussion on the subsidence predictions and 200 mm valley closure design tool for Longwalls 311-316 is provided in Section 5.

Metropolitan Coal developed a monitoring and adaptive management approach to the mining of Longwall 303 towards the Eastern Tributary. As Longwall 303 mined towards the Eastern Tributary, Metropolitan Coal used a TARP designed to monitor valley closure movements on the Eastern Tributary. The Eastern Tributary Valley Closure TARP has been successfully implemented by Metropolitan Coal for Longwalls 303, 304, and 305. The Waratah Rivulet is monitored by the same Global Navigation Satellite System (GNSS) valley closure monitoring methods used for the Eastern Tributary with consideration of the 200 mm valley closure design tool (as described in the Longwalls 308-310 Extraction Plan).

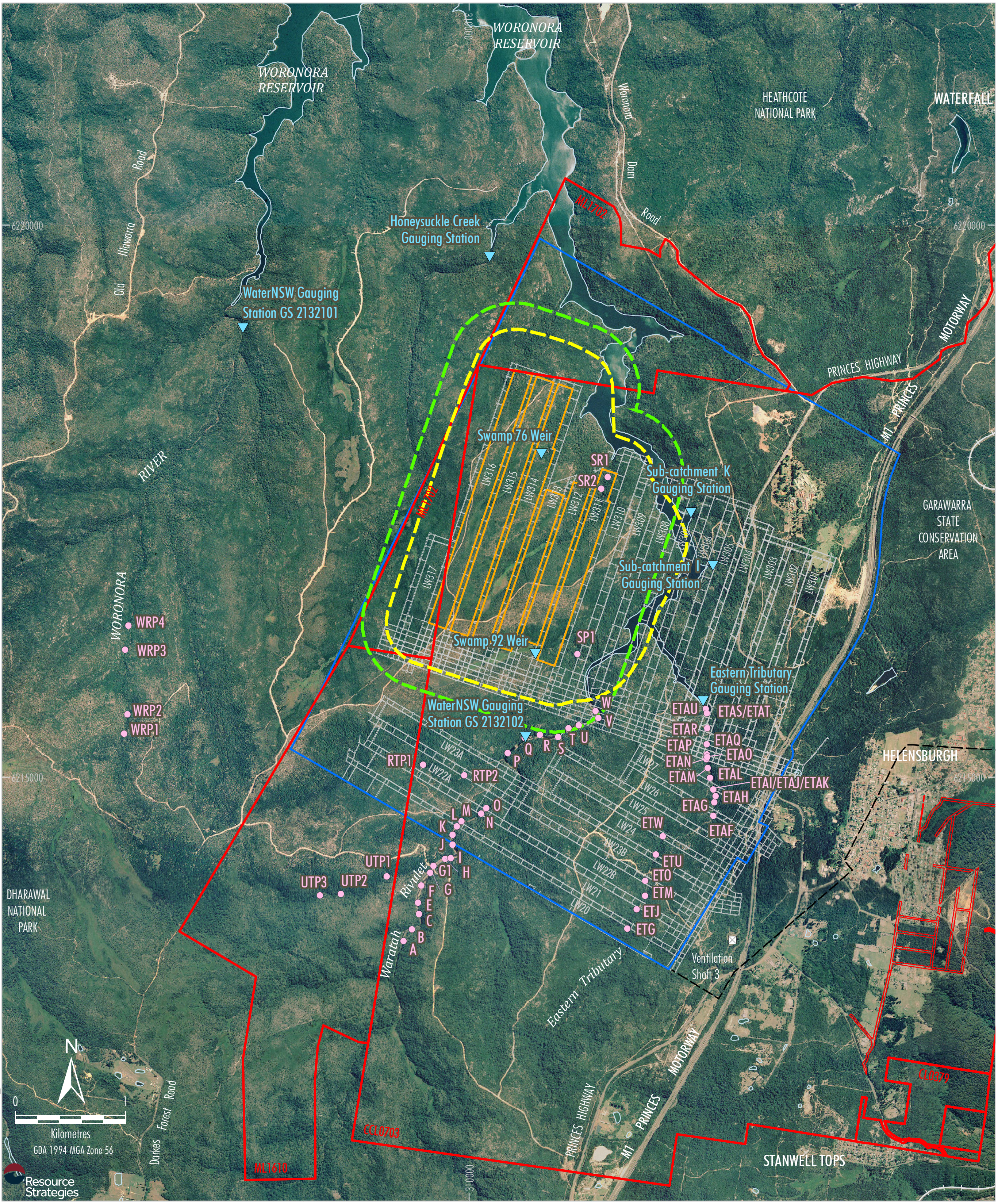
Pool Water Levels and Surface Water Flow

Visual inspections and photographic surveys have been conducted of the Waratah Rivulet, Eastern Tributary, Tributary A and Tributary B in accordance with the Metropolitan Coal WMPs.

Water levels in pools on the Waratah Rivulet (Pools A, B, C, E, F, G, G1, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V and W) have either been manually monitored on a daily basis or monitored using a continuous water level sensor and logger (Figure 6). A number of pools on the Eastern Tributary (Pools ETG, ETJ, ETM, ETO, ETU, ETW, ETAF, ETAG, ETAH, ETAI/ETAJ/ETAK[7], ETAL, ETAM, ETAN, ETAO, ETAP, ETAQ ETAR, ETAS/ETAT[8] and ETAU), Tributary P (SP1), Tributary R (SR1 and SR2), Tributary B (Pools RTP1 and RTP2) and Woronora River (Pools WRP1, WRP2, WRP3 and WRP4) have also been monitored using a continuous water level sensor and logger (Figure 6).

7 Only small rock bars separate Pools ETAI, ETAJ and ETAK. Pools join to become the one large pool. Pool ETAK is controlled by a rock bar. The water level meter situated in Pool ETAI is considered to be representative of the water level in Pools ETAJ and ETAK.

8 Due to the nature of rock bar ETAS, Pool ETAS and Pool ETAT typically sit at the same level. The water level meter situated in Pool ETAT is considered to be representative of the water level in Pool ETAS.



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 311-316 Secondary Extraction
- Longwalls 311-316 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 311-316 Secondary Extraction
- Existing Underground Access Drive (Main Drift)
- Gauging Station
- Pool Water Level Site

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2023); MSEC (2024)

Peabody

METROPOLITAN COAL

Surface Water Quantity Sites

Figure 6

The stream inspections, pool water level monitoring and surface water flow monitoring have identified subsidence impacts and environmental consequences consistent with those described in the Metropolitan Coal Project Environmental Assessment (Project EA) (HCPL, 2008), Preferred Project Report, and Metropolitan Coal WMPs. These documents identified that the key potential subsidence impacts in relation to pool water levels and surface water flow would include:

- The magnitudes of the predicted systematic and/or valley related movements are likely to result in some fracturing and dilation of the underlying strata of streams above and immediately adjacent to the longwalls.
- Cracking and dilation of bedrock are likely to result in the localised diversion of a portion of the surface flow through either:
  - **diversion into subterranean flows**, where water travels via new mining induced fractures and opened natural joints in the bedrock into near-surface dilated strata beneath the bedrock, ultimately re-emerging at the surface downstream; or
  - **leakage through rock bars**, where the rate of leakage from pools through rock bars to the downstream reaches of the stream is increased by new mining induced fractures.

The key potential environmental consequences in relation to pool water levels and surface water flow included:

- Changes in stream flows as a result of fracturing of bedrock and the consequent diversion of a portion of the total stream flow as underflow. The effects of underflow would be localised to the subsidence affected reaches of streams. Underflows would be most noticeable during periods of low flow and would depend on the frequency of no flow periods, while the effects on the frequency and magnitude of high flows would be negligible.
- Changes in pool water levels and in-stream connectivity - underflow has been observed to result in lower water levels in pools as they become hydraulically connected with the fracture network. During prolonged dry periods when flows recede to low levels, the number of instances where loss of flow continuity between pools occurs increases with a greater proportion of the flow being conveyed entirely in the subsurface fracture network.
- Negligible impacts on water quantity to the Woronora Reservoir.

Prior to the commencement of Longwall 20, the water levels in pools upstream of Flat Rock Crossing (i.e. Pools A to G, Figure 5) on the Waratah Rivulet had been impacted by mine subsidence. Since the commencement of Longwall 20, two additional pools on the Waratah Rivulet have been impacted by mine subsidence (i.e. fallen below their cease to flow levels and not as a result of climatic conditions, namely, Pool G1 in March 2011 and Pool N in September 2012[9]) (Figure 5). To date, stream remediation activities on the Waratah Rivulet have been conducted by Metropolitan Coal at Pools A, F and G. Mining has not resulted in the diversion of flows or change to the natural drainage behaviour of pools downstream of the maingate of Longwall 23 (i.e. Pools P to W) (Figure 5).

In 2021, Hydro Engineering & Consulting (2021a) assessed the effectiveness of pool remediation measures undertaken by Metropolitan Coal for restoring the water holding capacity of pools on the Waratah Rivulet. Hydro Engineering & Consulting (2021a) found that for Pools G1 and N, the water level recessionary behaviour post-remediation was consistent with pre-impact behaviour, and that for Pools B, C, E, F and G, water levels during low flow conditions were consistent with the water levels of similar, un-impacted pools. For Pool A, recorded water levels during low flow conditions were not consistent with the water levels of similar, unimpacted pools.

9 To date (September 2023), Pool N has overflowed its rock bar since December 2014, with the exception of relatively short periods. Pools on the Woronora River also stopped flowing within the same periods. Monitoring of Pool N will continue to be conducted.

Since 2012, sections of Tributary B have been mostly dry (in the vicinity of site RTP1; Figure 6) with no surface flow. Pool RTP2 on Tributary B regularly falls below its cease to flow level, however generally overflows during and following rainfall events.

Up until December 2016, the water levels/drainage behaviour of pools on the Eastern Tributary between the full supply level of the Woronora Reservoir and the Longwall 26 maingate were consistent with predictions. In the Longwalls 20-22 Extraction Plan Subsidence Assessment, it was recognised that fracturing resulting in surface flow diversion could be observed at a site where the predicted total closure is < 200 mm, although none had been observed to date. The report also noted that reference to the 200 mm predicted total closure value should be viewed as an indication of low probability (10 percent [%]) of impact rather than certainty. In the Longwalls 23-27 Extraction Plan Subsidence Assessment, additional case studies were added to the pool impact model, including cases where loss of pool water levels had occurred at < 200 mm predicted total closure. Similar to the previous database for Longwalls 20-22, the updated database showed that based on a maximum predicted total closure of 200 mm, the proportion of pools that experienced loss of pool water levels was around 10%.

In December 2016 and January 2017, a number of pools on the Eastern Tributary with predicted closure values of < 200 mm experienced loss of pool water levels. This resulted in the exceedance of the negligible environmental consequences performance measure for the Eastern Tributary in relation to diversion of flows and drainage behaviour (Eastern Tributary Incident). Downstream of the Longwall 26 maingate, mine subsidence has resulted in the diversion of flows or change to the natural drainage behaviour of Pools ETAG to ETAR (Figure 5). Mining has not resulted in the diversion of flows or change to the natural drainage behaviour of Pools ETAS, ETAT and ETAU (Figure 5).

The Longwalls 303, 304 and 305-307 Eastern Tributary Valley Closure TARPs were designed to minimise the risk that mining of Longwalls 303, 304 and 305-307 would result in exceedance of the Eastern Tributary performance measure, being negligible environmental consequences. Consistent with the TARP, the decision to cease mining of Longwalls 303, 304 and 305 was made at a very low magnitude of valley closure. High accuracy closure measurements taken directly on the rock bar or valley floor demonstrated that total rock bar closure was < 2 mm throughout the mining process and strains on the rock bar were < 0.5 millimetres per metre (mm/m), (i.e. in the order of survey accuracy). The Eastern Tributary Valley Closure TARP has been successfully implemented by Metropolitan Coal for Longwalls 303, 304 and 305.

The Waratah Rivulet Valley Closure TARP was designed to minimise the risk that the mining of Longwalls 308-310 would result in exceedance of the Waratah Rivulet Exceedance Measure, being negligible environmental consequences. The intent of the Waratah Rivulet Valley Closure TARP is to identify the initial development of valley closure prior to an impact occurring. The adaptive management approach is based on Metropolitan Coal conducting GNSS monitoring of the Waratah Rivulet to detect mining-induced effects and ceasing mining prior to extraction resulting in any unacceptable or adverse impacts on the Waratah Rivulet. The monitoring provides the earliest possible indicator for development of valley closure. The development of valley closure is recognised as the dominant mechanism that results in impact to a rock bar.

Woronora Reservoir Inflows

For the Project EA a comprehensive analysis of stream flow data and data on the yield behaviour of Woronora Reservoir indicated that past mining at Metropolitan Coal had no discernible effect on the inflow to, or yield from, the reservoir.

Surface water flow monitoring has been conducted at the Waratah Rivulet, Woronora River (Figure 6) and O'Hares Creek gauging stations since the commencement of Longwall 20 in 2010. As documented in the original model in the Project EA, the Waratah Rivulet catchment model is capable of reliably identifying a loss of 1 megalitre (ML) per day (ML/day). One (1) ML/day has been used as it is considered to be the limit of effective detection of an impact. It is also noted that 1 ML/day is well above the reduction in catchment yield that is actually predicted.

The surface water flow monitoring data obtained from the Eastern Tributary gauging station has also been assessed. The results indicate that flow at the Eastern Tributary gauging station has been continuous and that it has been generally consistent with, or above, model predictions. This indicates that flows reaching the Woronora Reservoir have not been reduced by mining.

Surface water flow monitoring indicates there is no evidence of a loss of flow from the Waratah Rivulet or Eastern Tributary reaching the Woronora Reservoir.

The gauging stations installed in sub-catchments I and K as a component of the Woronora Reservoir Impact Strategy are discussed in Section 4.3.

Gauging stations have also been installed immediately downstream of Swamp 76 (Swamp 76 Flume) and Swamp 92 (Swamp 92 Flume). The gauging stations were installed in November 2020 to enable a record of baseline flow data prior to the commencement of mining of Longwalls 311-316. The gauging station data would be analysed post commencement of mining of Longwalls 311-316 to aid in the assessment of potential impacts to Swamp 76 and Swamp 92.

Iron Staining

Hawkesbury Sandstone is the main geological feature of the Woronora River catchment within the Woronora Plateau (The University of Queensland, 2016a). The sandstone is held together by cements, most commonly carbonate, which contains iron (The University of Queensland, 2016a). Iron staining occurs naturally in the Waratah Rivulet and Eastern Tributary and other streams on the Woronora Plateau (examples of which can be found in Appendix 5).

As described in the Southern Coalfield Panel Report (Department of Planning, 2008) and the NSW Planning Assessment Commission's Report for the Metropolitan Coal Project (NSW Planning Assessment Commission, 2009), under certain conditions, the cracking of stream beds and underlying strata has the potential to result in changes in water quality, particularly ferruginous springs and/or development of iron bacterial mats. Experience at Metropolitan Coal prior to Project Approval indicated that areas of the substratum can be covered by iron flocculent material for several hundred metres downstream of mine subsidence fractures.

Metropolitan Coal has monitored the extent of iron staining through visual and photographic surveys and assessed the extent of iron staining against the subsidence impact performance measures as follows:

- Negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P).
- Negligible environmental consequences over at least 70% of the stream length (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26.

Monitoring to date indicates the subsidence impact performance measure in relation to iron staining has not been exceeded for the Waratah Rivulet.

In October 2016, Metropolitan Coal reported the exceedance of the *minimal iron staining* component of the Eastern Tributary performance measure (the Eastern Tributary Incident) to the Secretary of the Department of Planning, Industry and Environment (DPIE) and other relevant agencies in accordance with Condition 6, Schedule 7 of the Project Approval and the Metropolitan Coal Longwalls 23-27 WMP Contingency Plan. Inspection results of fresh iron staining/flocculent within the performance measure reach indicates the extent of iron staining/flocculent has varied over time since the exceedance (Metropolitan Coal, 2021).

The iron staining/flocculent is associated with Eastern Tributary water quality impacts, which have occurred in association with the exceedance of the Eastern Tributary watercourse performance measure. Reducing conditions (through water saturation excluding oxygen) has solubilised iron in the groundwater, which has been transferred to surface water through mine-induced cracking. The soluble iron (iron (II) ion, Fe^{2+}), rapidly oxidises to iron (III) Fe^{3+}, and forms insoluble hydrated ferric hydroxide in colloidal (< 0.45 micrometres [µm]) and particulate (> 0.45 µm) forms (The University of Queensland, 2018a). Iron oxidising bacteria can also create oxidised iron precipitate (National Health and Medical Research Council, 2011). The iron floc is a mixture of precipitated iron oxyhydroxide material > 0.45 µm size and colloidal material which is < 0.45 µm size. The colloidal material coagulates to give the larger size precipitated material and coats the creek bed rock surfaces (The University of Queensland, 2018a). The iron oxyhydroxide gradually converts to goethite (Yee *et al*., 2006) which has a darker colour (a dark reddish-brown) and is commonly found in the creek sediment. Goethite staining occurs both naturally and commonly and can be seen in many similar watercourses throughout the Southern Coalfield (Department of Planning, 2009).

It is anticipated that the stream remediation activities being conducted on the Eastern Tributary (Section 9.4.1) will reduce the transfer of iron from the groundwater to the Eastern Tributary.

Gas Releases

Prior to approval of the Project in 2009, no gas releases had been observed along the Waratah Rivulet, Eastern Tributary or other tributaries over the Metropolitan Coal lease, either before or during mining. Notwithstanding, the Project EA, Preferred Project Report and Metropolitan Coal Longwalls 20-22 WMP recognised there was the potential for gas releases to occur.

Gas releases (often sporadic) have since been observed on occasions over particular periods in Pools A, J, K, L, O, P, S, U and W on the Waratah Rivulet and Pools ETAG, ETAH, ETAI, ETAL and ETAM on the Eastern Tributary (Figure 5). Primarily, the two minor natural gas components that occur in gas releases from mine subsidence are carbon dioxide and methane. Assessments against the subsidence impact performance measure for negligible environmental consequence on the Waratah Rivulet and Eastern Tributary, *minimal gas releases*, to date indicate the performance measure has not been exceeded (Gilbert & Associates, 2014; The University of Queensland, 2014; 2016b; 2017; 2018b, 2018c, 2019a, 2020a – 2020d, 2021a – 2021e).

Changes in Bed Gradients, Scouring and Stream Alignment

The key potential subsidence impacts and environmental consequences in relation to bed gradients, scouring and stream alignment described in the Project EA, Preferred Project Report, and Metropolitan Coal WMPs included:

- Potential changes in bed gradients could occur, however, were anticipated to be small relative to the existing grades.

- An increased potential for scouring of the stream bed and banks (at locations where the predicted tilts considerably increase the natural pre-mining stream gradients). The potential for scouring is greatest in stream sections with alluvial deposits. Since the streambed of the Waratah Rivulet and the Eastern Tributary is predominantly erosion-resistant Hawkesbury Sandstone, scouring was expected to be very low.
- Subsidence fracturing of bedrock has the potential to cause dislodgement of rock fragments during high flow events.
- The potential for changes to stream alignment as a result of mine subsidence effects was considered to be low.
- Minor stream bank erosion, where changes in channel gradients result in increases in flow energy. It would be expected that bank erosion would be relatively minor and comprise a slow retreat of the bank until a new dynamic equilibrium is reached.

The results of the stream inspections have generally been consistent with these predictions. On the Waratah Rivulet (in a section of the stream over Longwall 21) and Eastern Tributary (in a section of the stream over Longwalls 20 and 21), increased ponding from changes in bed gradients has previously resulted in the prolonged inundation of the adjacent riparian vegetation which has resulted in some vegetation dieback on a local scale.

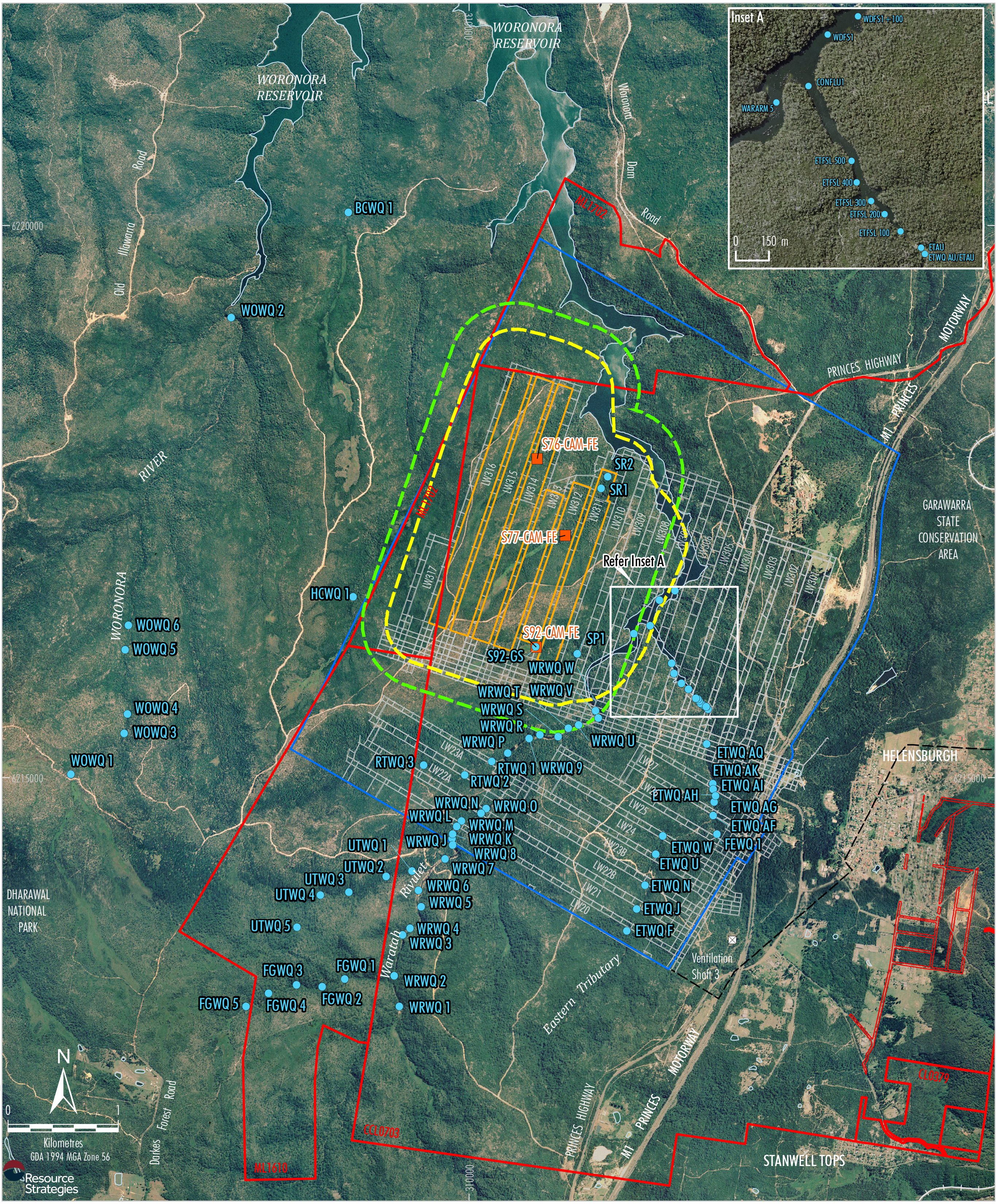
Surface Water Quality

Subsidence impacts on water quality were predicted by the Project EA, Preferred Project Report, and Metropolitan Coal WMPs to be similar to that previously observed at Metropolitan Coal, specifically, transient pulses of iron, manganese and to a lesser extent aluminium, which would likely occur following fresh cracking of the stream bed. Aluminium comes from erosion of rock material whereas iron and manganese arise from dissolution of minerals in sandstone via changes in redox conditions.

Surface water quality has been monitored at a number of sites on Waratah Rivulet, Tributary B, Tributary D, Eastern Tributary, Far Eastern Tributary, Tributary P, Tributary R, Honeysuckle Creek, Bee Creek and Woronora River. Recent trends in the monitoring data for key parameters (pH, electrical conductivity, dissolved iron, dissolved manganese and dissolved aluminium) at the sites listed in Table 2 have been summarised by Hydro Engineering & Consulting (2022). The water quality sites are shown on Figure 7.

The cracking and dilation of bedrock and associated diversion of surface flow and leakage of water through rock bars at pools which has occurred on the Eastern Tributary (including the reach associated with the exceedance of the Eastern Tributary watercourse performance measure) has resulted in impacts on water quality, in particular increases in dissolved manganese and at times iron. Reducing conditions (through water saturation excluding oxygen) has solubilised iron (and manganese) in the groundwater. The soluble iron and manganese has been transferred to surface water through mine-induced cracking, resulting in increases in iron and manganese concentrations in the Eastern Tributary. The soluble iron (iron (II) ion, Fe^{2+}), rapidly oxidises to iron (III) Fe^{3+}, and forms insoluble hydrated ferric hydroxide in colloidal (< 0.45 μm) and particulate (> 0.45 μm) forms (The University of Queensland, 2018a). Manganese remains dissolved in the water column as oxidation at near-neutral pH is slow (Raveendran *et al.,* 2001) and soluble manganese (II ion, Mn^{2+}) is the most stable species (Rayner-Canham, 1996) (The University of Queensland, 2018a). Low levels of manganese, e.g. < 0.1 milligrams per litre (mg/L) exist in the natural creek water. Dissolved manganese is however readily diluted by freshwater flow to low levels when higher creek flows occur.

Assessment of the water quality monitoring results to date by Associate Professor Barry Noller (The University of Queensland, 2018a, 2018d – 2018l; 2019b – 2019d, 2020e – 2020l, 2021f – 2021n) indicate there has been a negligible reduction in the quality of water resources reaching the Woronora Reservoir. Notwithstanding, subsidence impacts on water quality will continue to be monitored. Metropolitan Coal is committed to the remediation of pools on the Eastern Tributary.



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 311-316 Secondary Extraction
- Longwalls 311-316 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 311-316 Secondary Extraction
- Existing Underground Access Drive (Main Drift)
- Surface Water Quality Site
- Proposed Iron Staining Camera

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2023); MSEC (2024)

Peabody

METROPOLITAN COAL

Surface Water Quality Sites

Figure 7

Table 2
Stream Water Quality Monitoring Results

Stream	Monitoring Results to Date*
Waratah Rivulet (sites WRWQ 2, WRWQ 6, WRWQ 8, WRWQ 9, WRWQ M, WRWQ N, WRWQ P, WRWQ R, WRWQ T and WRWQ W)	• Water quality trends for the period of January to December 2022 were variable due to significant rainfall experienced in the first half of 2022, however, the range of constituent values recorded was generally within the range of historical records. • Upstream sites on Waratah Rivulet (sites WRWQ 2 and WRWQ 6) show slightly acidic to near neutral pH values with higher (slightly alkaline) values being recorded at lower to middle and lower reach sites (e.g. at sites WRWQ 8, WRWQ T and WRWQ W). • Electrical conductivity values were generally lower than historical values from January to June 2022 and within the range of historical values from July to December 2022. No historically high electrical conductivity values were recorded from January to December 2022. • Dissolved iron concentrations remained consistent with baseline values at all sites. • Historically high aluminium concentrations recorded at all upper and middle reach sites in May 2022 and at all lower reach sites in March and April 2022 except for WRWQ 9 and WRWQ W. In the second half of 2022, dissolved aluminium concentrations declined at all sites. • Dissolved manganese concentrations at the upper, middle and lower reach sites up to December 2022 have been generally consistent with previously recorded values (0.08 milligrams per litre [mg/L] to 0.30 mg/L). Historically high concentrations were recorded at WRWQ R, WRWQ T and WRWQ W in June 2022 although were less than 0.12 mg/L.
Woronora River (control sites WOWQ 1 and WOWQ 2)	• The pH values recorded at sites on Woronora River have generally been variable, ranging from slightly acidic to slightly alkaline. Slightly acidic conditions were recorded for the period January to December 2022. • Electrical conductivity values at all sites were less than or within range of baseline conditions. Historically low values were recorded mid-2022. • Dissolved iron has been generally low, with concentrations recorded in 2022 within the range of baseline concentrations. • Dissolved manganese concentrations recorded at WOWQ 1 during 2022 were within the range of baseline values. Dissolved manganese concentrations recorded at WOWQ 2 during 2022 were slightly elevated however within the range of historical concentrations. • Dissolved aluminium concentrations recorded at WOWQ 1 during 2022 were within the range of baseline values. Dissolved aluminium concentrations recorded at WOWQ 2 during 2022 were variable however remained within the range of historical concentrations.
Eastern Tributary (sites ETWQ F, ETWQ J, ETWQ N, ETWQ U, ETWQ W, ETWQ AF, ETWQ AH, ETWQ AQ and ETWQ AU)	• The pH values recorded at sampling sites on Eastern Tributary indicate slightly acidic to near neutral pH conditions. • Electrical conductivity values were consistent with historical values during 2022. • Dissolved manganese concentrations were within the range of historical concentrations during 2022. • Dissolved iron concentrations at some Eastern Tributary sites were slightly elevated, however consistent with historical values. • Generally elevated and variable dissolved aluminium concentrations have been recorded at all sites since 2016, with historically high concentrations recorded at ETWQ F in April 2022 and ETWQ N, ETWQ AF and ETWQ AU in March 2022.
Western Tributaries of Woronora Reservoir (sites SP1, SR1 and SR2)	• The pH values recorded at sampling sites SP1, SR1 and SR2 indicate acidic to slightly acidic pH conditions. • Electrical conductivity values have been low, ranging between 68 and 200 microSiemens per centimetre (µS/cm). • Dissolved iron concentrations recorded during the baseline period have remained below 0.36 mg/L. • Dissolved manganese concentrations recorded during the baseline period have remained below 0.065 mg/L. • Dissolved aluminium concentrations recorded during the baseline period have remained below 0.16 mg/L.

Table 2 (Continued)
Stream Water Quality Monitoring Results

Stream	Monitoring Results to Date*
Bee Creek, Honeysuckle Creek, Far Eastern Tributary, Tributary B and Tributary D (sites BCWQ 1, HCWQ 1, FEWQ 1, RTWQ 1, and UTWQ 1)	• Slightly acidic pH values have been recorded at sampling sites in Bee Creek and Honeysuckle Creek over the period of record. The pH records for Tributary D indicate slightly acidic to near neutral conditions while pH values recorded at Far Eastern Tributary and Tributary B have trended around pH 7 (near neutral). • Electrical conductivity values less than 600 µS/cm have been recorded at all sites over the period of record, with a generally declining trend in EC values recorded at the majority of sites since 2019. Elevated EC values were recorded at UTWQ 1 in early 2022 however remained below 500 µS/cm. • Dissolved iron concentrations of less than 1 mg/L have been recorded at the majority of sites since 2020. • Dissolved manganese concentrations have typically been low at all sites (< 1 mg/L). • A decline in dissolved aluminium concentrations was recorded at HCWQ 1 and BCWQ 1 in 2022, in comparison to elevated concentrations recorded during periods of 2018, 2020 and 2021. A historically high dissolved aluminium concentration was recorded at FEWQ 1 in April 2022 although concentrations generally declined over the remainder of 2022.

* Monitoring results to date are up to and including December 2022.
Source: after Hydro Engineering & Consulting (2022).

Woronora Reservoir Water Quality

The Project EA, Preferred Project Report, and Metropolitan Coal WMPs predicted the Project would not impact on the performance of the Woronora Reservoir and would have a neutral effect on water quality. Water quality monitoring results to date are consistent with the predictions.

Metropolitan Coal sources water quality data for the Woronora Reservoir from WaterNSW in accordance with a data exchange agreement and analyses data for total iron, total aluminium and total manganese from 0 m to 9 m below the reservoir surface.

The data has been assessed consistent with the TARP in Section 8.9. Since early to mid-2020, an increasing trend in total iron, total aluminium and total manganese has been recorded at sampling location DW01. Similar intermittent increases in the concentrations of iron, aluminium and manganese in the Woronora Reservoir are evident over the period of record, including during the baseline period prior to the start of Longwall 20. The intermittent increases in the concentrations of these constituents are considered related to above average rainfall conditions occurring during these periods.

While there was a more rapid increase in total aluminium in early 2020, recorded concentrations have remained consistent since then. It is noteworthy that similar intermittent increases in concentrations of iron, aluminium and manganese in the Woronora Reservoir are evident over the period of record, including during the baseline period prior to the start of Longwall 20.

The water quality monitoring results to date are consistent with the predictions and indicate there has been a negligible reduction in the water quality of the Woronora Reservoir.

4.2 GROUNDWATER

The conceptual hydrogeological model supports three distinct groundwater systems, including:

- Perched groundwater system – generally above and independent of the regional groundwater table (typically < 20 m below the ground surface). Excess rainfall produces a permanent perched water table within swamp sediments and outcropping sandstone that is independent of the regional water table in the Hawkesbury Sandstone. As the swamps are essentially rain-fed, water levels within upland swamps fluctuate seasonally with climatic conditions.
- Shallow groundwater system – the shallow groundwater system (extending typically to < 100 m below the ground surface) defines a regional water table and is separate from the overlying perched groundwater system.
- Deep groundwater system – although the shallow and deep groundwater systems are connected, low permeability of the Bald Hill Claystone provides a degree of isolation between the Hawkesbury Sandstone (Figure 8) that hosts shallow groundwater and the underlying Bulgo Sandstone and deeper formations that host deep groundwater. The deep groundwater system is typically > 100 m below the ground surface.

Recharge to the groundwater system is from rainfall and from lateral groundwater flow. Although groundwater levels are sustained by rainfall infiltration, they are controlled by ground surface topography and surface water levels. A local groundwater mound develops beneath elevated sandstone that ultimately discharges to creeks and waterbodies. Loss by evapotranspiration through vegetation where the water table is within a few metres of the ground surface occurs within upland swamps and outcropping sandstone.

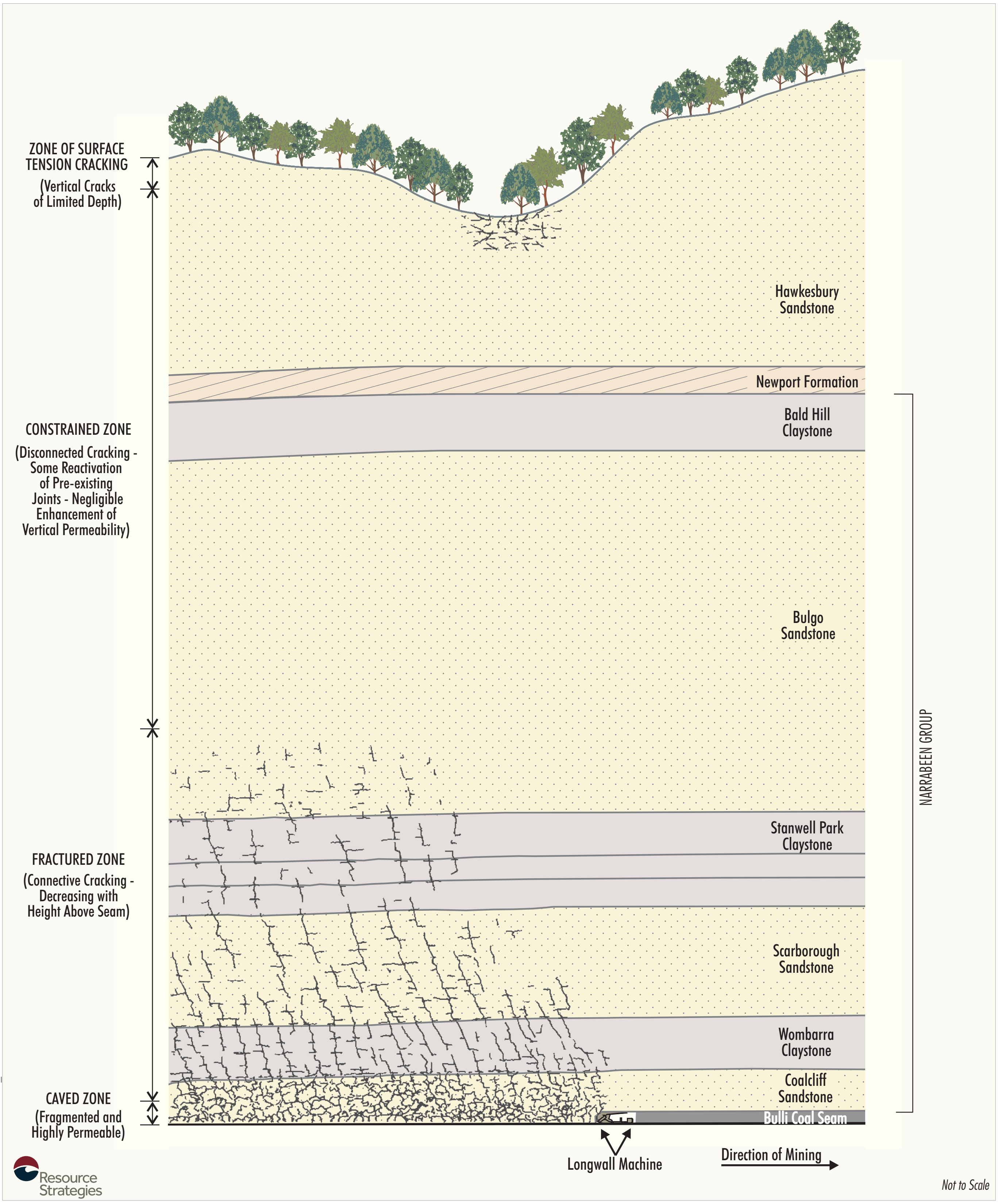
The only recognised economic aquifer in the area is the Hawkesbury Sandstone. The Hawkesbury Sandstone is a low yield aquifer of generally good quality beneath the Woronora Plateau and the Illawarra Plateau. Review of the WaterNSW 'Real-time Data' database (September 2023) indicates no privately owned registered bores, other than those registered by Metropolitan Coal, are located in the vicinity of the 300 series longwalls.

Groundwater Model

A tabulated list of groundwater models developed and used for the Project by HydroAlgorithmics and SLR Consulting is provided in Table 3.

A three-dimensional (3D) numerical model of groundwater flow was developed in 2008 for the Project EA. The groundwater model was recalibrated in December 2012 for the Preferred Project Layout by revising the hydraulic conductivities in the Hawkesbury Sandstone and the Bald Hill Claystone. At this time, two extra layers were added to the Hawkesbury Sandstone section to improve resolution of the vertical hydraulic gradient in the shallow groundwater system. The model simulations were based on initial conditions at the end of Longwall 14, consistent with the Project EA assessment (Heritage Computing, 2008). Model outputs have been examined every six months for review of environmental performance.

Transient calibration was undertaken in 2018 to incorporate Metropolitan Coal updates to the geological model. The previously revised model included an update of the topographical surface and geological interfaces, the addition of two model layers below the Bulli Seam and updated estimates of the fractured zone height. A report on the previously revised model was prepared (HydroSimulations, 2018), which was used for the assessment of the Longwall 304 and Longwalls 305-307 Extraction Plans.



Source: After Geosensing Solutions (2008)

Peabody
METROPOLITAN COAL

Schematic - Longwall Mining and Subsidence Profile

Figure 8

Table 3
Groundwater Model Tabulation

Date	Groundwater Model	Purpose
2008	MODFLOW 3D [13 layers]	Groundwater assessment of Longwalls 20-44 for the Project EA. Steady-state calibration.
2009	MODFLOW-SURFACT [13 layers]	Recalibration of the regional groundwater model prepared for Longwalls 20 to 44 with advanced software; high-inflow and low-inflow model versions.
2009	MODFLOW-SURFACT [13 layers]	Post-audit of the 3D groundwater model confirmed model performance at three new deep bores.
2012	MODFLOW-SURFACT [15 layers]	Recalibration of Hawkesbury Sandstone vertical head gradients and the addition of two extra layers to the Hawkesbury Sandstone section to improve resolution of the vertical hydraulic gradient in the shallow groundwater system.
2018	MODFLOW-SURFACT [17 layers]	Revised model, which includes an update of the topographical surface and geological interfaces, the addition of two model layers below the Bulli seam and updated estimates of the fractured zone height. Transient calibration.
2020	MODFLOW-USG [17 layers]	Revised model, including the implementation of ‘stacked drains’ in the groundwater model. Recalibration of model completed.

In 2020, and consistent with the recommendations of the Woronora Reservoir Impact Strategy (WRIS) Panel Stage 2 Report (Hebblewhite *et al*., 2019), the groundwater model was updated to include the incorporation of ‘stacked drains’ to represent the fractured zone instead of using enhanced hydraulic conductivity and storage properties. A calibration report for the updated model was prepared by SLR Consulting (2020), which has been used for the assessment of Longwalls 301-310 and 311-316.

In December 2020, Metropolitan Coal commissioned Dr Justin Bell (JBS&G) to undertake a peer review of the calibration report for the updated model (SLR Consulting, 2020). Although the peer review was focussed around the incorporation of stacked drains, Dr Bell reviewed the complete groundwater model as described in the calibration report. Dr Bell concluded that “*the current approach to the groundwater model is ‘fit-for-purpose’, as per the definition of the NSW Aquifer Interference Policy”*.

Perched Groundwater Systems (Upland Swamps)

The key potential subsidence impacts and environmental consequences on perched groundwater systems described in the Project EA, Preferred Project Report, and Metropolitan Coal WMPs and Biodiversity Management Plans, included:

- Any cracking of the bedrock within upland swamps was expected to be isolated and of a minor nature, due to the relatively low magnitudes of the predicted strains and the relatively high depths of cover.
- Surface cracking resulting from mine subsidence within the upland swamps was not expected to result in an increase in the vertical movement of water from the perched water table into the regional aquifer as the sandstone bedrock is massive in structure and permeability decreases with depth.
- It was expected that any surface cracking that may occur would be superficial in nature (i.e. would be relatively shallow) and would terminate within the unsaturated part of the low permeability sandstone. Any changes in swamp water levels as a result of cracking were expected to be unmeasurable when compared to the scale of seasonal and even individual rainfall event-based changes in swamp groundwater levels.

- Whilst swamp grades vary naturally, the predicted maximum mining-induced tilts were generally orders of magnitude lower than the existing natural grades within the swamps. The predicted tilts would not have any significant effect on the localised or overall gradient of the swamps or the flow of water. Any minor mining-induced tilting of the scale and nature predicted was not expected to significantly increase lateral surface water movements which are small in relation to the other components in the swamp water balance.

No changes to the fundamental surface hydrological processes and upland swamp vegetation were expected within upland swamps.

In relation to impacts of the Project on upland swamps, the NSW Planning Assessment Commission (2009) concluded that the mining parameters were such that:

- for most swamps in the Project Area, there was a low risk of negative environmental consequences; and
- that there was a very low risk that a significant number of swamps would suffer such consequences.

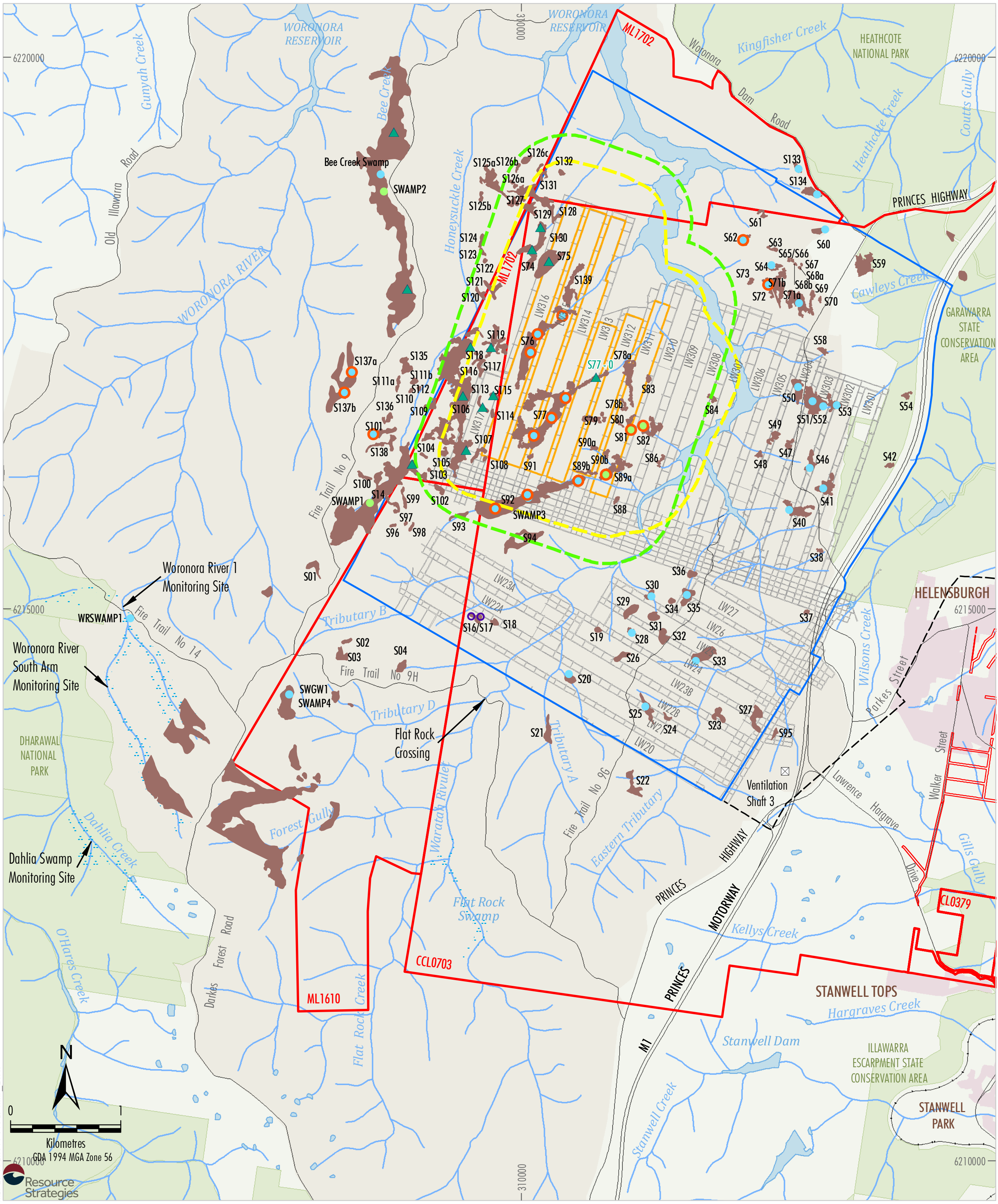
Groundwater monitoring of upland swamps has involved the use, where practicable, of paired piezometers, one swamp substrate piezometer (at approximately 1 m depth) and one sandstone piezometer (at a depth of approximately 10 m) (Figure 9). Specifically, paired piezometers have been monitored in Swamps 20 and 25 overlying Longwalls 20-22, Swamps 28, 30, 33 and 35 overlying Longwalls 23-27, Swamps 40, 41, 46, 51, 52 and 53 overlying Longwalls 301-303, Swamp 50 overlying Longwall 304, Swamps 71a and 72 adjacent to Longwalls 305-307, Swamps 62, 64, 82 and 92 adjacent to Longwalls 308-310 and in control Swamps 101, 137a, 137b, Woronora River Swamp 1 and Bee Creek Swamp (Figure 9). At Swamp 20 and control swamp Woronora River Swamp 1, multiple piezometers have been monitored (i.e. one swamp substrate piezometer to a depth of approximately 1 m and two sandstone piezometers to depths of approximately 4 and 10 m) (Figure 9).

The swamp substrate piezometer represents water levels within the swamp sediments and the piezometer at approximate depths of 4 m and 10 m allows comparison with the shallow water table in the Hawkesbury Sandstone. Data shows that water levels within the swamps over longwalls are typically perched above those of the local Hawkesbury sandstone groundwater levels and indicates a separate control on swamp water levels. That is, the swamps are primarily surface water fed systems and generally water infiltrates downwards from the swamps to the groundwater.

The substrate water levels in Swamp 20 changed from being permanently saturated to being periodically saturated as a result of the passing of Longwall 21 (Chart 1) (SLR Consulting, 2021). There is a very strong correlation with rainfall trend at Swamp 20 and control swamp Woronora River Swamp 1 over the period of record. As the rate of decline in the two piezometers is similar from 2013, but different in 2012, it is considered that Longwall 21 caused a mining effect at Swamp 20, but the effects were not exacerbated by Longwalls 22-27 (SLR Consulting, 2021).

A mining effect to the substrate water levels of Swamp 28 (overlying Longwall 24) was identified in 2016 based on the incomplete recovery of substrate water levels following rainfall events (Chart 2) (SLR Consulting, 2021). Swamp 28 is considered to have had an impact from mining of Longwall 25, although no effect on swamp substrate water levels occurred when Longwall 24 passed directly beneath the monitoring site (SLR Consulting, 2021).

Analysis of the swamp substrate water levels of Swamps 25, 30, 33, 35, 40, 41, 46, 50, 51, 52, 53, 71a and 72 including comparisons with control swamps and rainfall records have indicated the drop in swamp water levels (below sensor level) recorded in the swamps that prevailed up to early 2020 were a natural response to reduced rainfall (SLR Consulting, 2021). It should be noted that piezometers measure only free water within swamps substrates and not bound water such as that which occurs within peat.



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Railway
- Project Underground Mining Area
- Longwalls 20-27 and 301-317
- Longwalls 311-316 Secondary Extraction
- Longwalls 311-316 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 311-316 Secondary Extraction
- Existing Underground Access Drive (Main Drift)
- Upland Swamp
- Swamp Substrate and Shallow Groundwater Piezometer
- Swamp Substrate Groundwater Piezometer
- Swamp Shallow Groundwater Piezometer
- Swamp Soil Moisture Probe
- Proposed Future Monitoring Sites

Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2023); MSEC (2024); after NPWS (2003), Bangalay Botanical Surveys (2008); Eco Logical Australia (2015; 2016; 2018) and Ecoplanning (2021; 2023)

Note: Shallow Groundwater Piezometers at swamp monitoring site 92-1 is planned for installation by November 2024. Installation would be subject to suitable weather conditions and access to the Woronora Special Area. The future monitoring site locations in Bee Creek are indicative only and subject to change based on site access and swamp field investigations.

Peabody

METROPOLITAN COAL

Upland Swamps Groundwater Piezometer Locations

Figure 9

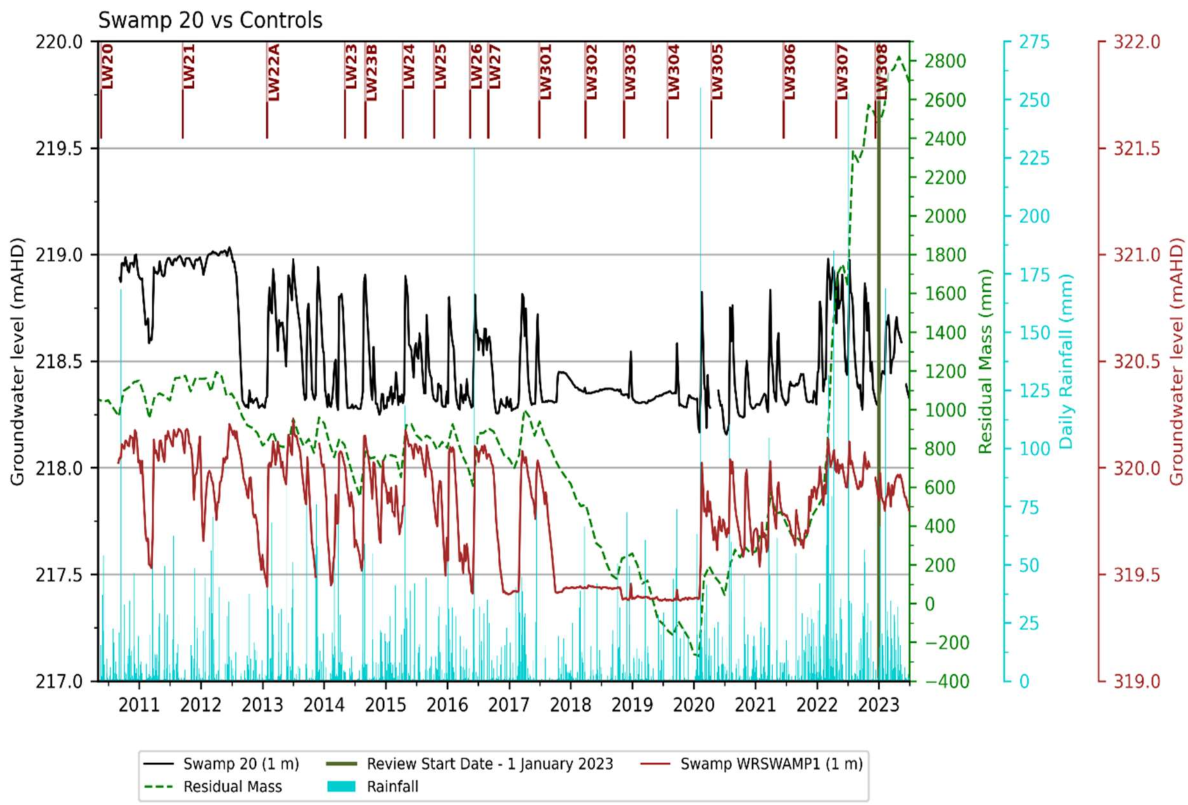


Chart 1 Comparison of Piezometer Responses at Swamp 20 and Woronora River 1 Control Swamp

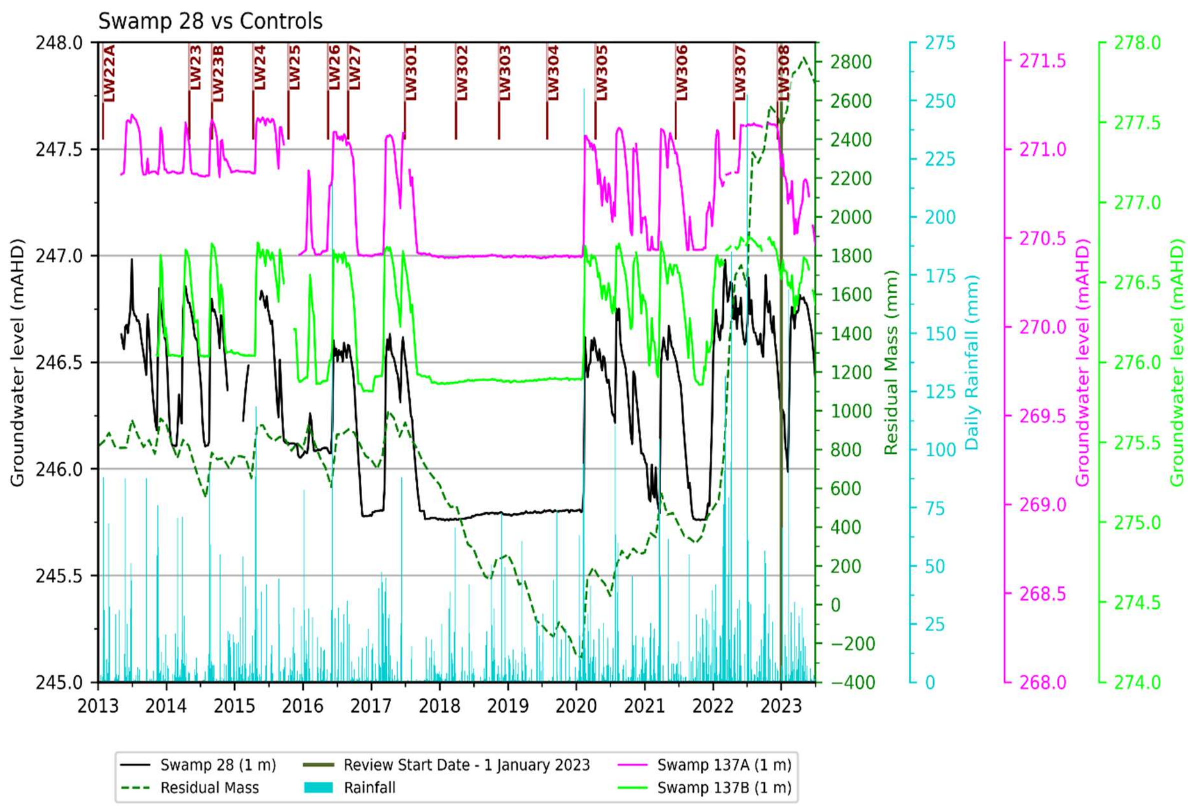


Chart 2 Groundwater Hydrographs at Swamp 28 and Two Control Swamps (137a and 137b)

While the water lost from Swamp 20 and Swamp 28 was retained in the unsaturated sandstone above the regional water table, the changes in swamp water levels as a result of cracking are measurable when compared to seasonal individual rainfall event-based changes in swamp groundwater levels. There is currently no sign that the vegetation in Swamp 20 is being impacted by the changed hydrological conditions. The vegetation monitoring results from autumn 2017 to autumn 2019 suggest the changes in vegetation occurring in Swamp 28 are significantly different from changes in the control swamps (Eco Logical Australia, 2018a, 2018b, 2019a, 2019b, 2020a). In spring 2019, the declining trend in the vegetation condition at Swamp 28 stabilised and has remained stable to date (Eco Logical Australia, 2020b, 2021a, 2021b).

No adverse impact has been observed on threatened vertebrate species that potentially could be present in swamps, particularly threatened amphibian species. However, since bound water is not currently being measured at these sites, potential adverse impacts on species using swamp substrates cannot be determined.

Consistent with the recommendations of Hydro Engineering & Consulting (2024) (Appendix 5), flow measuring flumes were installed immediately downstream of Swamps 76 and 92 in November 2020.

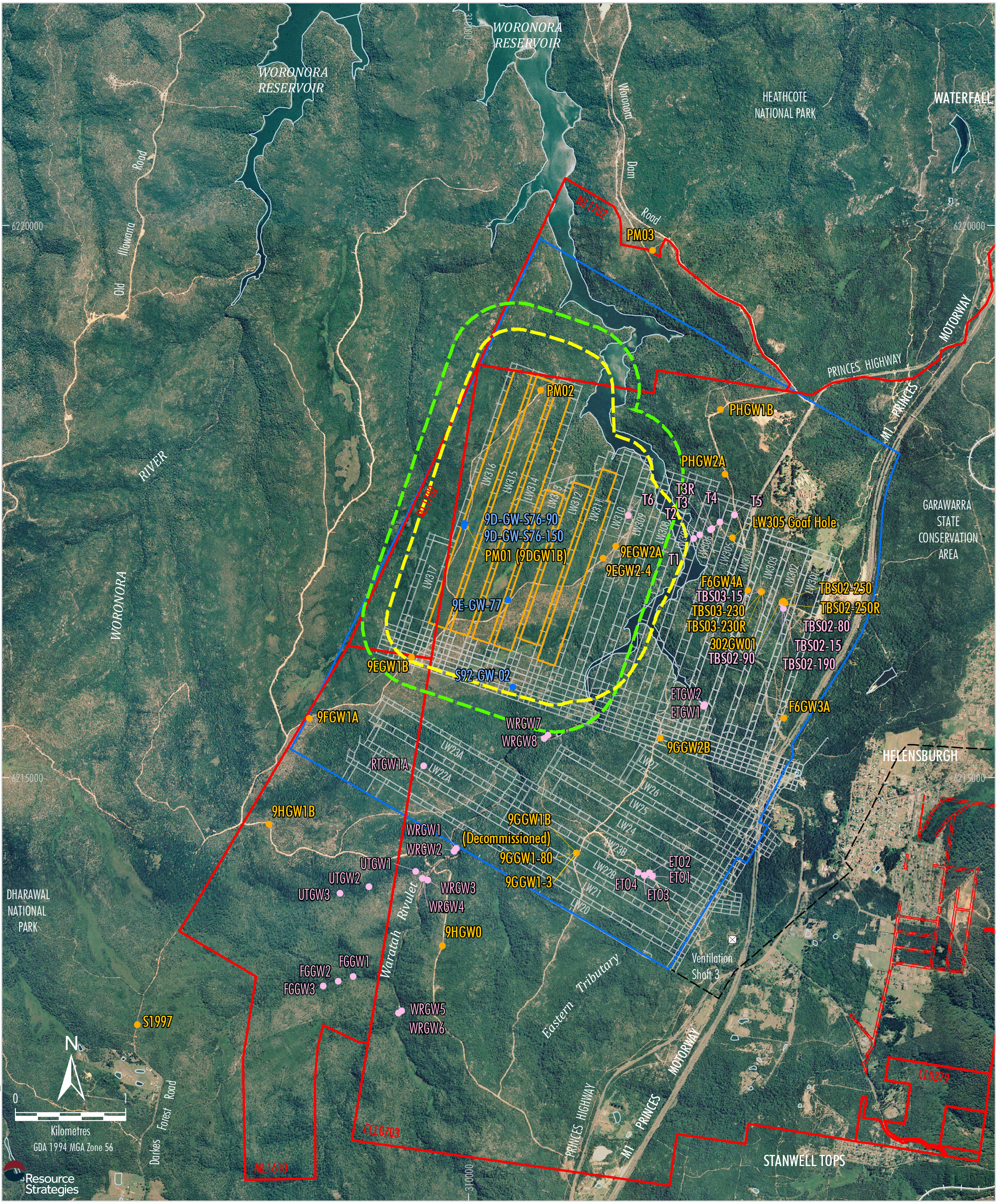
Shallow Groundwater Systems and Inflows to the Woronora Reservoir

The key potential subsidence impacts and environmental consequences on shallow groundwater systems and inflows to the Woronora Reservoir described in the Project EA, Preferred Project Report, and Metropolitan Coal WMPs included:

- Permanent mining-induced changes in the groundwater levels of shallow aquifers in connection with streams and ecosystems at Metropolitan Coal would not occur to any significant degree (i.e. the direction of shallow groundwater system flow [i.e. in the Hawkesbury Sandstone] would not be altered by mining).
- As there is an alternation of thick sandstone/claystone lithologies, there is a constrained zone in the overburden that remains rigid and acts as a barrier which isolates shallow and deep aquifers. At the substantial depths of cover of the Project, there would not be connective cracking from the mined seam to the surface.
- The depressurisation effects described below for the deep groundwater system would not propagate to the Hawkesbury Sandstone where the shallow groundwater system is located. As a result, no measurable impacts on registered bores in the wider Project area and surrounds would be expected.
- There would be negligible loss of groundwater yield to the Woronora Reservoir since groundwater modelling indicated negligible reduction in cumulative average inflows to the Woronora Reservoir. In relation to the potential loss of catchment yield, the NSW Planning Assessment Commission (2009) was of the view that the risk of any significant loss is very low unless a major geological discontinuity is encountered during mining that might provide a direct hydraulic connection between the surface and the mine workings.
- Local surface water quality impacts are expected as a result of enhanced groundwater – surface water interactions (as described for surface water quality above).

The locations of groundwater bores that have been sampled for groundwater levels/pressures and groundwater quality at Metropolitan Coal are shown on Figures 10 and 11, respectively.

The shallow groundwater monitoring results to date are considered to be consistent with the potential subsidence impacts and environmental consequences described in the Project EA, Preferred Project Report, and Metropolitan Coal WMPs.



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 311-316 Secondary Extraction
- Longwalls 311-316 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 311-316 Secondary Extraction
- Existing Underground Access Drive (Main Drift)
- Groundwater Level Bore
- Groundwater Level/Pressure Bore
- Proposed Groundwater Monitoring Site

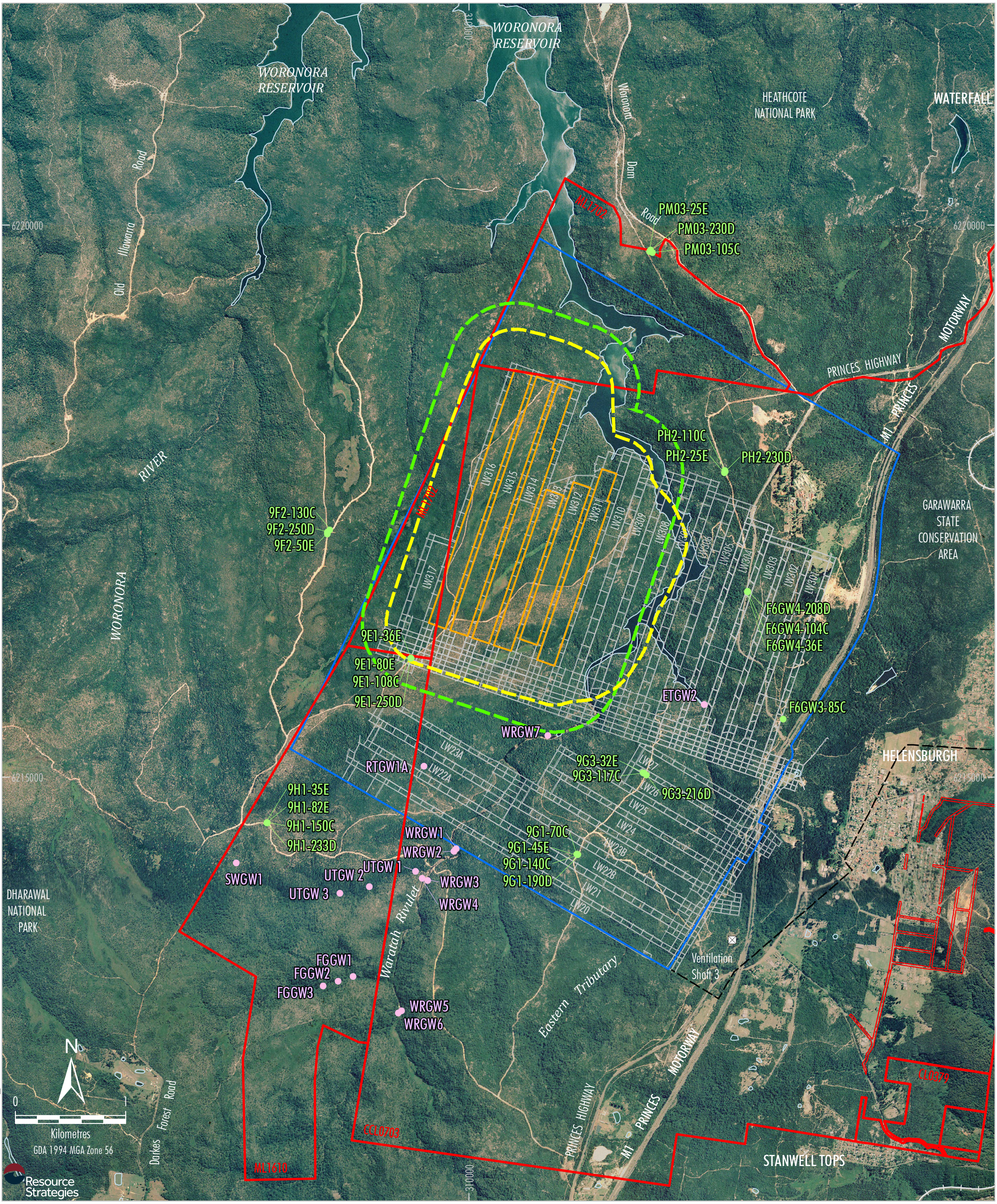
Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2023); MSEC (2024)

Peabody

METROPOLITAN COAL

Groundwater Level and/or Pressure Bore Locations

Figure 10



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 311-316 Secondary Extraction
- Longwalls 311-316 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 311-316 Secondary Extraction
- Existing Underground Access Drive (Main Drift)
- Deep Groundwater Chemistry Monitoring Site
- Stream Shallow Groundwater Quality Monitoring Site

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2023); MSEC (2024)

Peabody

METROPOLITAN COAL

Groundwater Quality Sites

Figure 11

Depressurisation of the Deep Groundwater System

Immediately above a mined coal seam, rocks collapse into the void created by the removal of coal to form a caved zone and a fractured zone develops above the caved zone (Figure 8). This causes aquifer properties to change (e.g. permeability and porosity) and results in a higher vertical permeability as a result of mining, with some increase also in horizontal permeability over the dimension of a longwall panel.

The key potential subsidence impacts and environmental consequences on the deep groundwater system described in the Project EA, Preferred Project Report, and Metropolitan Coal WMPs, included:

- Based on experience at Metropolitan Coal, substantial depressurisation of the deep aquifers in the fractured zone above the goaf is restricted to a height of less than about 130 m from the top of the goaf, while transient pressure effects have been observed to propagate to a height of about 300 m above the goaf. That is, there is a pronounced increase in vertical hydraulic gradient in the deep groundwater system over the Metropolitan Coal longwalls.
- Above goaf zones there would be substantial changes in fracture porosity and permeability, due to opening up of existing joints, new fractures and bed separation. Permeability increases would have accompanying reductions in lateral hydraulic gradients, with associated changes in groundwater levels and pressures. Pronounced changes in groundwater levels can occur without any significant drainage into a mine, particularly from the less permeable Narrabeen Group sandstones.
- Groundwater discharge to the mined seam would occur from above and below the seam in proportion to local permeabilities. Based on earlier modelling, the water make (i.e. groundwater inflow) was predicted to be in the order of 0.1 ML/day for Longwalls 20-27 and from 0.045 to 0.6 ML/day for Longwalls 301-303. Modelling indicated that the inflow could be up to 0.5 ML/day from the deep groundwater system during mining of Longwall 24 and up to 0.6 ML/day during the mining of Longwall 302[10]. The 2018 groundwater model predicted that inflow for Longwalls 305-307 would be approximately 0.02 ML/day to approximately 0.24 ML/day at the end of Longwall 307[11]. Predictions of groundwater inflow for Longwalls 311 to 316 range from approximately 0.09 ML/day to 0.13 ML/day.
- Due to the substantial depths of cover at the Project, there would not be connective fracturing from the mined seam to the surface. Groundwater modelling for the Project indicates that there is expected to be eventual recovery of deep groundwater system pressures over many decades following the cessation of mining.

The NSW Planning Assessment Commission (2009) concluded that given the considerable depth of mining and the restricted panel width in the Project area, in the absence of geological structures such as faults and igneous intrusions (sills, dykes and diatremes), there was a very high probability that a constrained zone would be associated with the mine layout proposed over the Project area, thereby preventing direct hydraulic connections between mine workings and surface water bodies.

[10] Modelling and assessments conducted for Longwalls 20-27 and Longwalls 301-303 were documented in the Metropolitan Coal Longwalls 20-22, 23-27 and 301-303 Extraction Plans.

[11] Modelling and assessments conducted for Longwalls 301-307 were documented in the Metropolitan Coal Longwalls 305-307 Extraction Plan.

Previously, two goaf holes drilled at Metropolitan Coal informed the height of connective fracturing (both holes indicating the height is less than 130 m from the top of the goaf). Comparisons of calculated fracture heights using the Ditton model and the Tammetta model have both supported the uppermost fractured layer that has been adopted in previous groundwater modelling for Metropolitan Coal (Ditton S. and Merrick N., 2014). The Metropolitan Coal longwall widths (narrower than typical Southern Coalfield longwalls), substantial depths of cover (compared to other Southern Coalfield mines) and the alternation of thick sandstone/claystone lithologies, would result in a constrained zone in the overburden that remains rigid and acts as a bridge which isolates shallow and deep aquifers.

Metropolitan Coal conducts weekly inspections of development workings for water accumulation. The mine inspections have not identified any abnormal water flows from the goaf, geological structures, or strata generally either prior to, or since, the commencement of Longwall 20.

Multiple structures have been intersected by development workings that are coincident with the Woronora Reservoir directly above the maingates of Longwall 305 (F0027, F0030), Longwall 306 (F0036, F0037), and Longwall 307 (F0037). These structures were dry at the time of intersection and have continued to remain dry during regular inspections conducted as part of the underground inspection program. In October 2021, Longwall 306 extracted through F0037 which lies directly beneath the reservoir. Inspections of the structure and development workings found that both continued to remain dry. Similar to previously encountered structures, changes to the hydraulic conductivities of F0008, F0021 and F0027 as a result of mining are considered highly unlikely.

Monitoring of the mine water balance (mine water make) is calculated from the difference between total mine inflows and total mine outflows (refer Section 8.6 for details). Given the large fluctuations in daily water usage and the cycle period for water entering the mine and for assessment of environmental performance of the mine, a 20-day average is used by Metropolitan Coal to provide a more reliable estimate of water make. The 20 day average daily mine water make has been below 0.5 ML/day (Charts 3a and 3b). The increased water make during the period April 2011 to July 2011 (Chart 3a) was a result of dewatering of old workings in advance of the 200 Mains Panel (Metropolitan Coal, 2011). From 2 January 2009 to 31 August 2023 the mine water make has averaged 0.02 ML/day, which is less than that predicted by groundwater modelling for the Project. During the extraction of Longwalls 305-309, mine water make has been at or below 0.15 ML/day (Chart 3c).

Continuous groundwater level/pressure monitoring has been conducted at bores 9HGW0 (Longwall 10 post-mining), 9EGW1B, 9FGW1A, 9GGW1-3, 9GGW1-80, 9GGW2B, 9HGW1B, PM02, PM01 (9DGW1B), 9EGW2A[12], 9EGW2-4, PM03, PHGW1B, PHGW2A, 302GW01, TBS02, TBS03, F6GW3A, LW305GW (Longwall 305 post-mining) and F6GW4A (Figure 10) in accordance with the Metropolitan Coal WMPs. The monitoring results indicate that a hydraulic gradient has been maintained between bores and the floor levels of the nearest streams and a hydraulic gradient exists from bores to the Woronora Reservoir at the level of the regional water table. The monitoring results also support the assessment of no connective cracking between the surface and the mine. The results of the additional groundwater monitoring conducted as a component of the Woronora Reservoir Impact Strategy are discussed in Section 4.3.

[12] Multi-level piezometer site 9EGW2A experienced failure of some lower level instrumentation. An additional hole was drilled adjacent to 9EGW2A (bore 9EGW2-4) to a depth of 557 m to install new piezometers at the same levels as the failed piezometers in December 2017.

In accordance with the Dams Safety NSW prior Approvals for mining within the Woronora Reservoir Notification Area[13], Metropolitan Coal has undertaken sampling programs to investigate the properties of groundwater above and below the Hawkesbury Sandstone and to establish chemical signatures that would indicate mining-induced fracturing through the Bald Hill Claystone, should it occur. The groundwater quality sites monitored in accordance with the Water Fingerprinting Monitoring Program are shown on Figure 11. The data analysis (to June 2021) shows through statistics, trend diagrams (Piper), time-series plots and ratio plots that although a few sampling sites were grout-impacted, there are sufficient reliable data to show a clear distinction between groundwaters in the upper Hawkesbury Sandstone, lower Hawkesbury Sandstone and upper Bulgo Sandstone, and that there is no evidence of mining-induced leakage across the Bald Hill Claystone.

The groundwater monitoring results are considered to be consistent with the potential subsidence impacts and environmental consequences described in the Project EA, Preferred Project Report, and Metropolitan Coal WMPs.

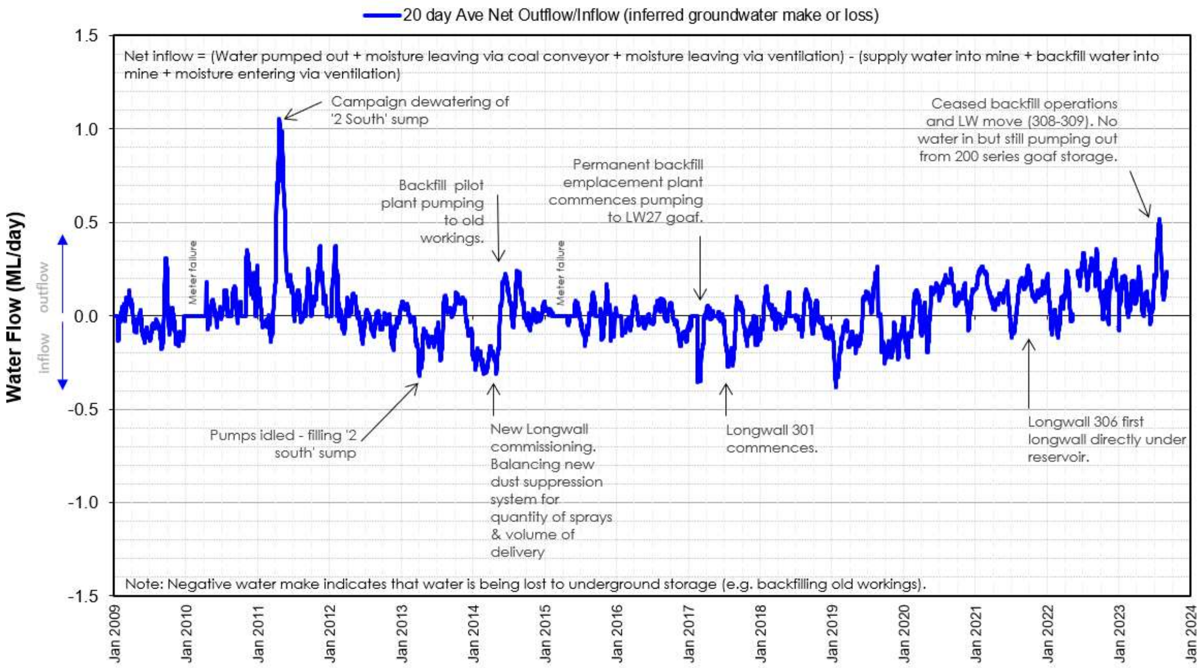


Chart 3a Estimated Daily Mine Water Make, 2009 to August 2023

[13] The Woronora Notification area was amended on 1 July 2022 to an area 1.5 km around the Woronora Dam wall which is outside or beyond the mining lease.

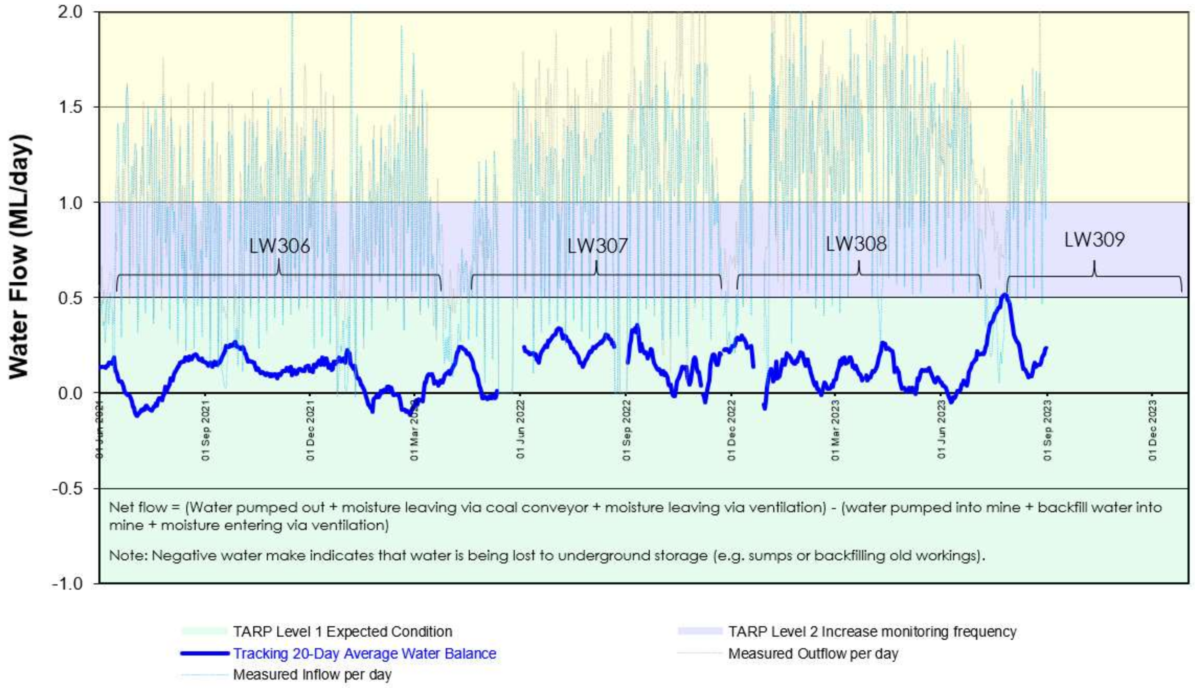


Chart 3b Estimated Daily Mine Water Make, January 2020 to August 2023

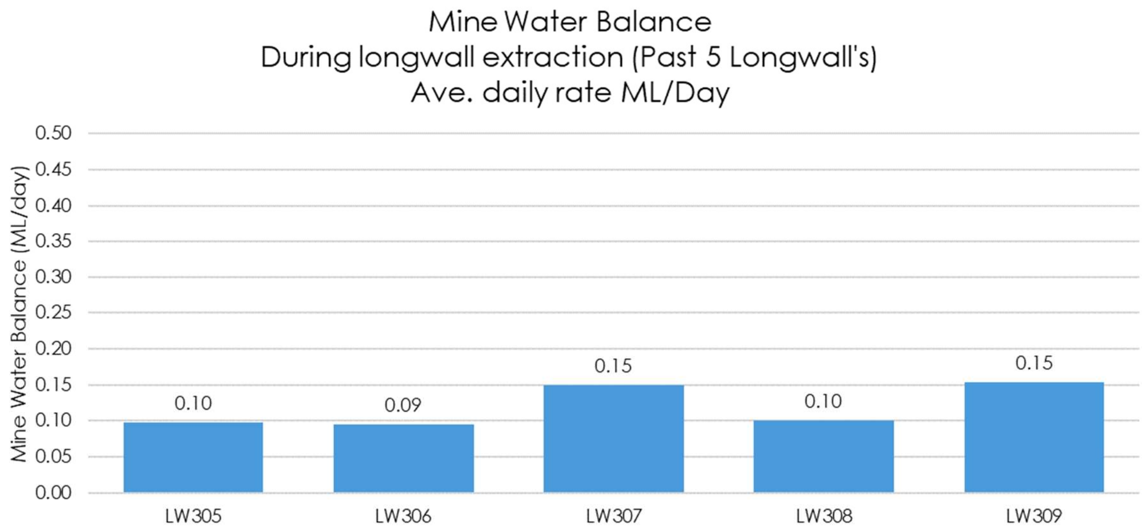


Chart 3c Mine Water Balance During Longwalls 305-309 Extraction

Significance of Chain Pillars on Simulated Groundwater Pressures

The Research Program, *Significance of Chain Pillars on Simulated Groundwater Pressures*, funded by Metropolitan Coal has been carried out by Dr. Noel Merrick (HydroSimulations, 2019). The research program has investigated the role played by chain pillars in isolating groundwater pressure reductions above mined longwall panels, and whether they might limit the outwards propagation of pressure reductions and environmental effects. The outcomes of this research provide an improved understanding of the significance of chain pillars with respect to alteration of the groundwater regime and a quantitative appreciation of critical pillar widths in absolute and relative terms.

The research program has examined spatial scale effects, and differences in spatial scales that are routinely applied in the geotechnical and hydrogeological disciplines. A cross-section model was built with a structured grid using traditional modelling software (MODFLOW-SURFACT), using a range of different scales.

The cross-sectional model was developed through three representative longwall panels (Longwalls 21, 22B and 23B) and several different scenarios with different model cell size and pillar width were run. The results of the modelled scenarios with variable model cell size show that the predicted mine inflows *decrease* with increasing cell size. The results of the modelled scenarios with variable chain pillar width show that the predicted mine inflows *decrease* with increasing pillar width. The cross-sectional model was found to be sensitive to reductions in the horizontal hydraulic conductivity above the chain pillars (to represent pillar overburden compression). Reducing the horizontal hydraulic conductivity results in a *decrease* in mine inflows, and an *increase* in pressure head above the pillars, for all model scenarios. The effect on mine inflow was found to be < 10%.

The cross-sectional model was not sensitive to the fracture zone shape. Changing the fracture zone from a rectangular to a parabolic shape did not result in a significant change to the mine inflows or groundwater levels. The use of a rectangular fracture zone shape, as is currently implemented in the Metropolitan Coal Mine regional groundwater model, and more generally in simulated mines elsewhere, is considered to be appropriate.

4.3 WORONORA RESERVOIR IMPACT STRATEGY

Condition 2 of the Longwalls 301 and 302 approval required Metropolitan Coal to conduct further investigation into potential impacts on the Woronora Reservoir. Metropolitan Coal engaged independent experts to prepare a Woronora Reservoir Impact Strategy to provide a staged plan of action for further investigations and a report into the impacts of mining near the reservoir. Professor Bruce Hebblewhite (B. K. Hebblewhite Consulting), Dr Frans Kalf (Kalf and Associates Pty Ltd) and Emeritus Professor Thomas McMahon (University of Melbourne) were endorsed by the DPIE for the Woronora Reservoir Impact Strategy in May 2017.

The *Woronora Reservoir Strategy Report – Stage 1* (Hebblewhite *et al.,* 2017) was provided by the independent experts to the DP&E in September 2017. The Stage 1 report included recommendations for further groundwater and surface water investigations and monitoring and was approved by the Secretary for Planning in December 2017.

The *Woronora Reservoir Strategy Report – Stage 2* (Hebblewhite *et al.,* 2019) was provided by the independent experts to the DPIE in June 2019. The Stage 2 report includes additional recommendations in regard to groundwater and surface water investigations and monitoring, based on further data and analysis arising from the ongoing monitoring programs, including those recommended in the original Stage 1 report.

The Stage 1 report included recommendations for further groundwater and surface water investigations and monitoring. The key outcomes and recommendations of the Stage 1 report were considered in the Longwall 304 Extraction Plan.

The Stage 2 report represents the second stage of the Woronora Reservoir Impact Strategy, based on further data and analysis arising from the ongoing monitoring programs, including those recommended in the Stage 1 report.

The surface water and groundwater monitoring locations that have been installed as a component of the Woronora Reservoir Impact Strategy are included in Sections 7 and 8, where appropriate.

The additional monitoring sites and environmental investigations for the Woronora Reservoir Impact Strategy included the installation of two streamflow monitoring stations in sub-catchments I and K to the west of Longwalls 301-303 and the installation of a pluviometer in the vicinity of the northern end of Longwall 307. The Stage 2 report recommended that further analysis of the data obtained from these monitoring sites (that covers at a minimum the initial 12-month period) be conducted. A summary of the outcomes of this assessment is provided below.

Data collected from the flumes on sub-catchments I and K commenced on 31 May 2018 and 3 June 2018, respectively (the flumes were installed on 17 May 2018 and 16 May 2018, respectively). Secondary extraction from Longwall 302 was occurring at the commencement of monitoring. Sub-catchment I overlies Longwall 301 to Longwall 305 while Sub-Catchment K predominately overlies Longwall 306 and Longwall 307. Sub-Catchment K formed a control for the assessment of potential impacts to streamflow in Sub-Catchment I associated with secondary extraction from Longwall 301 to Longwall 304.

Streamflow monitoring in sub-catchments I and K is proposed to continue up to the completion of Longwall 310.

Assessments of the dry weather recessions recorded at the flumes on sub-catchments I and K show consistent behaviour with time, although the recorded streamflow recession during low flow periods appears to be more rapid at the gauging station on Sub-Catchment K than on Sub-Catchment I. There is no visual indication of a change in recessionary behaviour (i.e. rate of recession) for Sub-Catchment I and no indication from the recorded stage and streamflow data that mining of Longwall 301 to Longwall 305 has impacted streamflow at the Sub-Catchment I gauging station. Additionally, there is no visual indication of a change in recessionary behaviour (i.e. rate of recession) for Sub-Catchment K and no indication from the recorded data that mining of Longwall 306 or Longwall 307 has impacted streamflow at the Sub-Catchment K gauging station (to June 2023), noting the Sub-Catchment K gauging was inundated by backwater from the Woronora Reservoir for periods of 2023. This is consistent with the results of monitoring of the quantity of water resources reaching the Woronora Reservoir for the Waratah Rivulet and Eastern Tributary.

A preliminary water balance of the Woronora Reservoir has been developed as a component of the Woronora Reservoir Impact Strategy. The primary purpose of the water balance analysis was to establish whether the inputs to and outputs from the Woronora Reservoir could be measured sufficiently and accurately to estimate a loss through the bed of the reservoir because of longwall mining being undertaken in the catchment and/or from other activities that may affect the water balance. The issues identified in the water balance suggest that the magnitude of bias and uncertainty in the data used in the analysis is such that it is doubtful that the water balance values provide a satisfactory baseline for assessing the potential loss of reservoir water through the bed and it was recommended that a Stage 2 water balance study be not undertaken.

A number of groundwater monitoring bores and inclinometer monitoring points have also been installed as a component of the Woronora Reservoir Impact Strategy. The results obtained to date are summarised below.

The Stage 2 report recommended groundwater model-derived cross sections be generated to display the pressure head profiles before and after mining specific panels with the zero pressure heads clearly displayed. Representative north-south and east-west cross sections have been prepared for Longwalls 311-316 using the re-calibrated model with stacked drains (Appendix 6).

In December 2019, the WRIS Panel prepared a letter report which provides a summary of the key conclusions from the Stage 1 and Stage 2 reports and considers the IEPMC *Report on Coal Mining Impacts in the Special Areas of the Greater Sydney Water Catchment* (dated 14 October 2019). It also considers feedback from the WRIS Panel's meeting with the DPIE, WaterNSW and Metropolitan Coal on 11 November 2019. The key findings of this report were:

1. *Connective fracturing/depressurisation and depressurisation alone extends up to approximately 195 m above the current 163 m wide longwall extraction zone (Figure 1).*
2. *There is virtually no pressure head propagation (i.e. depressurisation), that is pressure head loss, extending upwards beyond about 80 m from the surface and very little above 150 m from the surface (Figure 1). The depressurisation zone below 150m is recovering due to lateral groundwater flow.*
3. *There is no evidence of surface to longwall panel connectivity at the Metropolitan Mine, with inflows averaging 0.01 ML/day between January 2009 and April 2019.*
4. *There is a clear benefit in using narrower panels and wider chain pillars near and beneath the Woronora Reservoir as it substantially reduces subsidence predictions.*
5. *The ratios of 'width of panel' and 'depth of cover' at the Metropolitan Mine proposed for mining under the Woronora Reservoir (0.32 to 0.35) are similar to those used for the previously successful mining conducted with very low inflow reported at the South Bulli Mine and Bellambi West Colliery below the Cataract Reservoir (0.34 to 0.41).*
6. *Mining in the upper reaches of sub-catchment I has not impacted on flows recorded at the flume further downstream, consistent with the results of monitoring of the quantity of water resources reaching the Woronora Reservoir for the Waratah Rivulet and Eastern Tributary.*
7. *Water balance modelling of inputs to and outputs from the Woronora Reservoir indicates that the combined average loss from groundwater outflow under the dam wall and loss through the bed of the Woronora Reservoir is 2.9 ML/day with a 95% uncertainty band between 0.4 ML/day to 5.4 ML/day, in which ungauged inflows to the reservoir and reservoir evaporation are the major contributors to the uncertainty. The 2.9 ML/day equates to 3.6% of the total outputs modelled from the Woronora Reservoir. Taking into account the facts that groundwater outflow under than dam wall could not be adequately modelled, that there are problems in stream gauging a large proportion of the current ungauged area, and there are difficulties in estimating reservoir evaporation, it is recommended that a Stage 2 water balance study be not undertaken.*
8. *Based on the review of available data, analytical predictions and monitoring bore evidence at LW302, together with the use of narrower panels and wider chain pillars beneath the reservoir, the proposed longwall mining is not expected to result in connective cracking between the longwalls and surface or significant inflows from Woronora Reservoir to the mine extraction zone.*
9. *The existing monitoring regime should be continued, together with the additional monitoring recommended above. All monitoring results should be regularly reviewed against predicted values to provide ongoing confidence in the performance of the mining operation and its impacts.*

Metropolitan Coal understands that the WRIS Panel is no longer required to conduct investigations into potential impacts on the Woronora Reservoir and that these investigations will instead be conducted by the Independent Expert Advisory Panel for Mining (IEAPM).

4.3.1 Groundwater Monitoring Results

Groundwater pressures were first recorded at bore 302GW01 in November 2017 when the mining face was approximately 450 m to the south in the adjacent Longwall 301, heading away from 302GW01. During the extraction of Longwall 302, the heads in 302GW01 commenced rising in all but the shallowest piezometer when the mining face was about 300 m from the bore. The rises of 10-60 m are expected to be due to dynamic compression of the rock matrix as the mining face approached the bore. About a week before the mining face passed beneath the bore on 25 May 2018, the groundwater heads declined substantially, except for the shallowest piezometer at 80 m depth. About a week after the crossing, eight of the nine sensors ceased to function because the sensor cables sheared off at the shear planes identified by the TBS02 inclinometer surveys. However, the two corresponding sensors in bore TBS02 (20 m away), bracketing the Bald Hill Claystone, survived the crossing and continued to record meaningful data until November 2018 (P192) and January 2019 (P243). The maximum observed drawdowns were about 80 m at the base of the Hawkesbury Sandstone and about 140 m at the top of the Bulgo Sandstone. Since then, the water levels recovered by about 40 m and 50 m respectively (at November 2018), so that the pressure heads (the height of water above the sensor) at that time were about 70 m and 65 m respectively. Due to lost communication at TBS02, a redrill was installed to replicate the pre-mining hole adjacent to the 302GW01 hole (bore 302GW01-R). This hole commenced monitoring on 24 January 2019 with four Vibrating Wire Piezometers (VWPs) at 90 m (Hawkesbury Sandstone), 150 m (Hawkesbury Sandstone), 180 m (Hawkesbury Sandstone) and 245 m (Bulgo Sandstone). Apart from P245 which failed on 20 February 2019, the sensors have remained active. The pressure heads at the end of Longwall 305 were about 1 m, 30 m, and 50 m at piezometers P90, P150 and P180 respectively.

At bore TBS03 in the centre of Longwall 303, to the immediate west of TBS02, the corresponding pressure heads were about 90 m and 140 m respectively at November 2018. After that all communication was lost for these VWPs in December 2018. Four replacement piezometers were installed in a replacement hole (bore TBS03-230R) on 12 April 2019. Only the 162 m piezometer was installed in Hawkesbury Sandstone and three other piezometers at 213 m, 245 m, and 265 m were installed in the Bulgo Sandstone. All piezometers declined in head in April 2019 due to mining. Pressure heads recorded during the extraction of longwall 304 (15 September 2019 – last complete set of data) were about 54 m, 81 m, 67 m and 68 m at P162, P213, P245 and P265, respectively. VWP communication was lost at all sensors at TBS03 on 22 November 2019 after passing of LW304.

Further west, over the pillar between Longwalls 303 and 304, bore F6GW4A has been recording groundwater heads at eight depths since August 2013. The sensors at this bore responded to the passing of the mining face (450 m away) during Longwall 301 with mild rises in head at most depths followed by mild drawdown. During the extraction of Longwall 302 (250 m away), larger rises in head occurred prior to the date of crossing (25 May 2018) followed by substantial declines in the lowest three piezometers (from the lower Bulgo Sandstone to Bulli Coal). In January 2019, F6GW4A was undermined by Longwall 303 causing the depressurisation and disabling of the six lower sensors (139, 201, 278, 362, 440 and 512 metres below ground level [mbgl]). The upper and mid Hawkesbury Sandstone piezometers (50 and 90 mbgl) also displayed a lowering of groundwater head following the passage of Longwall 303; however, they showed no significant decline after the passage of Longwalls 304, 305 and 306. Both piezometers showed a slight increasing trend during January to June 2021. Both piezometers showed stable water levels since.

The deeper standpipe at TBS02-80 has recorded heads consistent with those at the 80 m piezometer at 302GW01, with a difference of about 3 m. While the 80 m piezometer at 302GW01 continues recording, with no evident sustained mining effect, the standpipe hole became obstructed. Replacement standpipes were installed in December 2018 to depths of 90 m (TBS02-90) and 190 m (TBS02-190). Since monitoring commenced from 20 February 2019, the 90 m hole appeared to run dry (at August 2019) before increasing and stabilising from 2022 onwards at approximately 18 m head.

4.3.2 Inclinometers

Two deep inclinometer monitoring points (TBS02-250 and TBS03-230) were established on the centreline axis of Longwall 302 and Longwall 303 to establish trends of horizontal shearing as the extraction of the respective longwalls progress towards the instruments. The inclinometers monitored horizontal shearing locations, measured the magnitude and direction of shearing in the Hawkesbury Sandstone and recorded any basal shearing on the sandstone contact with the Bald Hill Claystone formation. The installation was one of the deepest such inclinometer sites in Australia to date (Hebblewhite *et al*., 2019).

A total of 10 inclinometer surveys were completed pre-mining at TBS02-250 between January and June 2018. The data suggests lateral movement associated with the extraction of Longwall 302 has resulted in a north-east trending displacement across multiple shear planes identifiable at depths 74 m, 105 m, 114 m, 162 m and 202 m, the last depth being at the top of the Bald Hill Claystone. Inclinometer surveys were conducted at TBS02-230 between March and August 2018. The extent of shear movements is less than for site TBS02-250, with shear movements at depths within the 140 m to 190 m depth range, representing the time when Longwall 302 passed adjacent to the site. The inclinometer at TBS03-230 ceased to function after Longwall 303 passed beneath it. Based on this monitoring data, such shear plane activation is restricted to a region of less than 400 m from the edge of the goaf or edge of extraction (Hebblewhite *et.al*., 2019).

4.3.3 Permeability Measurements

In September 2017, pre-mining packer testing was conducted in bore 302GW01 for 15, 12 m sections from 238 m to 490 m depth, finishing in the Scarborough Sandstone. The interpreted hydraulic conductivities ranged from $8x10^{-7}$ metres per day (m/d) in the Scarborough Sandstone to $5x10^{-4}$ m/d in the lower Bulgo Sandstone, with a median of $8x10^{-5}$ m/d. Across these lithologies, the groundwater model has a median horizontal value of $3x10^{-3}$ m/d and a median vertical value of $1x10^{-5}$ m/d. Laboratory measurements of horizontal and vertical permeability were made on core taken from the Hawkesbury Sandstone, Bald Hill Claystone and Bulgo Sandstone. Typical results for horizontal hydraulic conductivity were $4x10^{-5}$, $4x10^{-6}$ and $2x10^{-6}$ m/d respectively. Corresponding typical values in the groundwater model are, respectively, $2x10^{-3}$, $7x10^{-5}$ and $6x10^{-3}$ m/d. The higher values in the model are consistent with the upscaling required when measurements are made at different scales.

At bore TBS02, pre-mining packer testing was conducted from 99 m in Hawkesbury Sandstone to 243 m total depth, beneath the Bald Hill Claystone. The Hawkesbury Sandstone hydraulic conductivities ranged from $2x10^{-6}$ m/d to $1x10^{-3}$ m/d with a median of $6x10^{-4}$ m/d. The Bald Hill Claystone measurements were $6x10^{-5}$ and $3x10^{-4}$ m/d (average $4x10^{-4}$ m/d), and the upper Bulgo Sandstone had a single value of $1x10^{-4}$ m/d. For these lithologies, the groundwater model has consistent horizontal hydraulic conductivities of $2x10^{-3}$ (median), $7x10^{-5}$ and $7x10^{-4}$ m/d.

In December 2018, post-mining packer testing was conducted in replacement hole 302GWR for 10 12-metre sections from 99 m to 243 m depth, with four shorter 6-metre sections at the top of the Bald Hill Claystone (183-207 m). The post-mining horizontal permeabilities were found to be not significantly different from the pre-mining values, except for a narrow highly permeable zone at the top of the Bald Hill Claystone or within the Newport Formation, corresponding to the shear plane identified by the inclinometer at 202 m depth. There is no evidence of any fracturing reaching the packer zone of investigation, which extended down to about 300 m above the Bulli coal seam. An acoustic televiewer downhole survey showed no fracturing to the maximum depth of the hole (300 m), about 250 m above the Bulli seam. Both investigations support the interpretation of the low pressures recorded at 302GW01 in the deeper piezometers as being anomalous (due to shearing) and not due to fracturing. The anticipated fracture heights (120-160 m) remain consistent with field investigations.

In May 2020, an exploratory hole was installed north-east of LW307 face line directly onto a seismic feature identified as a normal fault (FN004) 15 m above the Bulli Seam in the Wombarra Claystone. The purpose of the hole was to define permeability characteristics of the structure and surrounding host rock as well as gas reservoir definition to a total depth of 576 m. The fault was intersected at 479 m dipping at 43 degrees as predicted with drilling stopped immediately for packer testing. FN004 horizontal permeability measured $1.0x10^{-5}$ m/d versus the surrounding Wombarra Claystone at $1.0x10^{-4}$ m/d. Hydraulic conductivities measured across fault FN004 were comparable to those recorded in the unfractured host rock between the Bald Hill Claystone and the Bulli Seam, indicating negligible disturbance in horizontal flow associated with the FN004 fault at this location; i.e. the host claystone unit shares a similar transmissive signature to the intruding fault structure at this location, and the fault will not act as a conduit.

In August 2022, a groundwater monitoring hole was installed over the centreline Longwall 305 to review the groundwater behaviour of a narrow longwall after mining was completed. The hole was drilled to the base of the Bulgo Sandstone. Permeability testing was undertaken on the strata post-extraction and VWPs installed at certain horizons for long term review of groundwater behaviour.

Measured horizontal hydraulic conductivity (Kh) values and vertical conductivity (Kv) values are shown in Table 4 alongside their corresponding modelled values.

Table 4
Hydraulic Conductivity Information

Geology	Measured Kh Median (Range) (m/d)	Modelled Kh Median (m/d)	Measured Kv Median (m/d)	Modelled Kv Median (m/d)
Hawksbury Sandstone	$4x10^{-5}$ ($3x10^{-6}$ to $7x10^{-5}$)	$2x10^{-3}$	$8x10^{-5}$	$2x10^{-5}$
Bald Hill Claystone	$4x10^{-5}$	$7x10^{-5}$	$1x10^{-7}$	$7x10^{-4}$
Upper Bulgo Sandstone	$5x10^{-5}$ ($4x10^{-6}$ to $9x10^{-5}$)	$7x10^{-3}$	$5x10^{-6}$	$4x10^{-3}$
Lower Bulgo Sandstone	$4x10^{-4}$ ($9x10^{-4}$ to $1x10^{-1}$)	$1x10^{-1}$	$2x10^{-6}$	$2x10^{-2}$

Note: All values are stated at ±1 order of magnitude accuracy.

5 REVISED ASSESSMENT OF POTENTIAL ENVIRONMENTAL CONSEQUENCES

5.1 LONGWALLS 311-316 EXTRACTION LAYOUT

Longwalls 311-316 and the area of land within 600 m of Longwalls 311-316 secondary extraction are shown on Figures 1 and 2. Longwall extraction will occur from north to south. The layout of Longwalls 311-316 include 163 m and 138 m panel widths (void) and 45 m and 70 m pillar widths (solid). As the mine progresses west of the reservoir it will transition to 163 m panel widths, with 138 m panel widths remaining at the northern commencing within the angle of draw of the reservoir.

The provisional extraction schedule for Longwalls 311-316 is provided in Table 5.

Table 5
Provisional Extraction Schedule

Longwall	Estimated Start Date	Estimated Duration	Estimated Completion Date
Longwall 311	October 2024	8 Months	June 2025
Longwall 312	July 2025	6 Months	December 2025
Longwall 313	January 2026	5 Months	June 2026
Longwall 314	August 2026	9 Months	June 2027
Longwall 315	July 2027	8 Months	March 2028
Longwall 316	April 2028	8 Months	December 2028

The total cumulative predicted subsidence effects, subsidence impacts and/or environmental consequences at the completion of the Project are considered in the Project EA (HCPL, 2008) and the Preferred Project Report (HCPL, 2009), and the cumulative subsidence effects, subsidence impacts and environmental consequences will be assessed in future Extraction Plans.

5.2 ENVIRONMENTAL RISK ASSESSMENT

An Environmental Risk Assessment (ERA) was conducted for four of the key component plans of the Metropolitan Coal Longwalls 311-316 Extraction Plan[14] *viz.* Biodiversity Management Plan, Land Management Plan, Heritage Management Plan and this WMP to give appropriate consideration to risk assessment and risk management in accordance with the DPE (2022) *Extraction Plan Guideline*.

The suitably qualified and experienced experts endorsed by the Secretary of the DPE for the preparation of the Metropolitan Coal Longwalls 311-316 Extraction Plan participated in the ERA[15]. The ERA process involved the key steps described below.

[14] A risk assessment has been undertaken separately in relation to the Metropolitan Coal Longwalls 311-316 Public Safety Management Plan.

[15] Participants included Mr Peter DeBono (Mine Subsidence Engineering Consultants, Subsidence and Land), Ms Ines Epari (SLR Consulting, Groundwater), Mr Anthony Marszalek and Dr Camilla West (ATC Williams, Surface Water), Associate Professor Barry Noller (The University of Queensland, Surface Water Quality), Dr Sharon Cummins (Bio-Analysis Pty Ltd, Aquatic Fauna), Ms Elizabeth Norris (Ecoplanning, Flora), Mr Jamie Reeves (Niche Environment and Heritage, Heritage), Mr Jon Degotardi (Metropolitan Coal), Mr Stephen Love (Metropolitan Coal), Mr Nicolas Tucker (Metropolitan Coal), Mr Jamie Warwick (Resource Strategies), Ms Harper Mulloy (Resource Strategies) and Ms Abigail Ashford (Resource Strategies).

Review of Relevant Documentation and Risk Identification

In preparation for the ERA workshop, the ERA participants reviewed a number of documents relevant to the risk assessment. This included (but was not limited to):

- The 2008 *Environmental Risk Analysis* (SP Solutions, 2008) conducted for the Project EA (Appendix O of the Project EA).
- The Preferred Project Report (HCPL, 2009). During the NSW Government's assessment phase of the Project EA, and in recognition of concerns raised by key stakeholders during the formal Planning Assessment Commission assessment process, HCPL considered it appropriate to reduce the proposed extent of the original Project longwall mining area (i.e. Longwalls 20-44). This reduction in the extent of longwall mining resulted in a significant reduction to the extent of potential subsidence effects to the Waratah Rivulet and the Eastern Tributary and a reduction in the consequential potential environmental impacts.
- The Longwalls 308-310 Environmental Risk Assessment Report (Operational Risk Mentoring, 2019) (which included consideration of the Longwalls 301-303, Longwall 304 and Longwalls 305-307 Environmental Risk Assessment Reports).
- Figures showing the Longwalls 311-316 layout in relation to key surface features.
- Subsidence predictions for Longwalls 311-316 (including subsidence contours, Eastern Tributary, Waratah Rivulet, Woronora Reservoir, other streams, cliff sites, upland swamps and Aboriginal heritage sites).

The participants were asked to identify any additional (specific) issues/risks and/or changes to previously assessed levels of risk in preparation for the ERA workshop.

ERA Workshop

The ERA workshop for Longwalls 311-316 was conducted on 18 August 2023, with all participants attending via video conferencing. The ERA workshop was facilitated by an independent specialist, Dr Peter Standish of Risk Mentor and conducted in accordance with AS/NZS ISO 31000: *2009 Risk Management – Principles and Guidelines.*

The general consensus of the workshop participants was the additional (specific) issues/risks identified for Longwalls 311-316 were broadly assessed and ranked as part of the 2008 Environmental Risk Analysis, Longwalls 301-303, Longwall 304, Longwalls 305-307 and/or Longwalls 308-310 ERAs. However, additional (specific) issues were identified by the workshop participants relevant to Longwalls 311-316. Each of the issues/risks were explained systematically by the relevant workshop participants and each carefully reviewed.

Loss scenarios for the key potential environmental issues were identified for upland swamps, aquatic biota, threatened amphibians, Waratah Rivulet and the Woronora Reservoir. The risk rankings are within the "low-medium" range and consequently the potential outcomes can be integrated into the existing management systems for effective review and monitoring.

ERA Report Review

All ERA participants were asked to review the draft Longwalls 311-316 ERA report that was prepared to summarise the outcomes of the risk assessment. Participants' comments were incorporated into the final Risk Mentor (2023) report.

This WMP has been prepared to provide for effective management of the identified subsidence risks.

5.3 RISK ASSESSMENT FOR GEOLOGICAL FEATURES AND WATER QUANTITY TO THE WORONORA RESERVOIR AND ABORIGINAL HERITAGE

The IEPMC Initial Report recommended that the potential implications for water quantity of faulting, basal shear planes and lineaments be carefully considered and risk assessed at all mining operations in the Catchment Special Areas (IEPMC, 2018).

In relation to the Metropolitan Coal Mine, the IEPMC Initial Report concluded (pg 127):

> *In the case of Metropolitan Mine:*
>
> - *…..*
> - *the potential for water be diverted out of Woronora Reservoir and into other catchments through valley closure shear planes and geological structures including lineaments will require careful assessment in the future because it is planned that most of the remaining longwall panels in the approved mining area will pass beneath the reservoir.*

A risk assessment workshop was held on 25 July 2023. The workshop participants[16] identified and assessed the potential for mining effects on lineaments, joints, faulting, basal shear planes and dykes to impact on the quantity of water to the Woronora Reservoir, including the potential for water to be diverted out of Woronora Reservoir and into other catchments. Participants also assessed the impacts to Aboriginal heritage sites as a result of mining effects on geological features.

The participants considered the risk control measures and procedures to be reasonable to manage the identified risks.

Further information on the risk assessment is provided in the Longwalls 311-316 Coal Resource Recovery Plan.

5.4 REVISED SUBSIDENCE PREDICTIONS

The subsidence predictions for Longwalls 311-316 in relation to streams have been prepared by MSEC (2024)[17].

Waratah Rivulet

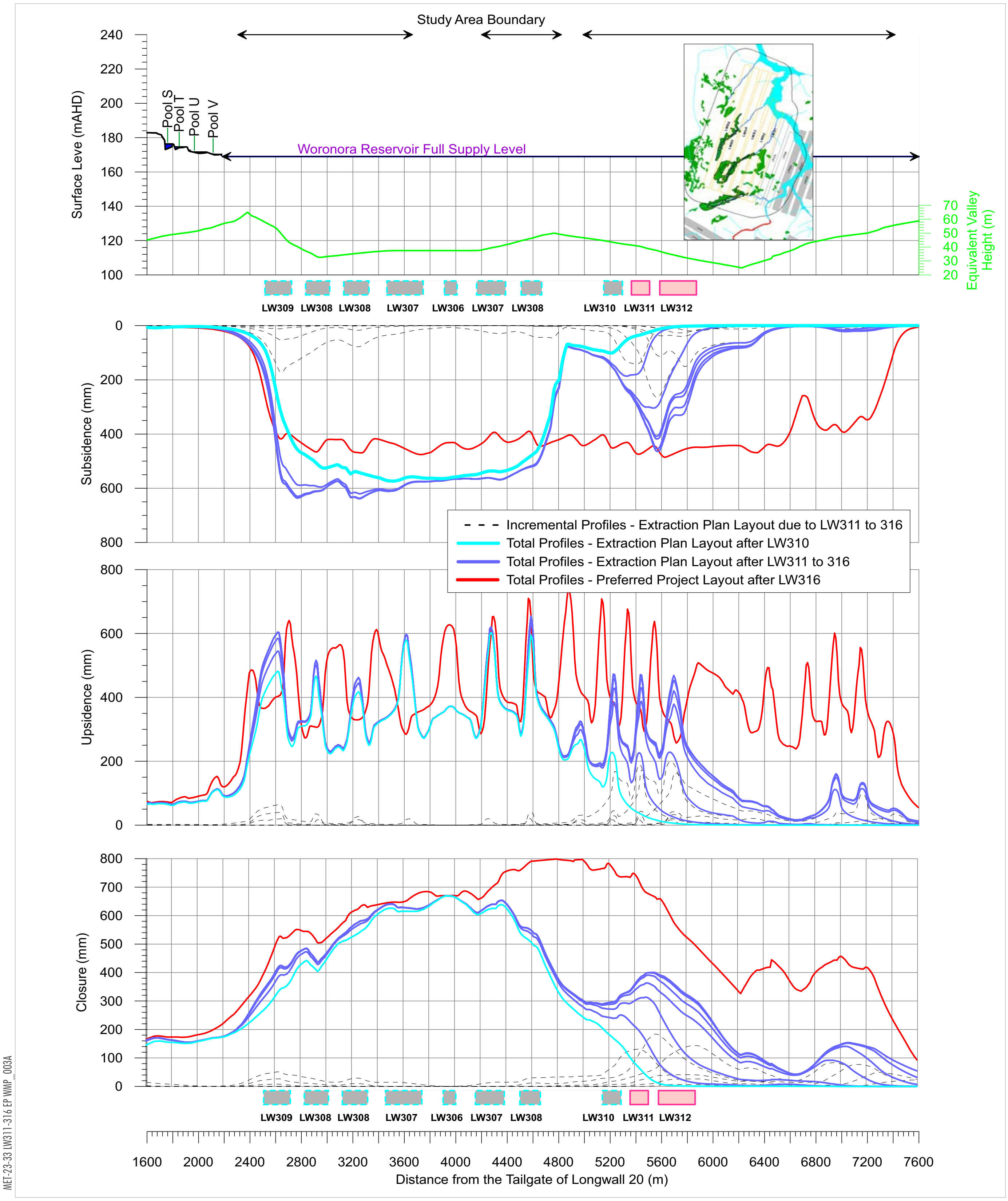
The Waratah Rivulet flows to the north-east and into the full supply level of the Woronora Reservoir, approximately 550 m to the south-east of Longwalls 311-316 (Figures 1 and 2). The predicted profiles of subsidence, upsidence and closure along the Waratah Rivulet (to the full supply level of the Woronora Reservoir), resulting from the extraction of Longwalls 311-316, are shown on Figure 12 (MSEC, 2024).

The maximum predicted values of upsidence and closure for the Waratah Rivulet (to the full supply of the Woronora Reservoir), after Longwall 310 and resulting from the extraction of Longwalls 311-316, is provided in Table 6 (MSEC, 2024). The values are the predicted maxima within the Longwalls 311-316 35° angle of draw and/or predicted 20 mm subsidence contour.

---

16 Participants included Ines Epari (SLR Consulting, Principal Hydrology & Hydrogeology) Peter DeBono (Mine Subsidence Engineering Consultants, Subsidence), Shane Kornek (Metropolitan Coal, Senior Geotechnical Engineer), Jon Degotardi (Metropolitan Coal, Approvals Manager), Roger Byrnes (Byrnes Geotechnical, Principal Geotechnical Engineer) and Stephen Love (Metropolitan Coal, Environment & Community Superintendent). The risk assessment was facilitated by Mr Nate Bain (Peabody Senior Mining Engineer).

17 The revised subsidence effects, subsidence impacts and potential environmental consequences to upland swamps are addressed in the Metropolitan Coal Longwalls 308-310 Biodiversity Management Plan (Figure 3).



Source: MSEC (2024)

Peabody
METROPOLITAN COAL

Predicted Profiles of Subsidence, Upsidence and Closure along the Waratah Rivulet and Woronora Reservoir due to Longwalls 311-316

Figure 12

The maximum predicted conventional tilt for the Waratah Rivulet is less than 0.5 mm/m (i.e. 0.05%, or 1 in 2,000) (MSEC, 2024). The maximum predicted conventional curvatures are less than 0.01 km^{-1} hogging and sagging, which equate to minimum radii of curvature of greater than 100 km. The predicted conventional strains for the Waratah Rivulet (based on 15 times the curvature) are less than 0.5 mm/m tensile and compressive (MSEC, 2024). The maximum predicted total closure on the Waratah Rivulet resulting from the extraction of Longwalls 311-316 is 175 mm (MSEC, 2024).

At distances of over 550 m from Longwalls 311-316, the Waratah Rivulet is located outside the Study Area and is not expected to experience measurable conventional vertical subsidence, tilts, curvatures, and strains (i.e. no greater than survey accuracy).

Table 6
Maximum Predicted Upsidence and Closure for the Waratah Rivulet Resulting from Longwalls 311-316 Extraction

Longwall	Maximum Predicted (to the full supply level of the Woronora Reservoir)	
	Upsidence[1] (mm)	Closure[2] (mm)
After LW310	100	175
After LW311	125	175
After LW312	125	175
After LW313	125	175
After LW314	125	175
After LW315	125	175
After LW316	125	175

Source: after MSEC (2024).
mm = millimetres
1 Upsidence is the reduced subsidence, or the relative uplift within a valley which results from the dilation or buckling of near surface strata at or near the base of the valley.
2 Closure is the reduction in the horizontal distance between the valley sides.

The maximum predicted valley closure for the rock bars/boulder field downstream of Pool P, resulting from Longwalls 311-316 is provided in Table 7. Rock bars V and W are located within the Longwalls 311-316 35° angle of draw and/or predicted 20 mm subsidence contour.

Table 7
Maximum Predicted Total Closure at Rock Bars/Boulder Field along the Waratah Rivulet

Longwall	Maximum Predicted Total Closure (mm)					
	RB-P	RB-Q	RB-R	RB-S	RB-T	RB-V
After LW310	125	125	150	150	150	175
After LW311	150	150	175	175	150	175
After LW312	150	150	175	175	150	175
After LW313	150	150	175	175	150	175
After LW314	150	150	175	175	150	175
After LW315	150	150	175	175	150	175
After LW316	150	150	175	175	150	175

Source: after MSEC (2024).
mm = millimetres

Table 7 indicates that there is negligible additional predicted closure at the rock bars upstream of the full supply level of the Woronora Reservoir (MSEC, 2024).

A comparison of the maximum predicted closure for the rock bars, resulting from the Extraction Plan Layout of Longwalls 311-316, with those based on the Preferred Project Layout is provided in Table 8.

Table 8
Comparison of Maximum Predicted Closure for the Waratah Rivulet Rock Bars based on the Preferred Project Layout and the Extraction Plan Layout

Layout	Maximum Predicted Total Closure (mm)					
	RB-P	RB-Q	RB-R	RB-S	RB-T	RB-V
Preferred Project Layout (after LW316)	150	150	175	175	200	225
Extraction Plan Layout	150	150	175	175	150	175

Source: after MSEC (2024).
mm = millimetres

The maximum predicted closure for the rock bars downstream of Pool P, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout at Rock Bars Q, R, S, T and V and the maximum predicted closure is the same at Rock Bar P (MSEC, 2024).

Eastern Tributary

The Eastern Tributary flows in an approximate south to north direction into the full supply level of the Woronora Reservoir approximately 1.4 km (at the full supply level) to the east of Longwall 311.

Being 1.4 km or more east of Longwall 311, the Eastern Tributary is not predicted to experience measurable valley related movements and conventional subsidence movements during the extraction of Longwalls 311-316.

The Eastern Tributary has been managed using an adaptive management approach during the extraction of Longwalls 303 to 306 with a comprehensive monitoring program undertaken at Rock Bar ETAU.

Woronora Reservoir

The Woronora Reservoir full supply level is located above the commencing ends of Longwalls 311-316. The area of the Woronora Reservoir full supply level immediately downstream of the Waratah Rivulet and Eastern Tributary is referred to as an inundation area. When the Woronora Reservoir is at full capacity, this area is flooded. When the water level is below the full supply level, portions of the inundation area form temporary pools above exposed rock bars.

The predicted profiles of vertical subsidence, upsidence and closure for the Woronora Reservoir full supply level, resulting from the extraction of Longwalls 311-316, are shown on Figure 12 (for the alignment of the Waratah Rivulet) and Figures 13a, 13b and 13c (for the alignment of Tributary P, Tributary R and Tributary S).

A summary of the maximum predicted values of total subsidence, tilt, curvature, upsidence and closure for the Woronora Reservoir full supply level, after Longwall 310 and resulting from the extraction of Longwalls 311-316 is provided in Table 9. The values are the predicted maxima within the 35° angle of draw and/or predicted 20 mm subsidence contour for Longwalls 311-316.

Table 9
Maximum Predicted Subsidence, Tilt, Curvature, Upsidence and Closure for the Woronora Reservoir Resulting from Longwalls 311-316 Extraction

Longwall	Maximum Predicted					
	Subsidence (mm)	Tilt (mm/m)	Hogging Curvature (km^{-1})	Sagging Curvature (km^{-1})	Upsidence (mm)	Closure (mm)
After LW310	575	2.5	0.02	0.03	600	675
After LW311	625	3.5	0.04	0.03	625	675
After LW312	625	4.0	0.04	0.03	650	675
After LW313	650	4.0	0.04	0.03	650	675
After LW314	650	4.0	0.04	0.03	650	675
After LW315	650	4.0	0.04	0.03	650	675
After LW316	650	4.0	0.04	0.03	650	675

Source: after MSEC (2024).
mm = millimetres; mm/m= millimetres per metre; km^{-1} =1/kilometres

The maximum predicted conventional tilt for the Woronora Reservoir full supply level is 4.0 mm/m (i.e. 0.4%, or 1 in 250). The maximum predicted conventional curvatures are 0.04 km^{-1} hogging and 0.03 km^{-1} sagging, which equate to minimum radii of curvature of 25 km and 33 km, respectively (MSEC, 2024). The predicted conventional strains for the Woronora Reservoir full supply level (based on 15 times the curvature) are < 1 mm/m tensile and compressive (MSEC, 2024).

A comparison of the maximum predicted vertical subsidence, upsidence and closure for the Woronora Reservoir full supply level resulting from the Extraction Plan Layout of Longwalls 311-316, with those based on the Preferred Project Layout after Longwall 316, is provided in Table 10.

The revised maximum predicted upsidence and closure for the Woronora Reservoir full supply level, are less than the maxima for the Preferred Project Layout (MSEC, 2024). The revised maximum predicted subsidence is greater than the maxima for the Preferred Project Layout (MSEC, 2024). The maximum predicted total closure on the Woronora Reservoir full supply level resulting from the extraction of Longwalls 311-316 is 825 mm (Table 10).

Table 10
Comparison of Maximum Predicted Conventional Subsidence Parameters for the Woronora Reservoir based on the Preferred Project Layout and the Extraction Plan Layout

Layout	Maximum Predicted Total Conventional		
	Subsidence (mm)	Upsidence (mm)	Closure (mm)
Preferred Project Layout (after LW316)	475	800	825
Extraction Plan Layout	650	650	675

Source: after MSEC (2024).
mm = millimetres

The maximum predicted closure based on the Extraction Plan Layout is less than the maximum predicted based on the Preferred Project Layout.

Other Drainage Lines/Streams

There are a number of other tributaries also located within the Longwalls 311-316 35° angle of draw and/or predicted 20 mm subsidence contour (Figure 2). These streams consist of shallow drainage lines from the topographical high points, forming tributaries where valley heights increase and drain into the Woronora Reservoir. The streams are located above Longwalls 311-316, and could experience the full range of predicted subsidence movements, with maximum predicted closure up to 700 mm (MSEC, 2024).

Three larger tributaries are located within the Longwalls 311-316 35° angle of draw and/or predicted 20 mm subsidence contour (Figure 2). These tributaries are identified as Tributary P (through Swamp 92), Tributary R (through Swamp 77) and Tributary S (through Swamp 76). The predicted profiles of subsidence, upsidence and closure through Swamps 76, 77 and 92 resulting from the extraction of Longwalls 311-316, are shown on Figure 13a, Figure 13b and Figure 13c, respectively.

5.5 REVISED ASSESSMENT OF POTENTIAL SUBSIDENCE IMPACTS AND ENVIRONMENTAL CONSEQUENCES

5.5.1 Surface Water

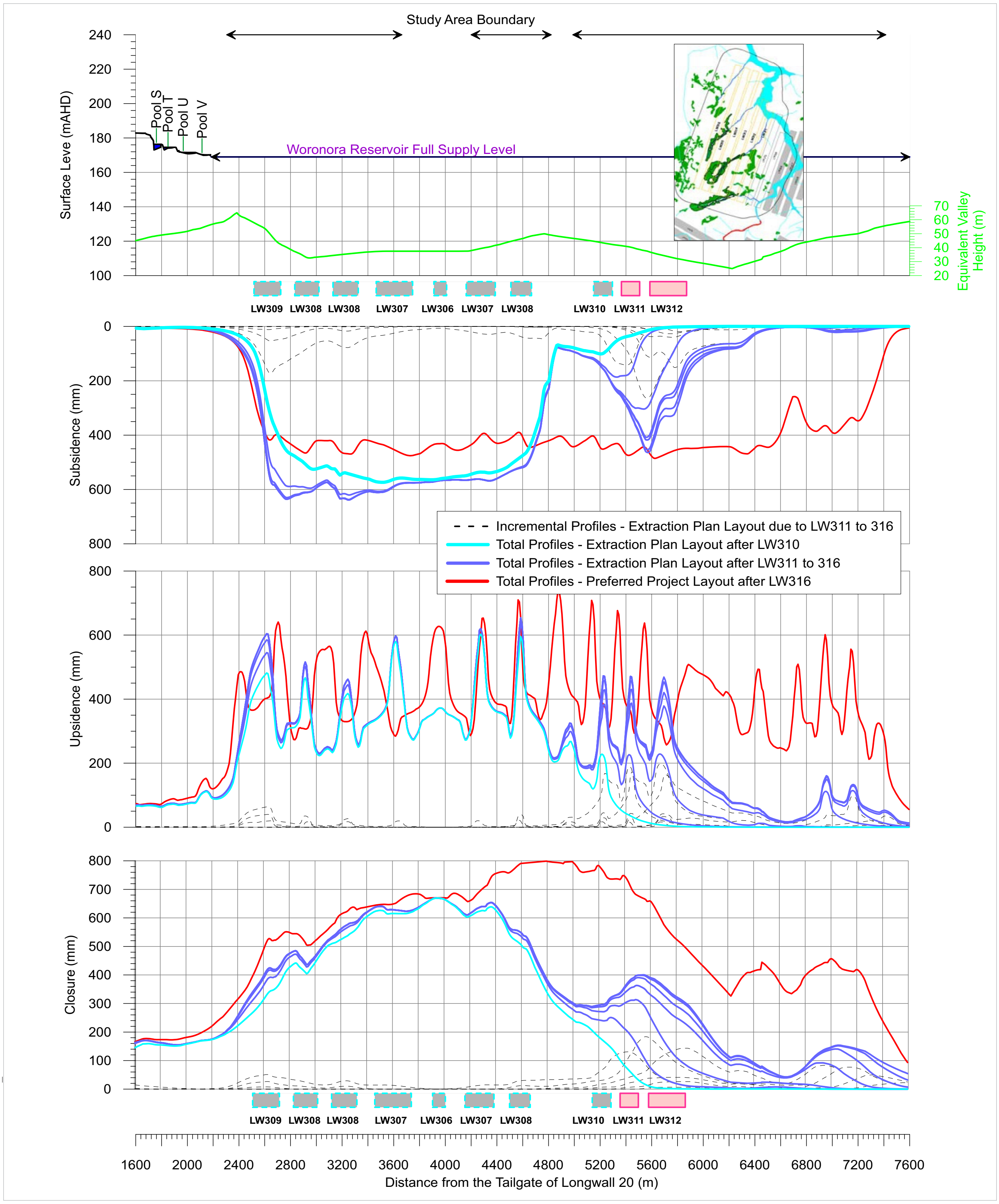
The maximum predicted subsidence parameters for the Waratah Rivulet, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout.

Previous assessments of stream impacts at Metropolitan Coal have used a relationship between predicted total closure at rock bars and proportion of impacted pools for streams in the Southern Coalfield. The relationship identified approximately 10% of pools were impacted at a predicted total valley closure of up to 200 mm (MSEC, 2021). Impacts to some pools along the Eastern Tributary resulting from the extraction of Longwall 27, have occurred at predicted values of total valley closure of less than 200 mm resulting in a higher proportion of impacted pools at lower magnitudes of predicted total valley closure. As a result of the observed impacts to the Eastern Tributary, the finishing ends of Longwalls 303, 304 and 305 were set back to minimise predicted valley closure at the Eastern Tributary.

As described in Section 4.1, Metropolitan Coal has established a comprehensive monitoring and adaptive management program to identify subsidence related movements at the Eastern Tributary to minimise the risk of further exceedance of the Eastern Tributary performance measure. The Eastern Tributary Valley Closure TARP has been successfully implemented by Metropolitan Coal for Longwalls 303, 304 and 305. The same monitoring and adaptive management program was used for the extraction of Longwalls 306, 307, 308 and 309.

As discussed in Section 4.1, the restriction of predicted total valley closure to 200 mm has been a successful design tool for complying with the negligible environmental consequence performance measure on the Waratah Rivulet. Furthermore, the geotechnical study of the Waratah Rivulet (detailed in Section 4.1) concluded that the geological features identified along the Eastern Tributary are considered to be unique, compared to the Waratah Rivulet. The Eastern Tributary is therefore more likely to be susceptible to subsidence movements. Restricting valley closure to 200 mm therefore continues to be an appropriate design tool for the Waratah Rivulet.

Given that the maximum predicted closure for the rock bars downstream of Pool P, based on the Extraction Plan Layout, are less than or equal to the maxima predicted based on the Preferred Project Layout, and that the maximum predicted total valley closure for the rock bars downstream of Pool P is 150 mm (Table 8), the potential subsidence impacts and environmental consequences described in the Project EA, Preferred Project Report, and Metropolitan Coal Water Management Plans in relation to the Waratah Rivulet continue to be applicable for Longwalls 311-316.



MET-23-33 LW311-316 EP WMP_003A

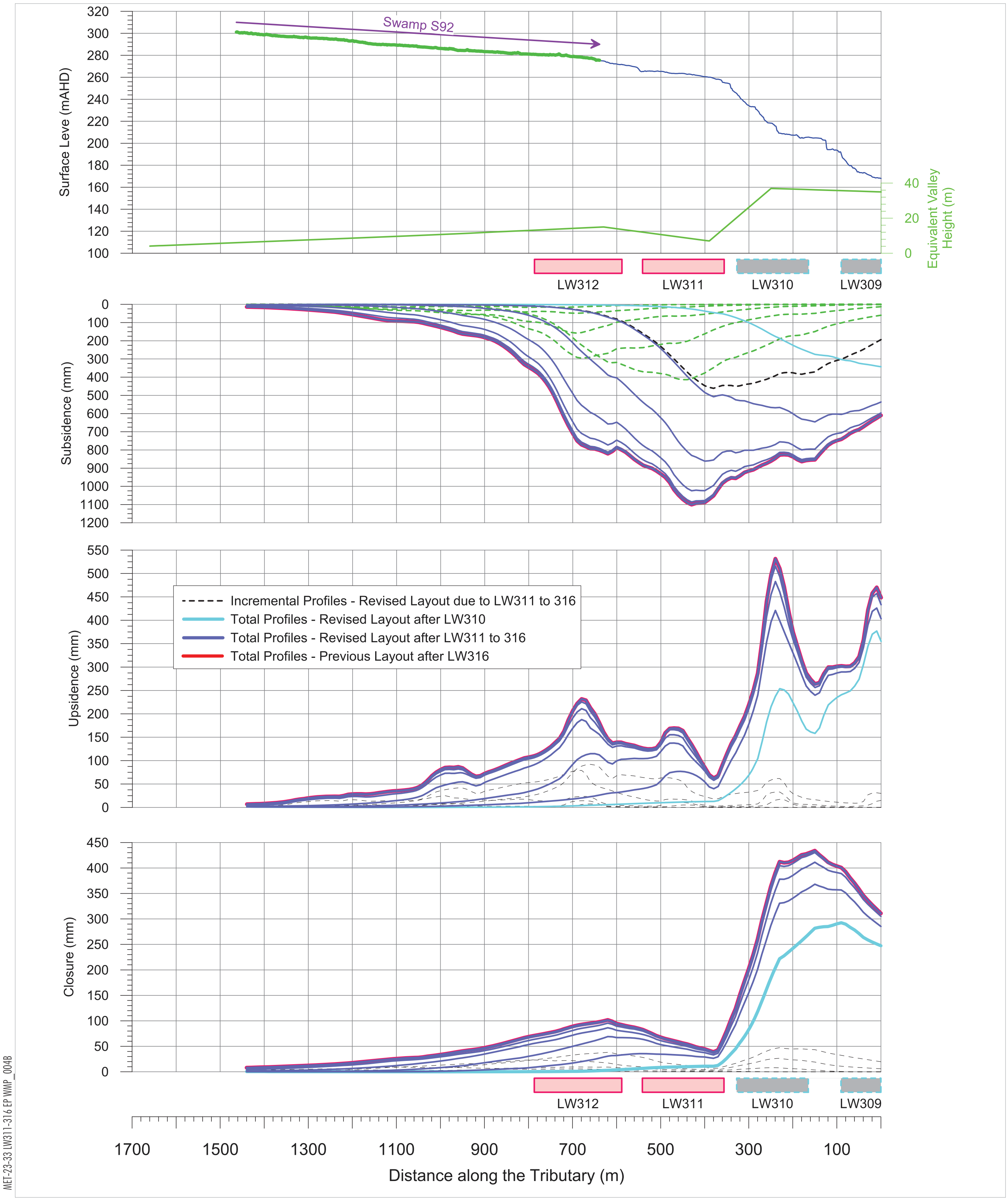
Source: MSEC (2024)

Peabody

METROPOLITAN COAL

Predicted Profiles of Subsidence, Upsidence and Closure along the Waratah Rivulet and Woronora Reservoir due to Longwalls 311-316

Figure 12



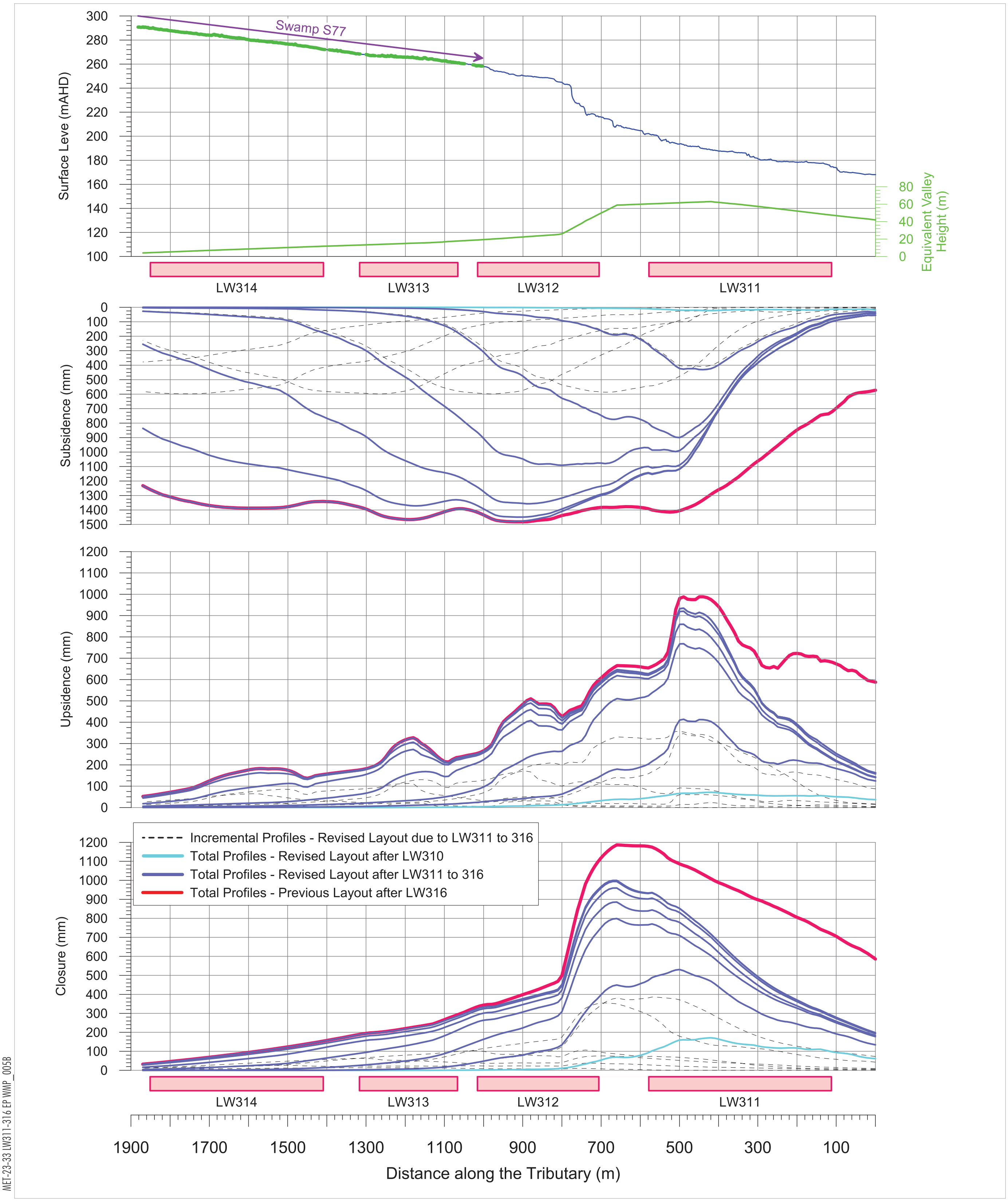
Source: MSEC (2024)

Peabody

METROPOLITAN COAL

Predicted Profiles of Subsidence, Upsidence and Closure along Tributary P due to Longwalls 311-316

Figure 13a



Source: MSEC (2024)

METROPOLITAN COAL

Predicted Profiles of Subsidence, Upsidence and Closure along Tributary R due to Longwalls 311-316

Figure 13b

The Independent Expert Scientific Committee's (IESC's) *Advice to decision maker on coal mining – Further advice on impacts to swamps (24 July 2015)* (IESC advice) and IEPMC (2018) Initial Report contend that areas containing lineaments may experience greater than normal subsidence. The IEPMC (2018) Initial Report indicates that in recent years it has been identified in the Western Coalfield that surface subsidence, groundwater and surface water responses to longwall mining can be significantly modified in the vicinity of lineaments[18]. Further to advice from the IEPMC, and at the request of the DPIE, specific regard was given in the Longwall 304, Longwalls 305-307 and Longwalls 308-310 Extraction Plans to the potential impacts of mining near and under lineaments on surface water features, including waterfalls. A similar assessment has been conducted for the Longwalls 311-316 Extraction Plan[19].

Lineaments and faults mapped by Metropolitan Coal in close proximity to streams within 600 m of Longwalls 311-316 are shown on Figure 14.

A lineament that aligns with the Eastern Tributary at the waterfall at the downstream end of Rock Bar ETAU (Figure 14) is aligned with a 20 mm wide minor strike-slip fault, F0021, which has zero vertical displacement. No moisture has been evident at seam level where it crosses the 300 mains or in the Longwalls 303 maingate. WaterNSW representatives were shown this particular strike-slip fault, along with F0008 during an underground inspection on 19 March 2019[20]. WaterNSW representatives concurred that the faults are not readily apparent without the assistance of Metropolitan Coal's geologist.

It is considered likely that Fault F0008 and Fault F0021, would have similar characteristics and behave in a similar manner to that experienced by mine extraction and development to date. Similar to the assessment for Longwall 304 and Longwalls 305-307, hydraulic connectivity via lineaments to the waterfall at Rock Bar ETAU on the Eastern Tributary is considered to be highly unlikely as a result of the extraction of Longwalls 311-316.

A strike slip fault, F0027, with zero vertical displacement, has been mapped in the gate roads leading into Longwalls 304 and 305. The associated surface linear is located approximately 250 m west of the end of the Eastern Tributary arm of Woronora Reservoir full supply level. No moisture has been evident at seam level where F0027 crosses the 300 mains or in the Longwalls 304 or 305 maingate. Similar to the assessment for F0008 and F0021, hydraulic connectivity of F0027 via lineaments on the Eastern Tributary is considered to be highly unlikely as a result of the extraction of Longwalls 311-316.

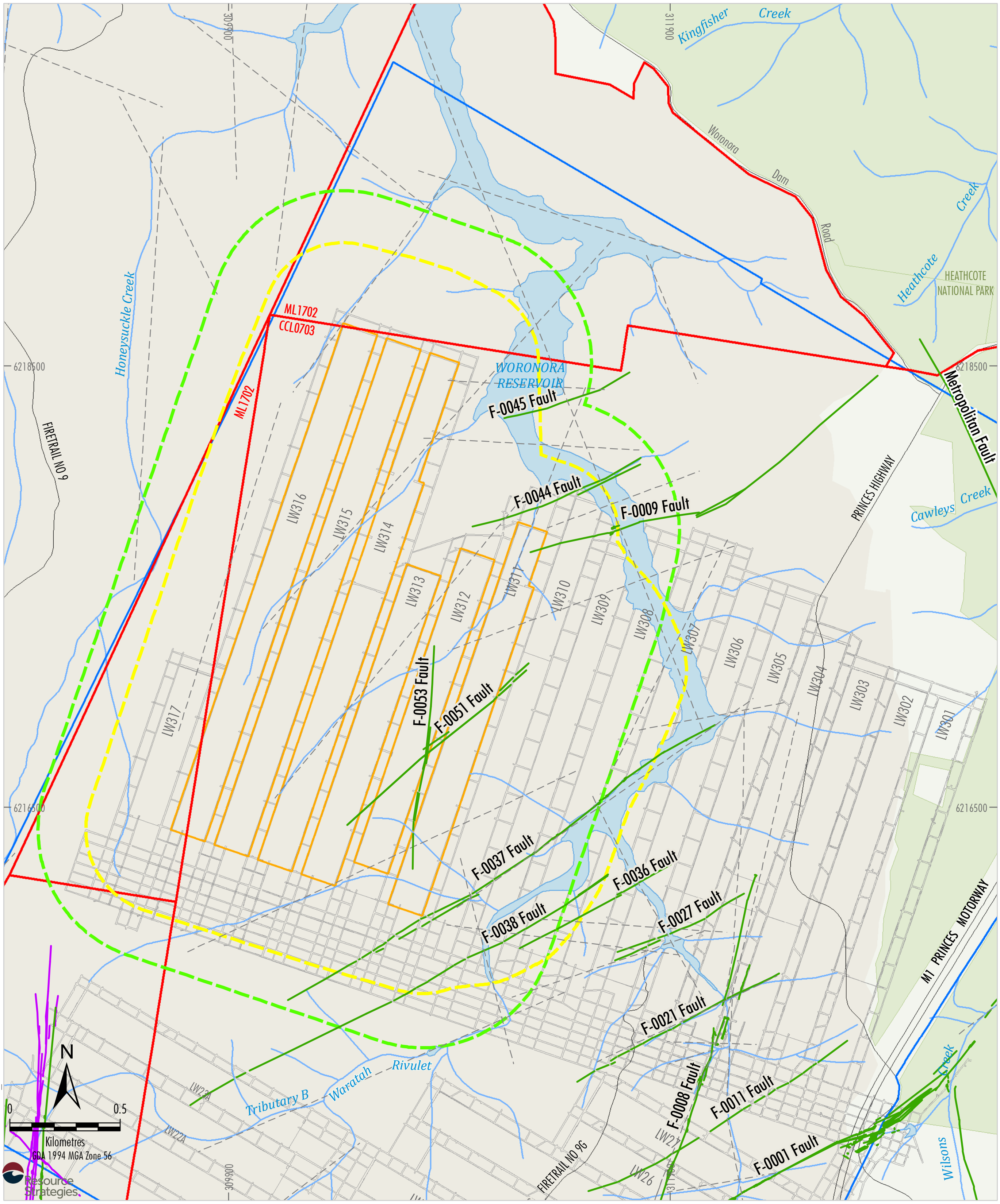
A strike slip fault, F0037, with zero vertical displacement, has been mapped in the gate roads and the three longwalls extracted through this feature, being Longwalls 306, 307 and 308. The associated surface linear is aligned with the Waratah Rivulet arm of Woronora Reservoir. Similar to previous experience of mining through these features no moisture has been evident from F0037 structure in the seam. The Longwalls 311-316 Geological Features Risk Assessment participants were shown images of F0037 during longwall extraction with the structure displaying dry and dusty conditions.

---

[18] Drawing comparisons of lineament behaviour between two geographically separated regions is problematic, given the degree of variables potentially present. Depth to the basement rock is a variable with likely substantive influence on behaviour of lineaments and markedly different between the Western and Southern Coalfields. Many features of the NSW Coalfields surface topography are directly correlated to the basement structure, the depth of the basement from the surface through many sedimentary epochs and the deformational episodes of the basement rock.

[19] The risk assessment conducted for potential impacts of mining effects on geological features on the quantity of water resources to the reservoir is discussed in Section 5.3. The risk assessment conducted for potential impacts of mining effects on geological features on surface water resources, including waterfalls is discussed in Section 5.2.

[20] WaterNSW representatives on the underground visit included Ms Fiona Smith (Executive Manager, Water and Catchment Protection) and Mr Peter Dupen (Manager, Mining).



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 311-316 Secondary Extraction
- Longwalls 311-316 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 311-316 Secondary Extraction
- Faults (of note or greater than 1 km strike)
- Dykes
- Lineament

Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2023); MSEC (2024);

Peabody

METROPOLITAN COAL

Mapped Faults and Lineament over Longwalls 311-316 and Surrounds

Figure 14

F0009 is a normal fault with a displacement of 0-18 m located north of Longwall 308 and with a south-west strike bisecting Longwall 309 and diminishing to 0 m displacement at Longwall 310. The displacement of F0009 combined with coal quality north of the structure led to an economic decision to reposition the Longwall 308 and 309 face line from the Preferred Project Layout to the Extraction Plan Layout. Longwall 310 is anticipated to be able to ramp through the structure.

A detailed seismic assessment of F0009 was commissioned to determine the vertical extent of the structure with multiple dedicated seismic lines installed to provide a suitable resolution throughout the stratigraphy. The Velseis (2018) report concluded:

> *The large normal fault F0009 can be seen to impact the Bulli Seam only, and there is no evidence from available seismic data that this normal fault extends to the shallower Bald Hill Claystone level in the stratigraphy*

From the detailed seismic report, the fault is not vertically extensive, residing at depth about the Illawarra Coal Measures. Whilst not vertically extensive, horizontally the structure extends north-west away from the extraction area towards the Metropolitan Fault. From the point where F0009 bisects Longwall 309 to the Metropolitan fault, the horizontal distance is approximately 1.5 km.

To demonstrate the structure poses negligible effects to the groundwater systems, a surface to seam borehole (2020EX02) was approved and installed in 2020. This hole, located along strike, approximately 500 m north-west of the intercept with Longwall 309, was designed to measure the horizontal permeability characteristics of F0009 by coring through the structure at depth. An assessment of the permeability characteristics found (Golder Associates Pty Ltd, 2020):

> *Hydraulic conductivities measured across the fault were comparable to those recorded for the unfractured host rock… there is negligible variance in horizontal flow characteristics associated with the fault measured at this location.*

Detailed surface mapping has not identified any associated surface linear with F0009. The Longwalls 311-316 Geological Features Risk Assessment participants were shown images of F0009 during development mining with the structure displaying dry and dusty conditions and a tight unbroken contact with the surrounding rock. Given the available data, it is highly unlikely that this feature would provide hydraulic connectivity either vertically or horizontally as a result of the extraction of Longwalls 311-316, similar to previous experiences of mining through other structures such as F0008, F0021, F0027 and F0037. The risk posed by F0009 was carefully considered and reviewed during the Longwalls 311-316 Geological Features Risk Assessment, with the continuation of a control to visual monitor F0009 for signs of moisture and further delineation to occur on roadway advancement (similar to controls previously used for structures passed through by mining).

The maximum predicted subsidence parameters for the Woronora Reservoir full supply level, based on the Extraction Plan Layout, are less than or equal to the maxima predicted based on the Preferred Project Layout. The potential impacts on the Woronora Reservoir, based on the Extraction Plan Layout, therefore, are predicted to be consistent with or less than those assessed based on the Preferred Project Layout (including cracking at the base of valleys and fracturing and dilation of the underlying strata when the reservoir level is lower than the full supply level). Further, it is noted that Longwall 306 commenced mining beneath the Woronora Reservoir (vertically) from September 2021, and Metropolitan Coal has not identified abnormal water flow from the goaf, geological structure, or the strata generally.

The first and second order streams located above Longwalls 311-316 (Figure 2) could experience the full range of predicted subsidence movements. The potential subsidence impacts and environmental consequences for these streams, based on the Extraction Plan Layout, are consistent with those assessed for the Preferred Project Layout that are described in Sections 4.1 and 5.4.

5.5.2 Groundwater

The revised subsidence predictions for the Extraction Plan Layout do not change the subsidence impact assessment or assessment of environmental consequences provided in the Project EA and Preferred Project Report for groundwater that are described in Section 4.

Potential environmental consequences of Longwalls 311-316 extraction on aquifers and baseflow to watercourses have been predicted using the latest calibrated model (SLR Consulting, 2020). The model provides predictions of impacts and mine inflow that can be used to assess the performance of the Project, as described in Section 8. As mining and data collection proceed, confidence levels in the model parameters will increase.

Catchment Yield[21]

Based on the period of record available for the Woronora Reservoir (1977 to 2008) at the time of the Project EA, the model predictions indicate a negligible reduction in catchment yield due to Longwalls 311-316 extraction (i.e. 0.4% of the annual average yield to the reservoir)[22].

Mine Groundwater Inflows

The simulated groundwater inflow to Longwalls 301-316 is presented on Chart 4 for the groundwater model, from the start of the 300-series mains to the end of Longwall 316 (assuming no subsequent mining). The groundwater inflow is expected to be approximately 0.02 ML/day at the start of Longwall 301 to a maximum of approximately 0.13 ML/day at the start of Longwall 314. As these rates are consistent with the predictions made in the Project EA, the Project EA estimates of mine groundwater inflow at the end of mining remain valid.

Chart 4 Predicted Groundwater Inflows to Longwalls 301-316 as Mining Proceeds

---

21 Total water flow from the catchment including surface and sub-surface contributions.

22 Gilbert & Associates (2008) prepared a water balance for Woronora Reservoir using Sydney Catchment Authority (now WaterNSW) reservoir data and calculated a total yield to Woronora Reservoir over 31 years of approximately 800,000 ML, which equates to an annual average yield of 25,806 ML. The updated groundwater model predicts 0.27 ML/day (100 ML/annum) reduction in catchment yield for Longwalls 311-316 extraction.

Vertical Head Profiles

Vertical profiles of potentiometric head are effective monitors of the capacity of an aquifer system to maintain pressure during the formation of deformation zones caused by caving and subsidence. Head profiles show a characteristic reduction in head with depth due to mining. That is, as mining moves closer, groundwater pressures are expected to fall.

The predicted head profiles for multi-piezometer bores are presented on Charts 5 to 13 at the end of Longwalls 311 and 316. The locations of these bores are shown on Figure 10.

All piezometer locations show a predicted reduction in potentiometric head from the Scarborough Sandstone downwards due to future mining at LW311-316; the magnitude of this reduction is dependent on proximity to mining. Piezometers PM01, PM02, and 9EGW1B all directly overlie LW311-316 and have the greatest predicted head changes between end of Longwall 310 and end of Longwall 316 (> 170 m). 9EGW2A, PHGW1B, and PHGW2A are located within 1 km of Longwalls 311-316 and show minor head changes (< 50 m). F6GW3A, F6GW4A, and 9GGW2B are greater than 1 km from mining and show no significant additional change in potentiometric head throughout the vertical profile from the end of LW310 to the end of LW316. As the responses at bores F6GW3A, F6GW4A, 9EGW2A, 9GGW2B, PHGW1B, and PHGW2A show no significant predicted change as mining progresses away from those sites to the west, there is no need for ongoing reporting at these sites.

The performance measures, *No connective cracking between the surface and the mine* and *Negligible leakage from the Woronora Reservoir* are predicted to not be exceeded by the mining of Longwalls 311-316.

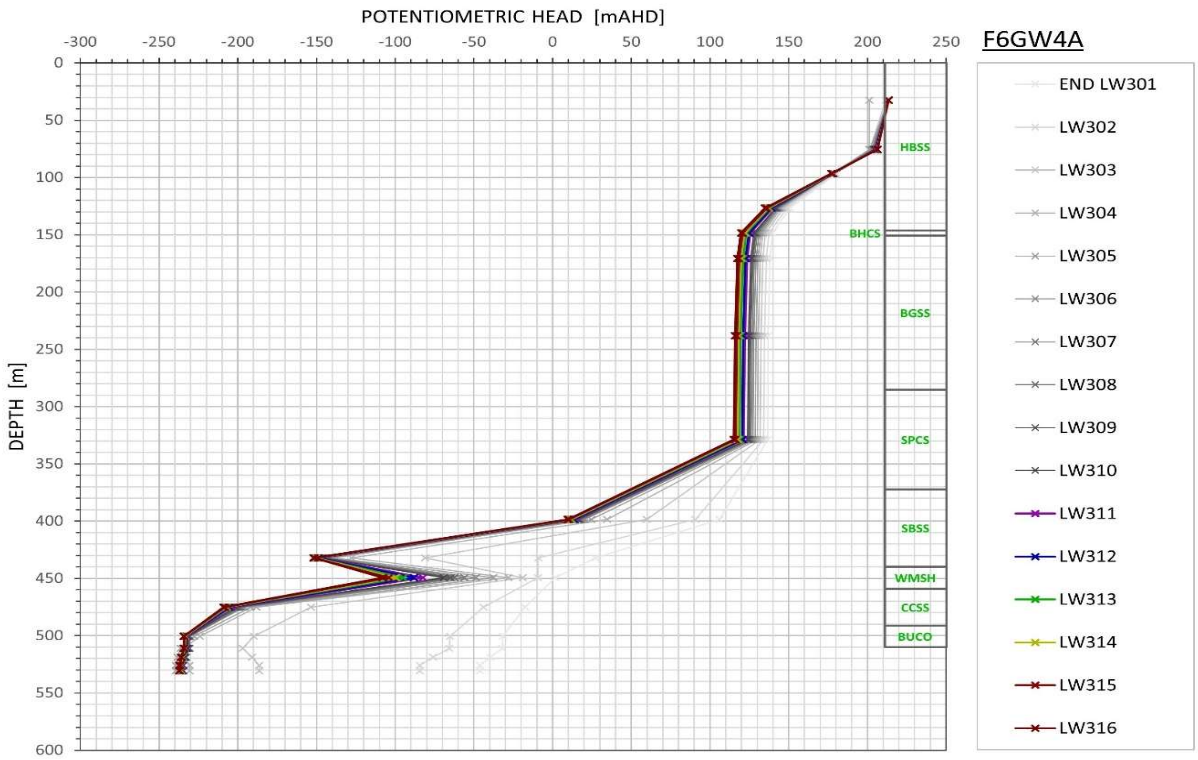


Chart 5 Predicted Vertical Head Profile at Bore F6GW4A at the end of Longwalls 311 to 316

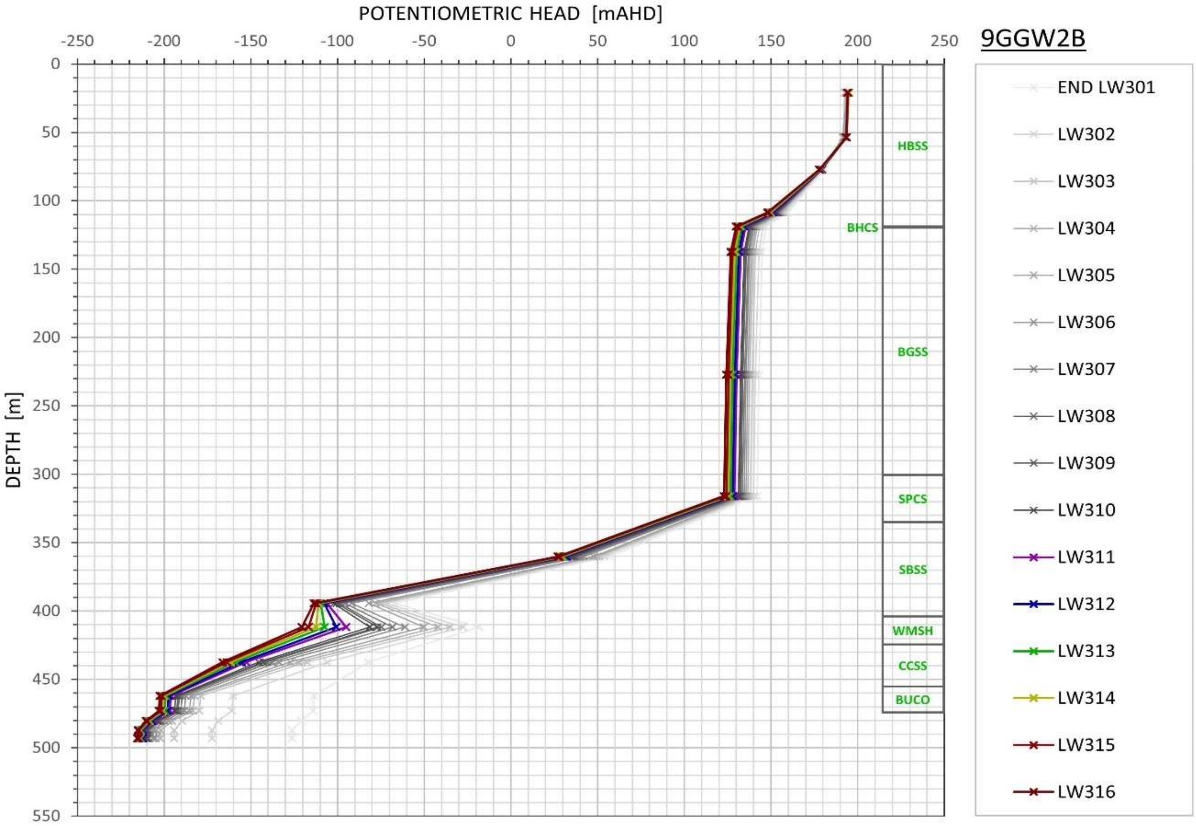


Chart 6 Predicted Vertical Head Profile at Bore 9GGW2B at the end of Longwalls 311 to 316

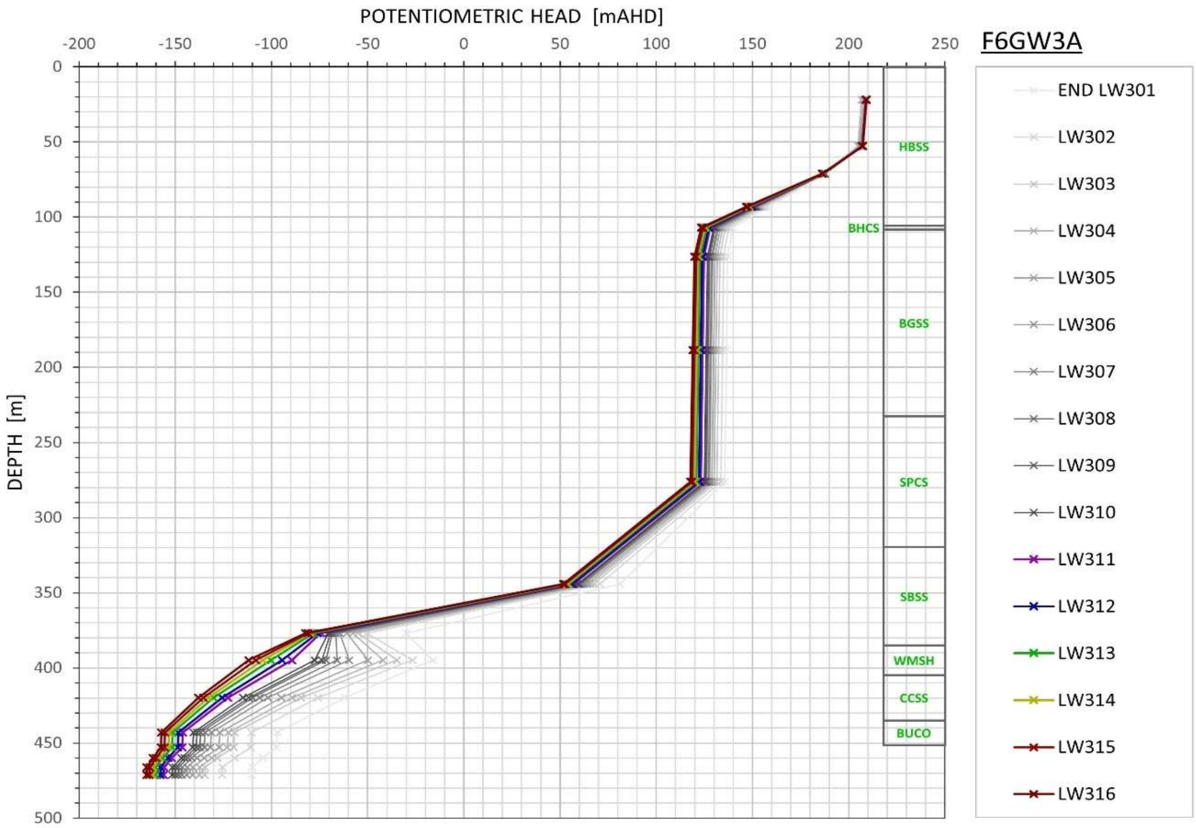


Chart 7 Predicted Vertical Head Profile at Bore F6GW3A at the end of Longwalls 311 to 316

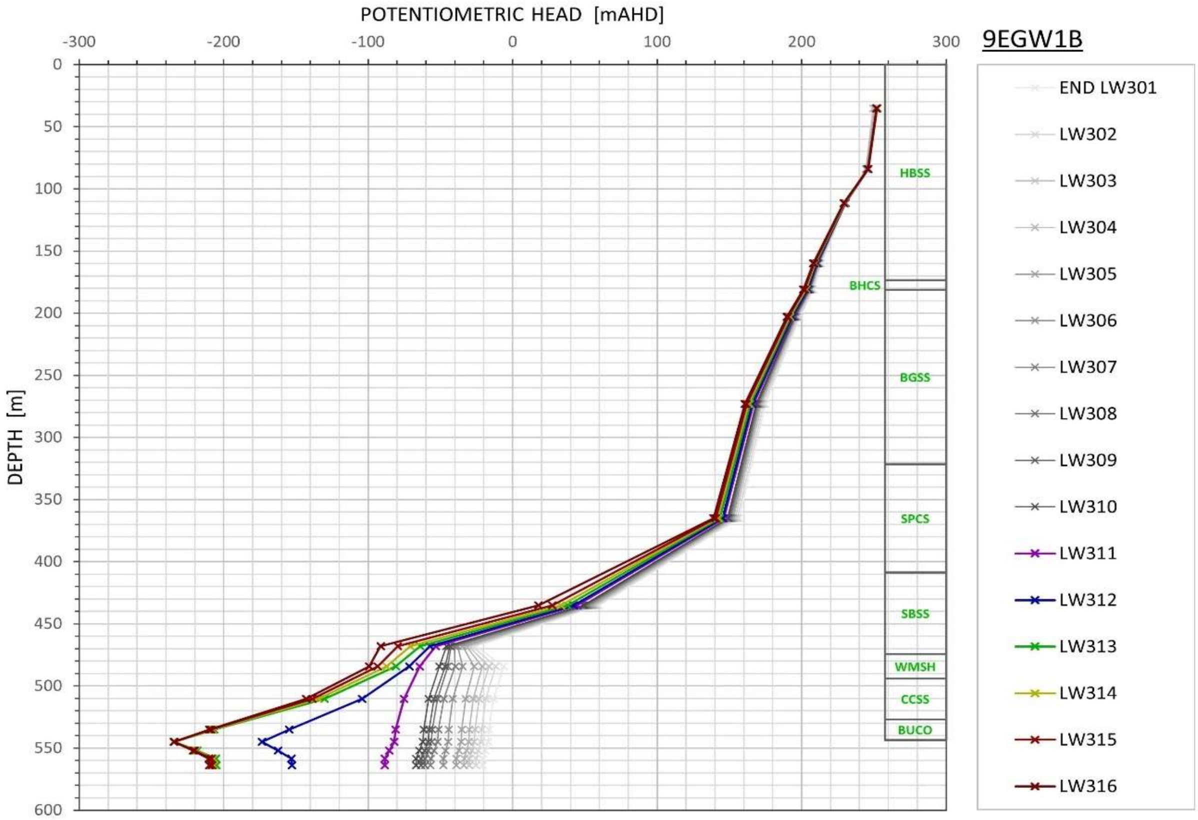


Chart 8 Predicted Vertical Head Profile at Bore 9EGW1B at the end of Longwalls 311 to 316

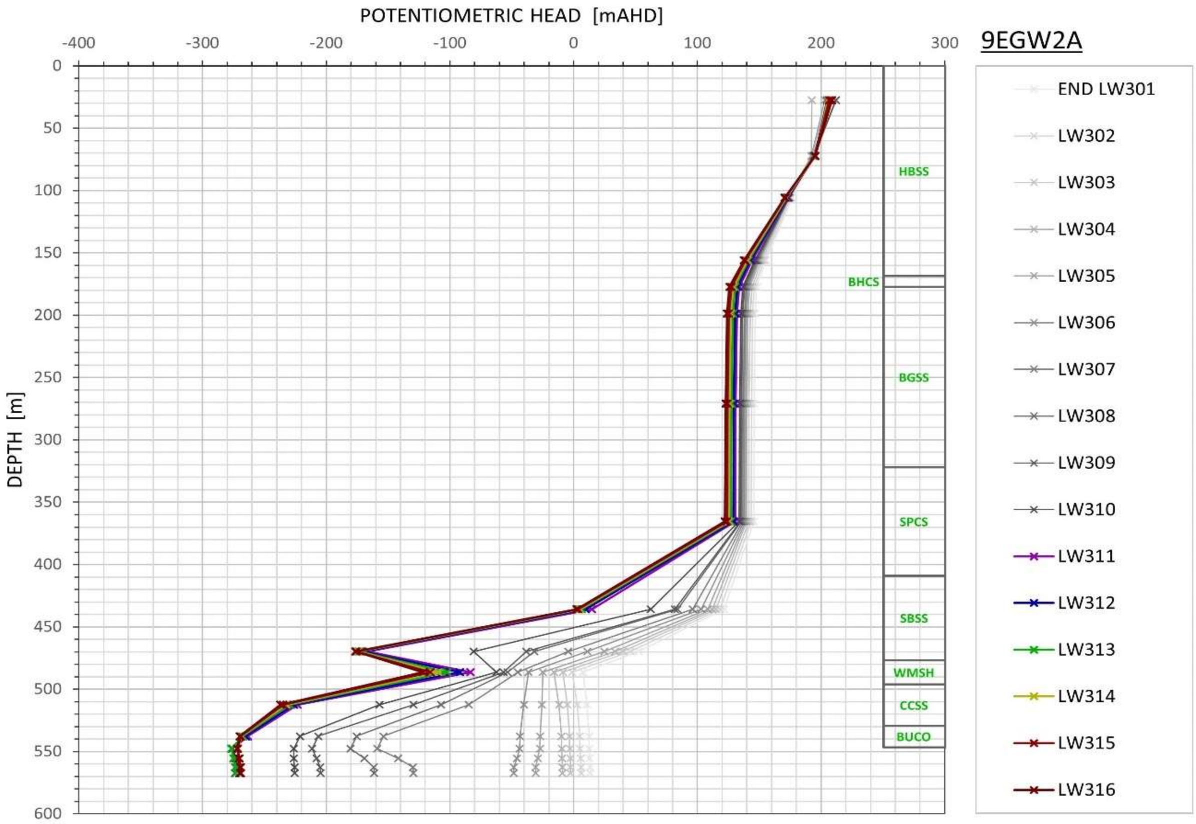


Chart 9 Predicted Vertical Head Profile at Bore 9EGW2A at the end of Longwalls 311 to 316

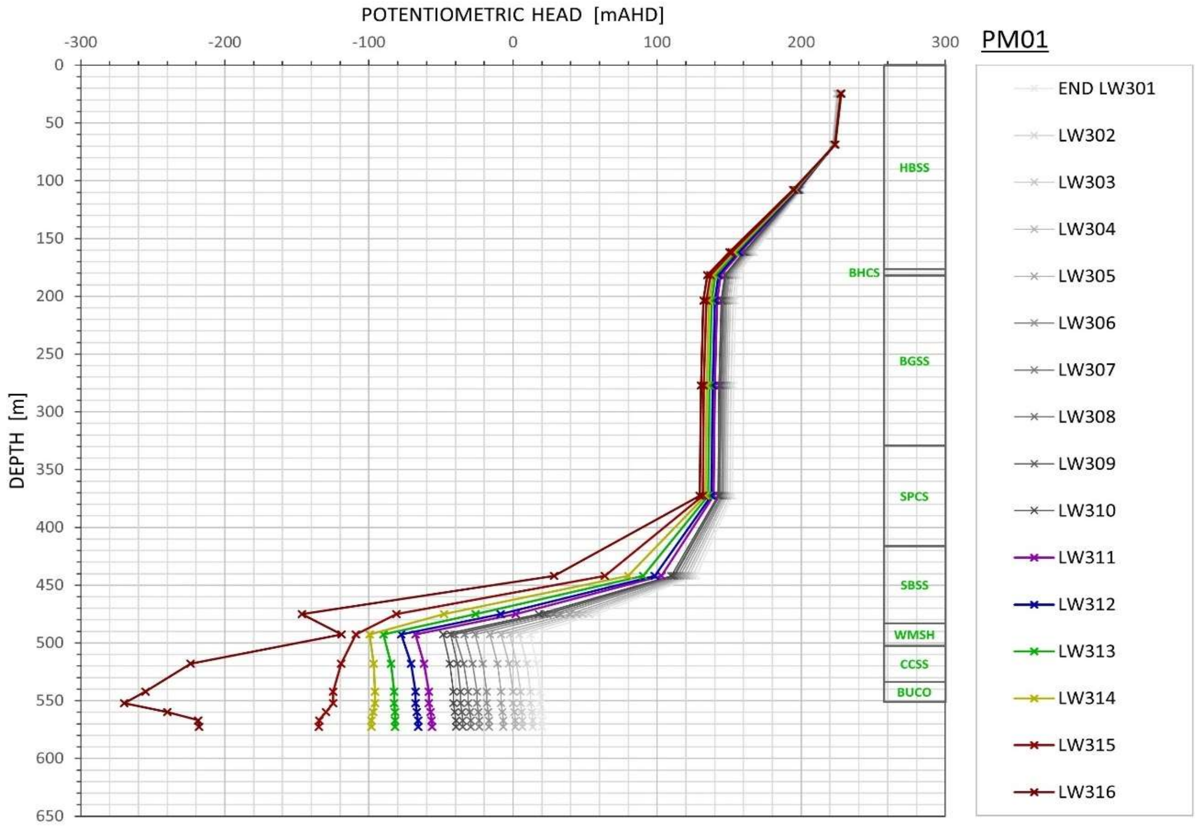


Chart 10 Predicted Vertical Head Profile at Bore PM01 at the end of Longwalls 311 to 316

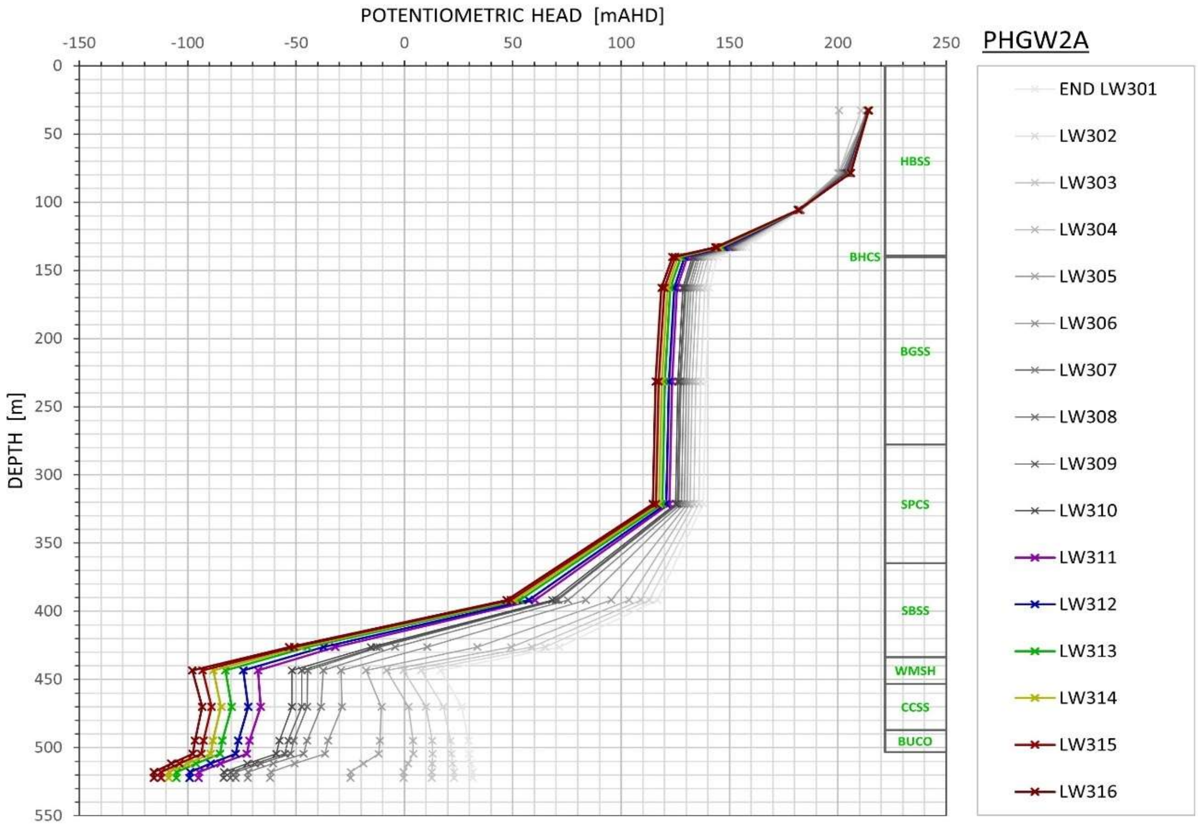


Chart 11 Predicted Vertical Head Profile at Bore PHGW2A at the end of Longwalls 311 to 316

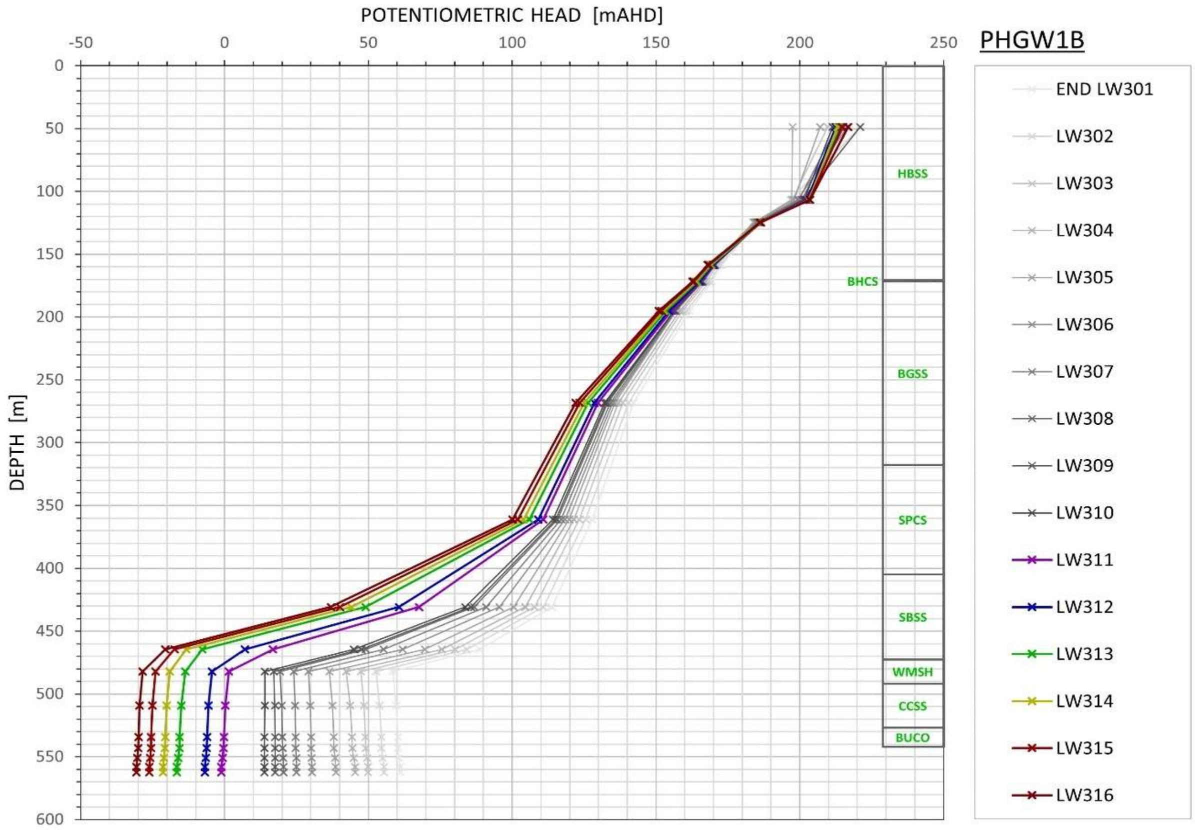


Chart 12 Predicted Vertical Head Profile at Bore PHGW1B at the end of Longwalls 311 to 316

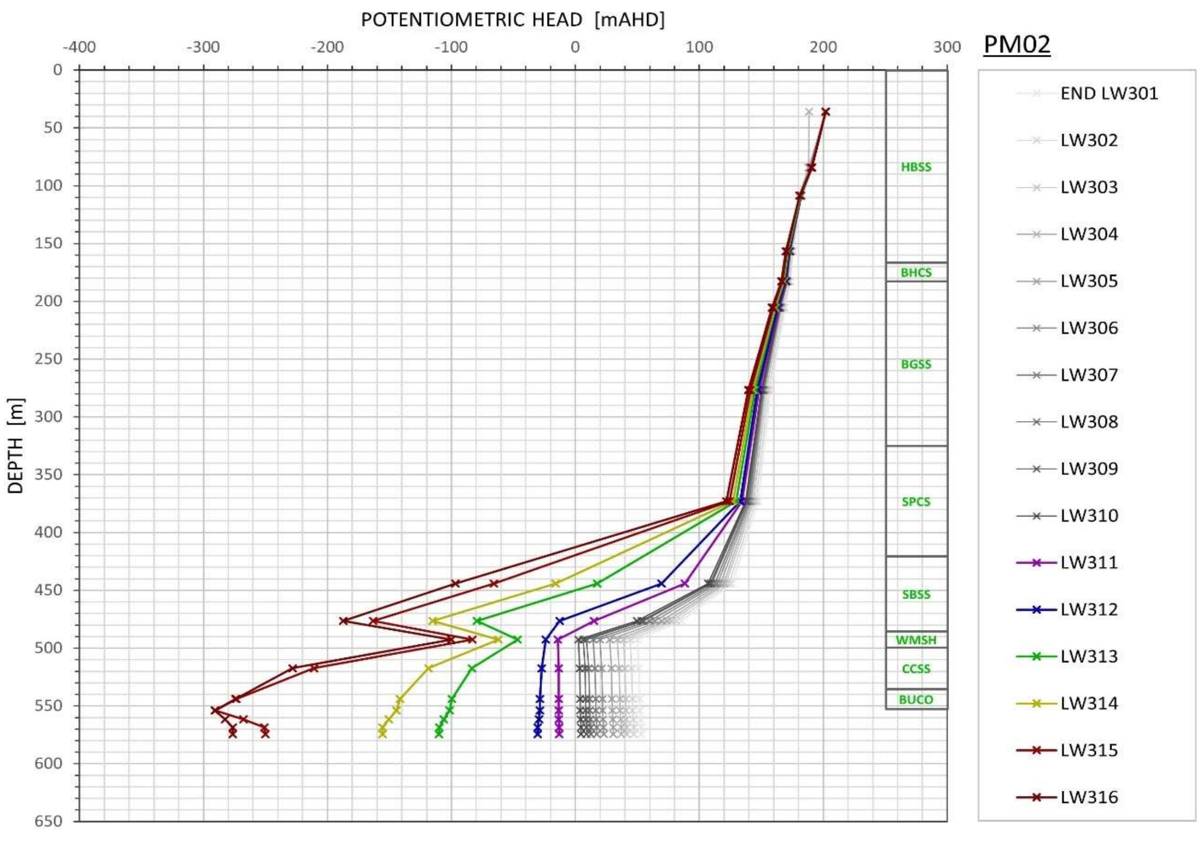


Chart 13 Predicted Vertical Head Profile at Bore PM02 at the end of Longwalls 311 to 316

6 PERFORMANCE MEASURES AND INDICATORS

The Project Approval requires Metropolitan Coal not to exceed the subsidence impact performance measures outlined in Table 1 of Condition 1, Schedule 3.

The subsidence impact performance measures specified in Table 1 of Condition 1, Schedule 3 in relation to water resources and watercourses are:

Table 1: Subsidence Impact Performance Measures

Water Resources	
Catchment yield to the Woronora Reservoir	*Negligible reduction to the quality or quantity of water resources reaching the Woronora Reservoir* *No connective cracking between the surface and the mine*
Woronora Reservoir	*Negligible leakage from the Woronora Reservoir* *Negligible reduction in the water quality of Woronora Reservoir*
Watercourses	
Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P).	*Negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases)*
Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26	*Negligible environmental consequences over at least 70% of the stream length (that is no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining and minimal gas releases)*

The term ‘negligible’ is defined in the Project Approval as *small and unimportant, such as to be not worth considering.*

Metropolitan Coal will also assess the Project against the water resource and watercourse performance indicators outlined in Table 11.

Table 11
Summary of Water Resource and Watercourse Performance Indicators and Measures

Performance Measure	Performance Indicator(s)
Negligible reduction to the quantity of water resources reaching the Woronora Reservoir.	*Changes in the quantity of water entering Woronora Reservoir are not significantly different post-mining compared to pre-mining, that are not also occurring in the control catchment.*
Negligible reduction to the quality of water resources reaching the Woronora Reservoir.	*Changes in the quality of water entering Woronora Reservoir are not significantly different post-mining compared to pre-mining concentrations that are not also occurring at control site WOWQ2.*
No connective cracking between the surface and the mine.	*Visual inspection does not identify abnormal water flow from the goaf, geological structure, or the strata generally.*
	The 20-day average mine water make does not exceed 1 ML/day.
	Significant departure from the predicted envelope of the vertical potentiometric head profile at Bore PM02 does not occur.
	Significant departure from the predicted envelope of the vertical potentiometric head profile at Bore PM01 does not occur.

Table 11 (Continued)
Summary of Water Resource and Watercourse Performance Indicators and Measures

Performance Measure	Performance Indicator(s)
No connective cracking between the surface and the mine. Negligible leakage from the Woronora Reservoir.	*The hydraulic gradient to the Woronora Reservoir at full supply level from Bore PHGW2A is reduced by no more than 40% from that measured to 30 June 2017.*
Negligible leakage from the Woronora Reservoir.	*The hydraulic gradient to the Woronora Reservoir at full supply level from Bore 9EGW2A is reduced by no more than 40% from that measured to 30 June 2017.*
	The hydraulic gradient to the Woronora Reservoir at full supply level from Bore PM02 is reduced by no more than 40% from that measured to 30 June 2017.
	The hydraulic gradient from transect bore T5 to bore T2 does not reduce outside the range seen during the baseline period
	The hydraulic gradient from transect bore T2 to the Woronora Reservoir remains positive (towards the Reservoir).
Negligible reduction in the water quality of Woronora Reservoir.	*Changes in the quality of water in the Woronora Reservoir are not significantly different post-mining compared to pre-mining concentrations.*
Negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P).	*No change to the natural drainage behaviour of Pools T, U, V and W.*
	Analysis of water level data for Pools T, U, V and W indicates the water level is at or above the pool's previous minimum.
	Visual inspection of the Waratah Rivulet from Pool T to the full supply level of the Woronora Reservoir does not show significant changes in the extent or nature of iron staining that isn't also occurring in the Woronora River (control site).
	Gas releases in Waratah Rivulet from Pool T to the full supply level of the Woronora Reservoir have not increased beyond those observed up to the commencement of Longwall 301 extraction.
Negligible environmental consequences over at least 70% of the stream length (that is no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining and minimal gas releases) of the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26.	*No change to the natural drainage behaviour of Pools ETAS, ETAT and ETAU.*
	Analysis of water level data for Pools ETAS/ETAT and ETAU indicates the water levels are above that required to maintain water over the downstream rock bars.
	Gas releases in Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26 have not increased beyond those observed up to the commencement of Longwall 301 extraction.

Section 8 describes the monitoring that will be conducted to inform the assessment of the Project against the subsidence impact performance indicators and measures for water resources and watercourses. The monitoring program includes the monitoring of:

- meteorology (Section 8.1);
- stream features (Section 8.2);
- surface water quantity (Section 8.3);
- surface water quality (Section 8.4);
- Woronora Reservoir water quality (Section 8.5);
- groundwater levels/pressures (Section 8.6);
- mine inflows (Section 8.7); and
- groundwater quality (Section 8.8).

Section 8.9 provides detailed TARPs to assess the water resource and watercourse subsidence impact performance indicators and measures.

7 BASELINE DATA

Sections 7.1 to 7.3 describe the baseline data available of relevance to water resources and watercourses.

Metropolitan Coal will maintain a register of water sites that includes: the location; date the site was established; and relevant comments. The water sites register will be made publicly available on the Peabody website and updated as required.

Baseline data will be made available to relevant regulatory agencies upon request.

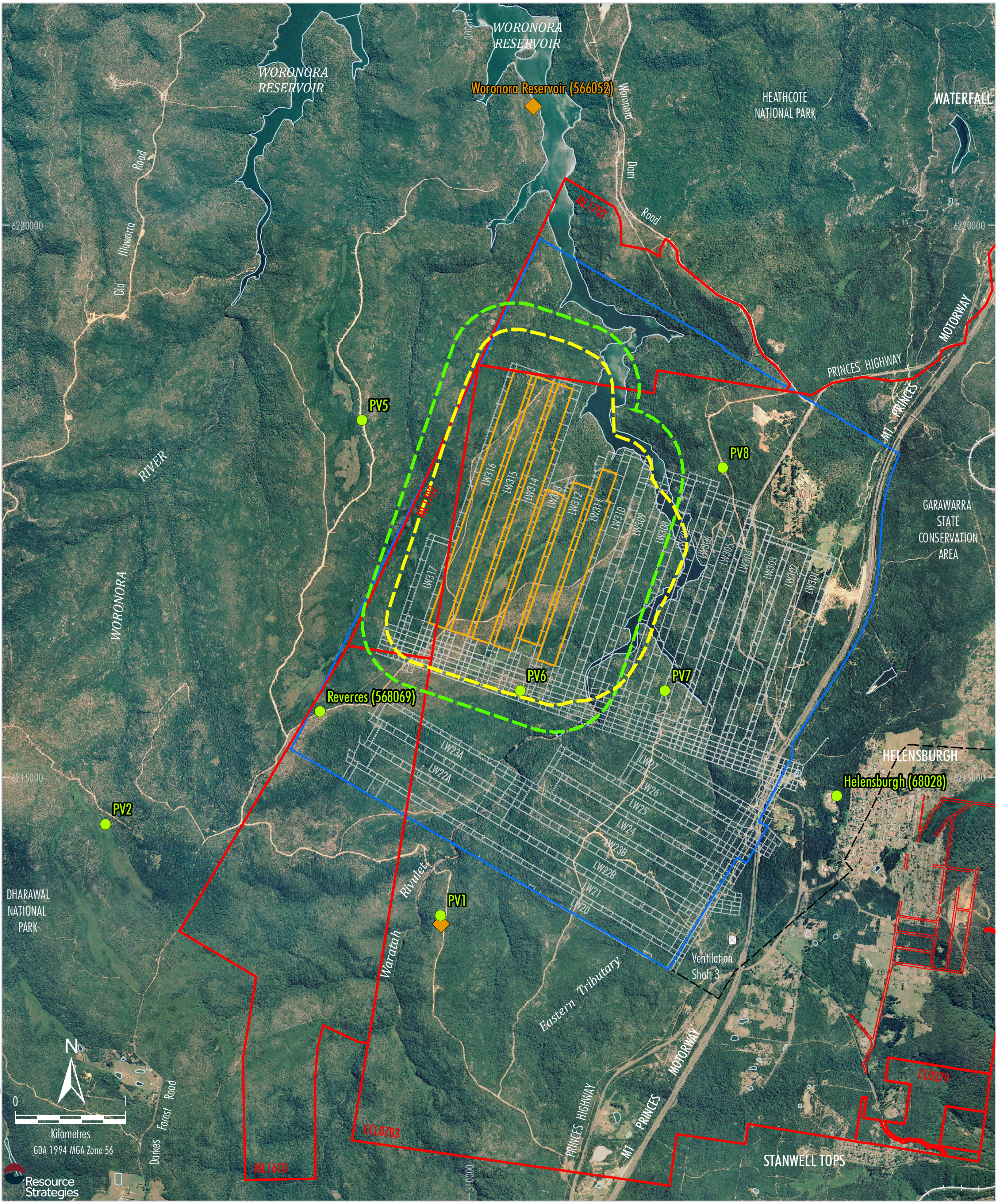
7.1 METEOROLOGY

Regional and local meteorological data is available from the Bureau of Meteorology (BoM) weather stations at Lucas Heights (Station Number 66078), Woronora Dam (Station Number 68070), Darkes Forest (Station Number 68024), and ‘Reverces’ (Station Number 568069) (Table 12). Rainfall data is also available from Metropolitan Coal pluviometers situated in the Waratah Rivulet catchment (site PV1), Woronora River catchment (site PV2), Honeysuckle Creek catchment (site PV5), Waratah Rivulet catchment (site PV6), Eastern Tributary catchment (site PV7) and Woronora Reservoir catchment (site PV8) (Figure 15).

Evaporation data is available from the WaterNSW station at the Woronora Dam (Table 12) and the Metropolitan Coal evaporimeter within the Waratah Rivulet catchment, at site PV1 (Table 12 and Figure 15).

Table 12
Meteorological Monitoring Station Locations and Recording Periods

Station Number	Data Type	Period of Record
Lucas Heights (BoM Station Number 66078)	Rainfall (daily read prior to pluviometer installation)Rainfall intensity Evaporation Air temperature, wet bulb temperature, barometric pressure, humidity, cloud cover, wind speed, wind direction	1958 to present 1958 to 1982, 1997 to present 1979 to 1982 1962 to 1982
Darkes Forest (BoM Station Number 68024)	Rainfall (BoM daily read converted to pluviometer)	1894 to present
Woronora Dam (BoM Station Number 68070, WaterNSW Station 566052)	Rainfall (BoM and WaterNSW daily read)	1927 to present
‘Reverces’ (BoM Station Number 568069)	Rainfall (pluviometer)	2000 to present
Waratah Rivulet (site PV1)	Rainfall (Metropolitan Coal pluviometer) Evaporation data (Metropolitan Coal evaporimeter)	2006 to present 2010 to present
Woronora River (site PV2)	Rainfall (Metropolitan Coal pluviometer)	2007 to present
Woronora Reservoir (WaterNSW station 566052)	Evaporation data	1976 to present
Honeysuckle Creek (site PV5)	Rainfall (Metropolitan Coal pluviometer)	2010 to present
Waratah Rivulet (site PV6)	Rainfall (Metropolitan Coal pluviometer)	2010 to present
Eastern Tributary (site PV7)	Rainfall (Metropolitan Coal pluviometer)	2010 to present
Woronora Reservoir catchment (site PV8)	Rainfall (Metropolitan Coal pluviometer)	January 2018 to present



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 311-316 Secondary Extraction
- Longwalls 311-316 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 311-316 Secondary Extraction
- Existing Underground Access Drive (Main Drift)
- Evaporimeter
- Pluviometer

Notes: 1. The Bureau of Meteorology pluviometer at Darkes Forest (68024) is not shown. It is located approximately 3.75 km south of the Metropolitan Coal pluviometer (PV2).
2. The Bureau of Meteorology pluviometer at Lucas Heights (66078) is not shown. It is located approximately 12.5 km north of the Metropolitan Coal pluviometer (PV8).

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2023); MSEC (2024)

Peabody

METROPOLITAN COAL

Meteorological Sites

Figure 15

7.2 SURFACE WATER

7.2.1 Stream Features

Prior to the commencement of Longwall 20, MSEC compiled a comprehensive survey and photographic record of Waratah Rivulet (from Flat Rock Crossing to the Woronora Reservoir full supply level), Eastern Tributary (from the east-west headings to the Woronora Reservoir full supply level), Tributary A (from its headwaters to its confluence with Waratah Rivulet) and Tributary B (from its headwaters to its confluence with Waratah Rivulet). The detailed mapping and photographic record of the Waratah Rivulet, Eastern Tributary, Tributary A and Tributary B is provided in Appendices 1 to 4, respectively.

Visual and photographic surveys conducted in accordance with the Metropolitan Coal WMPs have recorded:

- the location, approximate dimensions (length, width and depth), and orientation of surface cracks (specifically whether cracks are developed perpendicular to the stream flow or are controlled by rock joints or other factors, etc.);
- the nature of iron staining (e.g. whether isolated or across the entire streambed);
- the extent of iron staining (e.g. the length of stream affected);
- a description of gas release (e.g. isolated bubbles or continuous stream, and type of gas [methane or carbon dioxide]);
- the nature of scouring, for example the depth of scouring, type of soil exposed, any obvious vegetation impact, potential for severe erosion, etc.;
- water discoloration or opacity if present;
- natural underflow if evident (i.e. evidence of surface flows either entering or exiting the sub-surface domain via surface cracks in the streambed);
- rock bar characteristics such as extent of cracking, seepage, underflow;
- whether any actions are required (e.g. implementation of management measures, incident notification, implementation of appropriate safety controls, review of public safety, etc.); and
- any other relevant information.

The monthly visual surveys have recorded the stream visual parameters by exception (i.e. where they have differed to the baseline record).

Hydro Engineering & Consulting conducted a visual inspection and photographic survey of streams in the vicinity of Longwalls 304-310 (not previously inspected for Longwalls 301-303) in April 2018 (Hydro Engineering & Consulting, 2024). The visual inspection and photographic survey report is provided in Appendix 5.

7.2.2 Surface Water Flow

Surface water flow data is available for the gauging stations listed in Table 13. The locations of the Waratah Rivulet (GS 2132102), Woronora River (GS 2132101), Eastern Tributary (GS 300078), Honeysuckle Creek (GS 300077), Sub-catchment I (GS 300092), Sub-catchment K (GS 300093), Swamp 92 flume (GS 300143), Swamp 76 flume (GS 300142) gauging stations are shown on Figure 6. Surface water flow data is available from WaterNSW for the gauging stations on O'Hares Creek: an upstream gauging station at Darkes Forest (GS 212002) and a downstream gauging station near the town of Wedderburn (GS 213200). The O'Hares Creek catchment is located immediately south and west of the Woronora Dam catchment. Longwall mining occurred in the catchment of the Wedderburn gauging station (GS 213200) in 1986 to 1987 and 1990 to 1999.

As described in the Longwalls 305-307 WMP, Metropolitan Coal investigated the potential to install a small flow measuring flume immediately downstream of Swamps 76, 77 and 92 (Figure 9). Based on the initial site investigations, it was identified that there was potential to install flow measuring flumes immediately downstream of Swamps 76 and 92. Further investigations determined that it was not feasible to install a flow measuring flume downstream of Swamp 77.

Consistent with the recommendations of Hydro Engineering & Consulting (2024) (Appendix 5), flow measuring flumes were subsequently installed immediately downstream of Swamps 76 and 92 in November 2020 (Table 13) (Figure 6).

Table 13
Gauging Station Locations and Recording Periods

Station Number	Watercourse	Catchment Area (km^2)	Period of Record
WaterNSW (GS 2132102)	Waratah Rivulet, upstream of the Woronora Reservoir full supply level	20.2	February 2007 to present
WaterNSW (GS 2132101)[1]	Woronora River, upstream of the Woronora Reservoir full supply level	12.4	February 2007 to present
WaterNSW (GS 213002)	O'Hares Creek at Darkes Forest	16	1924 to 1930
WaterNSW (GS 213200)	O'Hares Creek at Wedderburn	73	1978 to present
Metropolitan Coal (GS 300078)	Eastern Tributary, upstream of the Woronora Reservoir full supply level	6.7	January 2013 to present
Metropolitan Coal (GS 300077)	Honeysuckle Creek (control site)	4.6	January 2013 to present
Sub-catchment I (GS 300092)	A tributary of the Woronora Reservoir	0.33	May 2018 to present
Sub-catchment K (GS 300093)	A tributary of the Woronora Reservoir	0.27	May 2018 to present
Swamp 92 flume (GS 300143)	A tributary of the Woronora Reservoir	0.86	November 2020 to present
Swamp 76 flume (GS 300142)	A tributary of the Woronora Reservoir	1.4	November 2020 to present

1 Note, the Woronora River gauging station (GS 2132101) contains periods of missing data.

Numerical catchment models for the Waratah Rivulet, and the Woronora River and O'Hares Creek control catchments, have been developed based on the nationally recognised Australian Water Balance Model (AWBM) (Boughton, 2004). The AWBM is a catchment-scale water balance model that estimates streamflow from rainfall and evaporation. The calibrated catchment model is used to assess potential subsidence impacts on the quantity of water resources reaching the Woronora Reservoir.

During 2015 the flow records from the Waratah Rivulet (GS 2132102) and Woronora River (GS 2132101) gauging stations were regenerated using amended rating relationships developed by Hydro Engineering & Consulting (formerly Gilbert & Associates Pty Ltd) on behalf of Metropolitan Coal (Gilbert & Associates, 2015a). A revised rating curve was also developed for O'Hares Creek at Wedderburn (GS 213200) based on the NSW Department of Industry – Water (now the DPE – Water) gaugings conducted over the period 1978 to 2003, as well as the known geometry of the V-notch and concrete weir control at this gauging station.

Revised and re-calibrated catchment models have also been developed for the Waratah Rivulet, Woronora River and O'Hares Creek gauging stations using the regenerated flow data (Gilbert & Associates, 2015b). The models were revised to include a variable baseflow index. The baseflow index (BFI) is defined as the ratio of baseflow to total flow. It is used as a constant parameter in the AWBM. As part of the model re-calibration, the BFI, as a constant parameter, was replaced by a function where its value was allowed to vary as a function of daily rainfall excess and the depth of water in baseflow storage. The revised rating curves and associated recalibration of the catchment models were peer reviewed by Emeritus Professor Tom McMahon (School of Engineering, The University of Melbourne).

Catchment models have also been developed for the Eastern Tributary and Honeysuckle Creek gauging stations with the same model structure as for Waratah Rivulet, Woronora River and O'Hares Creek.

7.2.3 Pool Water Levels

Pool water level data is available for a number of sites on the Waratah Rivulet, Eastern Tributary, Tributary B, Tributary D, Woronora River, and tributaries of the Woronora Reservoir (Table 14).

The locations of the pools are shown on Figure 6. Pools and rock bars along the Waratah Rivulet, Eastern Tributary, Tributary A and Tributary B are shown on the detailed mapping and photographs provided in Appendices 1 to 4, respectively.

Pool water level sites RTP1, RTP2, UTP1, UTP2 and UTP3 were installed within the Metropolitan Coal Mine mining area to monitor pool water level data as part of previous monitoring programs, however, will be removed from regular monitoring and reporting for Longwalls 311-316 as the monitoring sites are located more than 1 km from Longwalls 311-316 are expected to experience negligible impacts.

Table 14
Pool Water Level Sites (Manual and/or Continuous Water Level Data)

Site Number	Watercourse	Commencement Date[1]
Pool A	Waratah Rivulet	20/9/2005
Pool B	Waratah Rivulet	20/9/2005
Pool C	Waratah Rivulet	20/9/2005
Pool E	Waratah Rivulet	20/9/2005
Pool F	Waratah Rivulet	20/9/2005
Pool G	Waratah Rivulet	20/9/2005
Pool G1	Waratah Rivulet	13/10/2005
Pool H	Waratah Rivulet	11/10/2005
Pool I	Waratah Rivulet	11/10/2005
Pool J	Waratah Rivulet	3/4/2007
Pool K	Waratah Rivulet	13/5/2010
Pool L	Waratah Rivulet	11/12/2008
Pool M	Waratah Rivulet	11/12/2008
Pool N	Waratah Rivulet	11/12/2008[2]
Pool O	Waratah Rivulet	11/12/2008
Pool P	Waratah Rivulet	11/12/2008
Pool Q	Waratah Rivulet	20/2/2007
Pool R	Waratah Rivulet	11/12/2008
Pool S	Waratah Rivulet	11/12/2008
Pool T	Waratah Rivulet	20/1/2010
Pool U	Waratah Rivulet	20/1/2010
Pool V	Waratah Rivulet	20/1/2010
Pool W	Waratah Rivulet	20/1/2010
Pool ETG	Eastern Tributary	16/2/2011
Pool ETJ	Eastern Tributary	29/3/2011
Pool ETM	Eastern Tributary	11/12/2008
Pool ETO	Eastern Tributary	30/5/2019
Pool ETU	Eastern Tributary	18/5/2010
Pool ETW	Eastern Tributary	18/5/2010
Pool ETAF	Eastern Tributary	12/11/2010

Table 14 (continued)
Pool Water Level Sites (Manual and/or Continuous Water Level Data)

Site Number	Watercourse	Commencement Date[1]
Pool ETAG	Eastern Tributary	12/11/2010
Pool ETAH	Eastern Tributary	19/1/2011
Pool ETAI[3]	Eastern Tributary	19/1/2011
Pool ETAL	Eastern Tributary	3/10/2018
Pool ETAM	Eastern Tributary	3/10/2018
Pool ETAN	Eastern Tributary	3/10/2018
Pool ETAO	Eastern Tributary	3/10/2018
Pool ETAP	Eastern Tributary	3/10/2018
Pool ETAQ	Eastern Tributary	17/1/2011
Pool ETAR	Eastern Tributary	3/10/2018
Pool ETAT[4]	Eastern Tributary	24/5/2018
Pool ETAU	Eastern Tributary	23/9/2012
Pool RTP1	Tributary B	7/3/2007
Pool RTP2	Tributary B	7/3/2007
Pool UTP1	Tributary D	7/3/2007
Pool UTP2	Tributary D	7/3/2007
Pool UTP3	Tributary D	7/3/2007
Pool SR1	Tributary of Woronora Reservoir	23/5/2019
Pool SR2	Tributary of Woronora Reservoir	23/5/2019
Pool SP1	Tributary of Woronora Reservoir	3/6/2019
Pool WRP1[5]	Woronora River (Control Site)	1/1/2016

1 The dates provided represent the dates from which pool water level monitoring commenced, however, some of the data is known to be unreliable and could not be used for the assessment of pre-impact behaviour.

2 Data from 11 December 2008 contains periods of missing data and periods where data is considered to be largely unreliable due to sensor error/instability.

3 Only small rock bars separate Pools ETAI, ETAJ and ETAK. Pools join to become the one large pool. Pool ETAK is controlled by a rock bar. The water level meter situated in Pool ETAI is therefore considered to be representative of the water level in Pools ETAJ and ETAK.

4 Due to the nature of Rock Bar ETAS, Pool ETAS and Pool ETAT typically sit at the same level.

5 Pool water level data for the Woronora River pools prior to January 2016 is considered to be largely unreliable as a result of water level sensor issues.

7.2.4 Surface Water Quality

Water quality data has been collected at a large number of sites including sites on the Waratah Rivulet, Eastern Tributary, Far Eastern Tributary, Woronora River, Bee Creek, Honeysuckle Creek, Tributary B, Tributary D and Forest Gully. The water quality sites are summarised in Table 15 and shown on Figure 7.

Water quality data sites UTWQ 1, UTWQ 2, UTWQ 3, UTWQ 4, UTWQ 5, FGWQ 1, FGWQ 2, FGWQ 3, FGWQ 4, FGWQ 5, RTWQ 2 and RTWQ3 were installed within the Metropolitan Coal Mine mining area to monitor pool water level data as part of previous monitoring programs, however, will be removed from regular monitoring and reporting for Longwalls 311-316 as the monitoring sites are located more than 1 km from Longwalls 311-316 and are expected to experience negligible subsidence impacts due to future longwall mining.

Table 15
Stream Water Quality Sites

Site Number	Watercourse	Commencement Date
WRWQ 1	Waratah Rivulet	27/9/2006
WRWQ 2	Waratah Rivulet	27/9/2006
WRWQ 3	Waratah Rivulet	27/9/2006
WRWQ 4 (Pool B)	Waratah Rivulet	27/9/2006
WRWQ 5	Waratah Rivulet	27/9/2006
WRWQ 6 (Pool F)	Waratah Rivulet	27/9/2006
WRWQ 7 (Pool H)	Waratah Rivulet	27/9/2006
WRWQ 8	Waratah Rivulet	27/9/2006
WRWQ 9 (Pool Q)	Waratah Rivulet	27/9/2006
WRWQ J	Waratah Rivulet	27/1/2010
WRWQ K	Waratah Rivulet	27/1/2010
WRWQ L	Waratah Rivulet	11/12/2008
WRWQ M	Waratah Rivulet	11/12/2008
WRWQ N	Waratah Rivulet	11/12/2008
WRWQ O	Waratah Rivulet	11/12/2008
WRWQ P	Waratah Rivulet	11/12/2008
WRWQ R	Waratah Rivulet	11/12/2008
WRWQ S	Waratah Rivulet	11/12/2008
WRWQ T	Waratah Rivulet	10/2/2010
WRWQ U	Waratah Rivulet	10/2/2010
WRWQ V	Waratah Rivulet	10/2/2010
WRWQ W	Waratah Rivulet	10/2/2010
UTWQ 1	Waratah Rivulet	3/8/2006
UTWQ 2	Tributary D	3/8/2006
UTWQ 3	Tributary D	3/8/2006

Table 15 (Continued)
Stream Water Quality Sites

Site Number	Watercourse	Commencement Date
UTWQ 4	Tributary D	3/8/2006
UTWQ 5	Tributary D	3/8/2006
FGWQ 1	Forest Gully	1/8/2006
FGWQ 2	Forest Gully	1/8/2006
FGWQ 3	Forest Gully	1/8/2006
FGWQ 4	Forest Gully	1/8/2006
FGWQ 5	Forest Gully	1/8/2006
RTWQ 1	Tributary B	3/8/2006
RTWQ 2	Tributary B	3/8/2006
RTWQ 3	Tributary B	3/8/2006
ETWQ F	Eastern Tributary	17/2/2010
ETWQ J	Eastern Tributary	17/2/2010
ETWQ N	Eastern Tributary	7/9/2007
ETWQ U	Eastern Tributary	28/1/2010
ETWQ W	Eastern Tributary	28/1/2010
ETWQ AF	Eastern Tributary	28/1/2010
ETWQ AG	Eastern Tributary	28/1/2010
ETWQ AH	Eastern Tributary	28/1/2010
ETWQ AI	Eastern Tributary	28/1/2010
ETWQ AK	Eastern Tributary	28/1/2010
ETWQ AQ	Eastern Tributary	28/1/2010
ETWQ AU	Eastern Tributary	28/1/2010
FEWQ 1	Far Eastern Tributary	7/9/2007
BCWQ 1	Bee Creek	7/9/2007
HCWQ 1	Honeysuckle Creek	7/9/2007
WOWQ 1	Woronora River (Control Site)	7/9/2007
WOWQ 2	Woronora River (Control Site)	17/1/2008
WOWQ 3	Woronora River (Control Site)	11/12/2008
WOWQ 4	Woronora River (Control Site)	28/1/2010
WOWQ 5	Woronora River (Control Site)	28/1/2010
WOWQ 6	Woronora River (Control Site)	28/1/2010
Pool SR1	Tributary of Woronora Reservoir	24/11/2021
Pool SR2	Tributary of Woronora Reservoir	24/11/2021
Pool SP1	Tributary of Woronora Reservoir	23/11/2021

Note: Water quality sampling sites WRWQ J to WRWQ W have been taken from Pools J to W on the Waratah Rivulet and water quality sampling sites ETWQ F to ETWQ AU have been taken from Pools ETF to ETAU on the Eastern Tributary, respectively.

In October 2016, Metropolitan Coal increased the frequency of water quality sampling at select sites on the Eastern Tributary (sites ETWQF, ETWQN, ETWQAF, ETWQAG, ETWQAH, ETWQAI, ETWQAK, ETWQAQ and ETWQAU) and at site WOWQ2 on the Woronora Reservoir from monthly to weekly in response to the Eastern Tributary Incident, which is described in Section 4.1.

Additional water quality data has also been collected at site ETAU[23] and at a number of sites downstream of site ETAU to inform assessments against the water quality performance measure for catchment yield to the Woronora Reservoir. Sampling has been conducted at site ETAU, ETFSL 0, ETFSL 20, ETFSL 40, ETFSL 60, ETFSL 80, ETFSL 100, ETFSL 200, ETFSL 300, ETFSL 400 and ETFSL 500 (Figure 7). Site ETAU has sampled the pool at the Eastern Tributary gauging station and site ETFSL 0 has sampled the pool at the top of the waterfall. Sites ETFSL 20 to 500 m have been sampled at the designated distances when the water level of the reservoir is reduced enough such that the Eastern Tributary extends downstream of ETFSL 0 (without inundation) (Figure 7). The additional sampling commenced in August 2017 and continues to date[24].

In response to reducing water levels in the Woronora Reservoir, sampling from 22 November 2018 has been conducted at site ETWQ AU (November)/site ETAU (from 12 December 2018), site ETFSL 200, site ETFSL 500, site CONFLU1, site WARARM5, site WDFS1 and site WDFS1+100 (Figure 7)[25].

7.2.5 Woronora, Nepean and Cataract Reservoir Water Quality

WaterNSW has an extensive water quality database for the Woronora Reservoir, Nepean Reservoir and Cataract Reservoir. Metropolitan Coal obtains surface water quality data for the Woronora Reservoir (site DW01, from 0 m to 9 m below the reservoir surface), Nepean Reservoir and Cataract Reservoir (including total iron, total manganese and total aluminium concentrations) from WaterNSW in accordance with a data exchange agreement.

7.3 GROUNDWATER

7.3.1 Swamp Groundwater Levels

Groundwater level data is available for a number of upland swamps including from piezometers in the swamp substrate and/or piezometers in the shallow sandstone, as summarised in Table 16. The piezometer locations are shown on Figure 9.

Swamp substrate and shallow groundwater level sites overlying Longwalls 20-27, namely sites SWAMP4, SWGW1, S25, S30, S33 and S35 were installed within the Metropolitan Coal Mine mining area to monitor shallow groundwater level/pressure as part of previous monitoring programs, however, will be removed from regular monitoring and reporting for Longwalls 311-316 as the monitoring sites are located more than 1 km from Longwalls 311-316 and are expected to experience negligible impacts.

[23] Site ETAU is the same as site ETWQ AU (i.e. samples are taken at the same location). The difference between the sites relates to the time of sampling. Site ETWQ AU monitoring is conducted on the same day as sites upstream of ETWQ AU/ETAU, while site ETAU monitoring is conducted on the same day as the sites downstream of ETWQ AU/ETAU.

[24] Sampling was suspended in November 2018 at sites ETFSL 100, ETFSL 300 and ETFSL 400. Monitoring at these recommenced in February 2020 .

[25] Due to the increasing water level in the Woronora Reservoir throughout February and March 2020, sampling at sites WARARM5, WDFS1 and WDFS1+100 has not been undertaken since March 2020, and site CONFLU1 has not been sampled from July 2020.

Table 16
Swamp Substrate and Shallow Groundwater Level Sites

Site Number	Swamp	Easting (m)	Northing (m)	RL (m AHD)	Depth (m)	Lithology	Commencement Date
SWAMP1	S14	308625	6215963	295.6	3.1	Hawkesbury Sandstone	7 February 2007
SWAMP2	Bee Creek Swamp	308755	6218787	245.3	1.5	Hawkesbury Sandstone	4 April 2007
SWAMP3	S92	310063	6216007	294.7	4.3	Hawkesbury Sandstone	7 February 2007
SWAMP4	S06	307891	6214219	344.1	1.0	Hawkesbury Sandstone	12 March 2009
SWGW1	S06	307893	6214226	343.7	~20	Hawkesbury Sandstone	12 March 2009
S25	S25	311125	6214115	273.1	~0.9	Hawkesbury Sandstone	31 August 2010
		311126	6214117	272.9	~10		
S101 (control)	S101	308658	6216585	293.4	~0.9	Hawkesbury Sandstone	31 August 2010
		308659	6216585	293.4	~10		
S16[1]	S16	309702	6214791	251.2	~10	Hawkesbury Sandstone	30 August 2010
S17	S17	309599	6214931	240.6	~10	Hawkesbury Sandstone	1 September 2010
S20	S20	310431	6214413	219.3	~0.9	Hawkesbury Sandstone	1 September 2010
		310429	6214403	219.1	~4		
		310428	6214401	219.1	~10		
WRSWAMP1 (control)	Woronora River 1	306454	6214914	321.1	~0.9	Hawkesbury Sandstone	2 September 2010
		306452	6214913	321.1	~4		
		306451	6214912	321.0	~10		
S28	S28	311003	6214783	247.9	~1	Hawkesbury Sandstone	8 March 2013
		311002	6214782	247.8	~10		
S30	S30	311180	6215115	236.2	~1	Hawkesbury Sandstone	8 March 2013
		311176	6215115	236.0	~10		
S33	S33	311582	6214529	241.3	~1	Hawkesbury Sandstone	8 March 2013
		311585	6214528	241.2	~10		
S35	S35	311501	6215126	256.0	~1	Hawkesbury Sandstone	8 March 2013
		311500	6215156	256.1	~10		
S137a (control)	S137a	308466	6217145	271.3	~1	Hawkesbury Sandstone	8 March 2013
		308463	6217148	271.1	~10		
S137b (control)	S137b	308399	6216962	276.6	~1	Hawkesbury Sandstone	8 March 2013
		308396	6216961	276.7	~10		
Bee Creek Swamp (control)	Bee Creek Swamp	308724	6218941	241.1	~1	Hawkesbury Sandstone	8 March 2013
		308723	6218939	241.3	~10		
S40	S40	312428	6215898	231.9	1.0	Hawkesbury Sandstone	28 June 2016
		312429	6215897	232.1	9.9		
S41	S41	312740	6216093	279.6	0.8	Hawkesbury Sandstone	28 June 2016
		312739	6216093	279.4	9.9		
S46	S46	312615	6216277	282.6	0.7	Hawkesbury Sandstone	28 June 2016
		312616	6216278	282.8	10.1		

Table 16 (Continued)
Swamp Substrate and Shallow Groundwater Level Sites

Site Number	Swamp	Easting (m)	Northing (m)	RL (m AHD)	Depth (m)	Lithology	Commencement Date
S50	S50	312510	6217013	266.8	0.4	Hawkesbury Sandstone	27 June 2016
		312509	6217012	266.9	9.9		
S51	S51	312639	6216883	274.9	0.6	Hawkesbury Sandstone	28 June 2016
		312638	6216884	274.9	9.9		
S52	S52	312739	6216836	283.8	1.1	Hawkesbury Sandstone	30 June 2016
		312738	6216835	283.7	9.8		
S53	S53	312859	6216845	295.6	1.7	Hawkesbury Sandstone	28 June 2016
		312858	6216845	295.5	9.9		
S60	S60	312754	6218443	282.9	1.6	Hawkesbury Sandstone	4 February 2019
		312754	6218443	273.6	10.9		
S62	S62	312011	6218339	263.7	1.3	Hawkesbury Sandstone	4 February 2019
		312011	6218339	254.1	10.8		
S64	S64	312269	6218118	266.4	1.0	Hawkesbury Sandstone	4 February 2019
		312269	6218118	256.5	10.9		
S71a	S71a	312519	6217774	276.6	0.3	Hawkesbury Sandstone	27 June 2016
		312519	6217772	276.6	9.9		
S72	S72	312239	6217938	263.1	1.4	Hawkesbury Sandstone	4 February 2019
		312239	6217938	253.6	10.9		
S76-1	S76	310371	6217651	266.7	0.9	Hawkesbury Sandstone	15 November 2020
S76-2	S76	310142	6217474	280.1	0.9	Hawkesbury Sandstone	15 November 2020
		310142	6217474	272.6	~10		
S76-3	S76	310059	6207350	282.4	0.9	Hawkesbury Sandstone	15 November 2020
S77-1	S77	310397	6216915	273.1	0.9	Hawkesbury Sandstone	15 November 2020
S77-2	S77	310269	6216732	281.8	0.9	Hawkesbury Sandstone	15 November 2020
		310269	6216732	272.5	~10		
S77-3	S77	310114	6216572	296.2	0.46	Hawkesbury Sandstone	15 November 2020
S81	S81	310993	6216619	264.6	0.3	Hawkesbury Sandstone	15 November 2020
S82	S82	311104	6216658	256.1	0.6	Hawkesbury Sandstone	15 November 2020
S89	S89	310769	6216216	262.3	0.6	Hawkesbury Sandstone	15 November 2020
S92-1	S92	310515	6216166	278.1	0.9	Hawkesbury Sandstone	15 November 2020
S92-2	S92	310054	6216033	292.9	0.9	Hawkesbury Sandstone	15 November 2020
		310054	6216033	283.2	~10		
S92-3	S92	309763	6215908	302.8	0.9	Hawkesbury Sandstone	15 November 2020
S133	S133	312513	6218988	248.6	1.3	Hawkesbury Sandstone	4 February 2019
		312513	6218988	239.1	10.9		

Table 16 (Continued)
Swamp Substrate and Shallow Groundwater Level Sites

Site Number	Swamp	Easting (m)	Northing (m)	RL (m AHD)	Depth (m)	Lithology	Commencement Date
S134	S134	312682	6218760	260.6	1.5	Hawkesbury Sandstone	4 February 2019
		312682	6218760	251.3	10.8		

[1] As discussed in the *Metropolitan Coal 2013 Annual Review and Annual Environmental Management Report* (Metropolitan Coal, 2014), the sensor in the Swamp 16 piezometer became unreliable.

7.3.2 Swamp Moisture Probes

Metropolitan Coal installed soil moisture probes (linked to a datalogger) at various depth intervals to monitor the vertical profile of soil moisture in the swamp substrate of Swamps 62, 72, 76, 77, 81, 82, 89, 92, 101, 137a and 137b (Table 17). The location of these soil moisture probes is shown on Figure 9.

Table 17
Swamp Soil Moisture Monitoring Sites

Site Number	Swamp	Easting (m)	Northing (m)	RL (m AHD)	Depth (m)	Commencement Date
S62	S62	312011	6218341	264.41	0.6	15 November 2020
S72	S72	312238	6217939	263.80	0.6	15 November 2020
S76-1	S76	310372	6217655	267.94	1.2	15 November 2020
S76-2	S76	310146	6217492	281.03	0.9	15 November 2020
S76-3	S76	310081	6217323	283.20	0.9	15 November 2020
S77-1	S77	310399	6216911	274.39	1.2	15 November 2020
S77-2	S77	310273	6216732	283.10	1.2	15 November 2020
S77-3	S77	310114	6216573	296.72	0.3	15 November 2020
S81	S81	310514	6216161	265.20	0.3	15 November 2020
S82	S82	310053	6216032	256.65	0.6	15 November 2020
S89	S89	309763	6215909	263.25	0.9	15 November 2020
S92-1	S92	310995	6216622	179.10	1.2	15 November 2020
S92-2	S92	311102	6216659	294.01	1.2	15 November 2020
S92-3	S92	310763	6216217	303.71	1.2	15 November 2020
S101	S101	308657	6216586	292.09	0.9	15 November 2020
S137a	S137a	308461	6217145	270.90	0.9	15 November 2020
S137b	S137b	308395	6216960	276.83	0.9	15 November 2020

7.3.3 Shallow Groundwater Levels Near Streams

Shallow groundwater level data is available for a number of sites near streams, as summarised in Table 18. The piezometer locations are shown on Figure 10.

Shallow groundwater level sites in the vicinity of Longwalls 20-27, namely sites SWGW1, WRGW4, WRGW8, RTGW1A, FGGW1, FGGW2, FGGW3, UTGW1, UTGW3 and ETGW1 were installed within the Metropolitan Coal Mine mining area to monitor groundwater levels and quality as part of previous monitoring programs, however, will be removed from regular monitoring and reporting for Longwalls 311-316 as the monitoring sites are located more than 600 m from Longwalls 311-316 and are expected to experience negligible impacts.

Table 18
Shallow Groundwater Level Sites Near Streams

Site Number	Location	Easting (m)	Northing (m)	RL (m AHD)	Depth (m)	Lithology	Commencement Date
WRGW1	Waratah Rivulet	309886	6214360	207.8	~20	Hawkesbury Sandstone	16 February 2007
WRGW2	Waratah Rivulet	309868	6214335	207.9	~20	Hawkesbury Sandstone	16 February 2007
WRGW3	Waratah Rivulet	309629	6214072	215.0	~20	Hawkesbury Sandstone	16 February 2007
WRGW4[1]	Waratah Rivulet	309579	6214090	217.8	~20	Hawkesbury Sandstone	16 February 2007
WRGW5	Waratah Rivulet	309393	6212890	225.4	~20	Hawkesbury Sandstone	4 April 2007
WRGW6	Waratah Rivulet	309361	6212871	226.1	~20	Hawkesbury Sandstone	4 April 2007
WRGW7	Waratah Rivulet	310717	6215382	184.2	~20	Hawkesbury Sandstone	September 2010
WRGW8[2]	Waratah Rivulet	310685	6215353	184.3	~20	Hawkesbury Sandstone	September 2010
RTGW1A[3]	Tributary B	309593	6215109	222.0	~19.5	Hawkesbury Sandstone	23 August 2007
FGGW1	Forest Gully	308951	6213200	232.4	~20	Hawkesbury Sandstone	8 March 2007
FGGW2	Forest Gully	308816	6213158	240.5	~20	Hawkesbury Sandstone	4 April 2007
FGGW3	Forest Gully	308682	6213113	250.4	~20	Hawkesbury Sandstone	4 April 2007
UTGW1	Tributary D	309520	6214151	218.2	~20	Hawkesbury Sandstone	16 February 2007
UTGW2	Tributary D	309097	6214012	237.6	~20	Hawkesbury Sandstone	7 March 2007
UTGW3	Tributary D	308833	6213951	247.2	~20	Hawkesbury Sandstone	7 March 2007
ETGW1	Eastern Tributary	312129	6215644	172.6	~20	Hawkesbury Sandstone	September 2010
ETGW2	Eastern Tributary	312134	6215664	172.1	~20	Hawkesbury Sandstone	September 2010
ETO1	Eastern Tributary	311665	6214107	228.0	~39	Hawkesbury Sandstone	30 May 2019
ETO2	Eastern Tributary	311634	6214141	217.3	~20	Hawkesbury Sandstone	30 May 2019
ETO3	Eastern Tributary	311589	6214112	221.0	~26.5	Hawkesbury Sandstone	30 May 2019
ETO4	Eastern Tributary	311534	6214143	216.2	~38.5	Hawkesbury Sandstone	30 May 2019

1 Site WRGW4 was sheared in 2011 and has subsequently not been sampled.

2 As reported in the *Metropolitan Coal 2014 Annual Review and Annual Environmental Management Report/Rehabilitation Report* (Metropolitan Coal, 2015), site WRGW8 is faulty and is no longer recording reliable data.

3 Due to bore failure as a result of subsidence, bore RTGW1A on Tributary B has not been able to be dipped since December 2013. The diver was able to be downloaded up until May 2014.

7.3.4 Groundwater Levels/Pressures

Metropolitan Coal installed groundwater transect bores T1 to T5 in June 2016 (data loggers installed in September 2016) and groundwater transect bore T6 to the west of the Woronora Reservoir in December 2017 (Table 19 and Figure 10).

Table 19
Groundwater Transect

Site Number	Easting (m)	Northing (m)	Top of Collar (m AHD)	Sensor[1] (m AHD)	Hole Depth (m)	Lithology	Commencement Date
T1	312048	6217168	174.106	154.96	21	Hawkesbury Sandstone	7 September 2016
T2	312092	6217209	195.118	161.04	35	Hawkesbury Sandstone	7 September 2016
T3[2]	312201	6217246	225.450	166.49	61	Hawkesbury Sandstone	7 September 2016
T3-R[3]	312203	6217256	226.826	145.83	82	Hawkesbury Sandstone	20 May 2021
T4[4]	312280	6217296	236.306	170.16	67	Hawkesbury Sandstone	7 September 2016
T5	312423	6217379	258.041	166.80	94	Hawkesbury Sandstone	7 September 2016
T6	311447	6217375	255.87	165.90	130	Hawkesbury Sandstone	18 December 2017

1 Sensor depth may vary over time if a diver is replaced, i.e. a new cable length.

2 Bore T3 ceased recording in December 2020. The bore was replaced by a redrilled bore T3-R, approximately 10 m to the north of the original T3 location.

3 Bore T3-R collapsed in March 2024 and is no longer recording.

4 Bore T4 ceased recording in August 2021. Prior to this the water level data obtained at bore T4 remained anomalous and unreliable as its head is higher than the head at upgradient site T5. This is considered unlikely to be a groundwater divide as it is not related to the topographic ridge well upgradient (SLR Consulting, 2021). Bore T4 has been removed from the monitoring program as part of the Longwalls 311-316 monitoring regime.

Metropolitan Coal groundwater level and/or pressure data is also available from the multi-level piezometers and single-level piezometers listed in Table 20 and shown on Figure 10. Groundwater level/pressure data is also available at site S1997, courtesy of Illawarra Metallurgical Coal (Table 20 and Figure 10).

Table 20
Groundwater Level and Groundwater Level/Pressure Sites

Site Number	Location	Easting (m)	Northing (m)	Collar (m AHD)	Depth (m)	Elevation (m AHD)	Lithology	Commencement Date
9HGW0	Longwall 10 post-mining on Fire Trail 9H	309762	6213480	274.5	35.0	239.5	Hawkesbury Sandstone	12 April 2007
					70.0	204.5	Hawkesbury Sandstone	
					110.0	164.5	Hawkesbury Sandstone	
					135.0	139.5	Bald Hill Claystone	
					165.0	109.5	Bulgo Sandstone	
					205.0	69.5	Bulgo Sandstone	
					250.0	24.5	Bulgo Sandstone	
					300.0	-25.5	Bulgo Sandstone	
9HGW1B	Fire Trail 9H west of Longwall 18	308189	6214580	351.2	52.0	299.2	Hawkesbury Sandstone	12 November 2008
					81.5	269.7	Hawkesbury Sandstone	
					158.0	193.2	Hawkesbury Sandstone	
					174.6	176.6	Newport Formation	
					205.4	145.8	Bald Hill Claystone	
					225.4	125.8	Bulgo Sandstone	
					303.0	48.2	Bulgo Sandstone	
					385.6	-34.4	Bulgo Sandstone	
9GGW1B[1]	Fire Trail 9G	310974	6214317	287.9	45.0	242.9	Hawkesbury Sandstone	14 March 2009
					59.5	228.4	Hawkesbury Sandstone	
					124.0	163.9	Hawkesbury Sandstone	
					159.0	128.9	Bald Hill Claystone	
					179.0	108.9	Bulgo Sandstone	
					345.1	-57.2	Bulgo Sandstone	
					385.1	-97.2	Bulgo Sandstone	
					404.1	-116.2	Stanwell Park Claystone	
					416.0	-128.2	Scarborough Sandstone	
					476.7	-188.8	Coal Cliff Sandstone	

Table 20 (Continued)
Groundwater Level and Groundwater Level/Pressure Sites

Site Number	Location	Easting (m)	Northing (m)	Collar (m AHD)	Depth (m)	Elevation (m AHD)	Lithology	Commencement Date
9GGW1-3	Longwall 22B post-mining on Fire Trail 9G	310974	6214317	286.61	60.0	226.6	Hawkesbury Sandstone	31 August 2016
					124.0	162.6	Hawkesbury Sandstone	
					159.0	127.6	Hawkesbury Sandstone	
					200.0	86.6	Shale	
					250.0	36.6	Bulgo Sandstone	
9GGW1-80	Fire Trail 9G	310974	6214317	287.0	80.0	206.9	Hawkesbury Sandstone	21 November 2013
9GGW2B	Fire Trail 9G at western end of Longwall 27	311734	6215359	240.8	55.0	185.8	Hawkesbury Sandstone	20 April 2010
					80.3	160.5	Hawkesbury Sandstone	
					105.5	135.3	Hawkesbury Sandstone	
					137.8	103.0	Bald Hill Claystone	
					162.5	78.3	Bulgo Sandstone	
					304.0	-63.2	Bulgo Sandstone	
					339.5	-98.7	Stanwell Park Claystone	
					393.0	-152.2	Scarborough Sandstone	
					437.0	-196.2	Wombarra Claystone	
					474.1	-233.3	Bulli Coal Seam	
9FGW1A	Fire Trail 9F west of Longwall 22A	308556	6215537	310.2	55.0	255.2	Hawkesbury Sandstone	19 February 2010
					73.5	236.7	Hawkesbury Sandstone	
					137.0	173.2	Hawkesbury Sandstone	
					184.5	125.7	Bald Hill Claystone	
					209.5	100.7	Bulgo Sandstone	
					369.0	-58.8	Bulgo Sandstone	
					404.5	-94.3	Stanwell Park Claystone	
					455.0	-144.8	Scarborough Sandstone	
					490.5	-180.3	Wombarra Claystone	
					513.3	-203.1	Bulli Coal Seam	

Table 20 (Continued)
Groundwater Level and Groundwater Level/Pressure Sites

Site Number	Location	Easting (m)	Northing (m)	Collar (m AHD)	Depth (m)	Elevation (m AHD)	Lithology	Commencement Date
9EGW1B	Fire Trail 9E	309483	6216091	309.0	52.0	257.0	Hawkesbury Sandstone	1 November 2009
					91.0	218.0	Hawkesbury Sandstone	
					170.0	139.0	Hawkesbury Sandstone	
					213.0	96.0	Bald Hill Claystone	
					233.0	76.0	Bulgo Sandstone	
					403.0	-94.0	Bulgo Sandstone	
					424.0	-115.0	Stanwell Park Claystone	
					450.0	-141.0	Scarborough Sandstone	
					488.0	-179.0	Scarborough Sandstone	
					541.5	-232.5	Coal Cliff Sandstone	
9EGW2A	Fire Trail 9E	311331	6217099	276.9	60.0	216.9	Hawkesbury Sandstone	28 May 2011
					107.5	169.4	Hawkesbury Sandstone	
					155.0	121.9	Hawkesbury Sandstone	
					211.8	65.1	Bald Hill Claystone	
					234.5	42.4	Bulgo Sandstone	
					406.5	-129.6	Bulgo Sandstone	
					432.5	-155.6	Stanwell Park Claystone	
					454.0	-177.1	Scarborough Sandstone	
					483.5	-206.6	Scarborough Sandstone	
					517.0	-240.1	Wombarra Claystone	
					556.5	-279.6	Bulli Coal Seam	
9EGW2-4[2]	Fire Trail 9E	311216	6216986	276.3	407.0	-131	Bulgo Sandstone	18 December 2017
					454.0	-178	Scarborough Sandstone	
					484.0	-208	Scarborough Sandstone	
					517.0	-241	Wombarra Shale	
					557.0	-281	Bulli Coal Seam	

Table 20 (Continued)
Groundwater Level and Groundwater Level/Pressure Sites

Site Number	Location	Easting (m)	Northing (m)	Collar (m AHD)	Depth (m)	Elevation (m AHD)	Lithology	Commencement Date
F6GW3A	Old Princes Hwy east of LW 301	312855	6215539	242.6	50.0	192.6	Hawkesbury Sandstone	17 June 2013
					70.0	172.6	Hawkesbury Sandstone	
					100.0	142.6	Hawkesbury Sandstone	
					135.0	107.6	Newport Formation	
					220.0	22.6	Bulgo Sandstone	
					308.0	-65.4	Bulgo Sandstone	
					380.0	-137.4	Bulgo Sandstone	
					450.0	-207.4	Bulli Seam	
F6GW4A	Old Princes Hwy between LW303 and LW304	312531	6216694	265.0	50.0	215.0	Hawkesbury Sandstone	17 June 2013
					90.0	175.0	Hawkesbury Sandstone	
					139.0	126.0	Hawkesbury Sandstone	
					201.0	64.0	Bulgo Sandstone	
					278.0	-13.0	Bulgo Sandstone	
					362.0	-97.0	Bulgo Sandstone	
					440.0	-175.0	Scarborough Sandstone	
					512.0	-247.0	Bulli Seam	
PHGW2A	Fire Trail west of Princes Highway	312322	6217752	263.0	60.0	203.0	Hawkesbury Sandstone	16 March 2011
					97.5	165.5	Hawkesbury Sandstone	
					135.0	128.0	Hawkesbury Sandstone	
					181.5	81.5	Bald Hill Claystone	
					201.0	62.0	Bulgo Sandstone	
					365.0	-102.0	Bulgo Sandstone	
					389.0	-126.0	Stanwell Park Claystone	
					411.0	-148.0	Scarborough Sandstone	
					437.0	-174.0	Scarborough Sandstone	
					470.0	-207.0	Wombarra Claystone	
					508.0	-245.0	Bulli Coal Seam	

Table 20 (Continued)
Groundwater Level and Groundwater Level/Pressure Sites

Site Number	Location	Easting (m)	Northing (m)	Collar (m AHD)	Depth (m)	Elevation (m AHD)	Lithology	Commencement Date
PHGW1B	Fire Trail west of Princes Highway	312281	6218335	289.8	65.0	224.8	Hawkesbury Sandstone	28 June 2010
					115.5	174.3	Hawkesbury Sandstone	
					166.0	123.8	Hawkesbury Sandstone	
					215.5	74.3	Bald Hill Claystone	
					238.0	51.8	Bulgo Sandstone	
					396.0	-106.3	Bulgo Sandstone	
					432.0	-142.3	Stanwell Park Claystone	
					482.3	-192.6	Scarborough Sandstone	
					518.3	-228.6	Wombarra Claystone	
					554.1	-264.4	Bulli Coal Seam	
PM01 (9DGW1B)	Fire Trail 9D	309971	6217271	283.6	52.0	231.7	Hawkesbury Sandstone	5 February 2010
					90.0	193.7	Hawkesbury Sandstone	
					170.0	113.7	Hawkesbury Sandstone	
					218.0	65.7	Bald Hill Claystone	
					238.0	45.7	Bulgo Sandstone	
					415.0	-131.3	Bulgo Sandstone	
					440.0	-156.3	Stanwell Park Claystone	
					482.0	-198.3	Scarborough Sandstone	
					494.0	-210.3	Scarborough Sandstone	
					547.5	-263.8	Coal Cliff Sandstone	
PM02	Fire Trail 9D	310650	6218509	267.4	35.0	232.4	Hawkesbury Sandstone	23 December 2007
					100.0	167.4	Hawkesbury Sandstone	
					220.0	47.4	Bald Hill Claystone	
					250.0	17.4	Bulgo Sandstone	
					400.0	-132.7	Bulgo Sandstone	
					435.0	-167.7	Stanwell Park Claystone	
					475.0	-207.7	Scarborough Sandstone	
					495.0	-227.7	Scarborough Sandstone	

Table 20 (Continued)
Groundwater Level and Groundwater Level/Pressure Sites

Site Number	Location	Easting (m)	Northing (m)	Collar (m AHD)	Depth (m)	Elevation (m AHD)	Lithology	Commencement Date
PM03	Woronora Dam Road	311664	6219773	265.0	64.0	201.0	Hawkesbury Sandstone	14 February 2011
					106.5	158.5	Hawkesbury Sandstone	
					149.0	116.0	Hawkesbury Sandstone	
					189.3	75.7	Bald Hill Claystone	
					214.0	51.0	Bulgo Sandstone	
					385.0	-120.0	Bulgo Sandstone	
					408.0	-143.0	Stanwell Park Claystone	
					430.2	-165.2	Scarborough Sandstone	
					462.0	-197.0	Scarborough Sandstone	
					492.0	-227.0	Wombarra Claystone	
					526.0	-261.0	Coal Cliff Sandstone	
S1997*	North Cliff	306997	6212765	370.2	24.0	346.2	Hawkesbury Sandstone	10 June 2009
					68.5	301.7	Hawkesbury Sandstone	
					132.0	238.2	Hawkesbury Sandstone	
					218.0	152.2	Bulgo Sandstone	
					292.5	77.7	Bulgo Sandstone	
					372.0	-1.8	Bulgo Sandstone	
					429.0	-58.8	Scarborough Sandstone	
					441.5	-71.3	Scarborough Sandstone	
					454.0	-83.3	Scarborough Sandstone	
					504.5	-134.3	Coal Cliff Sandstone	
					511.6	-141.4	Bulli Coal Seam	

Table 20 (Continued)
Groundwater Level and Groundwater Level/Pressure Sites

Site Number	Location	Easting (m)	Northing (m)	Collar (m AHD)	Depth (m)	Elevation (m AHD)	Lithology	Commencement Date
302GW01[3]	Overlying Longwall 302	312952	6216553	305.1	80.0	225.1	Hawkesbury Sandstone	Commenced 23 November 2017 End Date: 25 May 2018
					150.0	155.1	Hawkesbury Sandstone	
					200.0	105.1	Newport Formation	
					245.0	60.1	Interbedded Shale and Sandstone	
					340.0	-34.9	Bulgo Sandstone	
					380.0	-74.9	Bulgo Sandstone	
					400.0	-94.9	Bulgo Sandstone	
					410.0	-104.9	Bulgo Sandstone	
					440.0	-134.9	Scarborough Sandstone	
TBS02-80[4] (pre-mining standpipe)	Overlying Longwall 302	312849	6216579	305.1	82.5	222.6	Hawkesbury Sandstone	1 October 2017 End Date 12 January 2018
TBS02-90 (post-mining standpipe)	Overlying Longwall 302	312843	6216580	306.5	90.0	216.5	Hawkesbury Sandstone	13 February 2019
TBS02-190 (post-mining standpipe)	Overlying Longwall 302	312837	6216583	305.7	190.0	115.7	Hawkesbury Sandstone	8 February 2019
TBS02-250[5] (pre-mining hole)	Overlying Longwall 302	312852	6216598	306.1	192.0	114.1	Newport Formation	27 October 2017 End Date 22 October 2018
					243.0	63.1	Shale/ Sandstone	27 October 2017 End Date 22 October 2018
TBS02-250R (post-mining hole)	Overlying Longwall 302	312865	6216583	307.4	90.0	217.4	Hawkesbury Sandstone	24 January 2019 VWP 245 failed during grouting
					150.0	157.4	Hawkesbury Sandstone	
					180.0	127.4	Hawkesbury Sandstone	
					245.0	62.4	Upper Bulgo Sandstone	

Table 20 (Continued)
Groundwater Level and Groundwater Level/Pressure Sites

Site Number[7]	Location	Easting (m)	Northing (m)	Collar (m AHD)	Depth (m)	Elevation (m AHD)	Lithology	Commencement Date
TBS02A-15	Overlying Longwall 302	312837	6216577	304.2	15.5	288.7	Hawkesbury Sandstone	31 October 2017
TBS03-230[6] Pre-Mining	Overlying Longwall 303	312652	6216685	281.9	162.0	119.9	Newport Formation	22 February 2018
					213.0	68.9	Shale/ Sandstone	End Date 13 December 2018
TBS03-230R (post-mining hole)	Overlying Longwall 303	312648	6216686	281.5	162.0	119.5	Newport Formation	12 April 2019
					213.0	68.5	Shale/ Sandstone	
					245.0	36.5	Bulgo Sandstone	
					265.0	16.5	Bulgo Sandstone	
TBS03-15	Overlying Longwall 303	312647	6216684	281.9	15.5	266.4	Hawkesbury Sandstone	23 February 2018
LW305GW (Longwall 305 post-mining)	Overlying Longwall 305	312390	6217173	257.3	94	163.3	Hawkesbury Sandstone	7 October 2023
					105	152.3	Hawkesbury Sandstone	
					136	121.3	Hawkesbury Sandstone	
					203	54.3	Bulgo Sandstone	
					250	7.3	Bulgo Sandstone	
					331	-73.7	Bulgo Sandstone	

1 Multi-level piezometer site 9GGW1B was installed above Longwall 22 to monitor deep groundwater levels/pressure as part of the Longwalls 20-22 monitoring program, however this site was decommissioned due to safety risks in late 2013 prior to Longwall 22 passing the site. Metropolitan Coal replaced this site with a new bore (9GGW1-80) which monitors the groundwater level with a single piezometer at 70 m depth.

2 Multi-level piezometer site 9EGW2A experienced failure of certain lower level instrumentation. An additional hole was drilled adjacent to 9EGW2A (bore 9EGW2-4) to a depth of 557 m to install new piezometers at the same RL as the failed piezometers in December 2017.

3 302GW01 piezometer site intended to be first site to safely monitor throughout the longwall extraction process with new optical fibre piezometers. Optical fibres unfortunately were severed by ground movement as Longwall 302 passed under the site.

4 TBS02-80 m hole found obstructed 12 Dec 2018, unable to clear obstruction or dip water level. Hole remediated, and replacement hole installed 13 Feb 2019 at 90 m depth.

5 TBS02-250 (pre-mining) VWP communications lost 22 Oct 2018. Hole remediated, and replacement hole installed 24 Jan 2019.

6 TBS03-230 (pre-mining) VWP communication lost as Longwall 303 passed underneath. Post mining hole (TBS03-230R) reinstated 12 April 2019.

7 Sites S92-GW-02, 9E-GW-77, 9D-GW-76-90, and 9D-GW-76-150 planned to be installed early 2025.

* Data courtesy of Illawarra Metallurgical Coal.

Measured Vertical Head Profiles

The measured vertical hydraulic head profiles for installed multi-piezometer bores will be monitored as a component of this WMP. The measured vertical hydraulic head profiles for multi-piezometer bores PHGW2A, PHGW1B, 9EGW1B, 9EGW2A/9EGW2-4, PM01 (9DGW1B), and PM02 will be compared against their predicted vertical head profiles as described in Section 8.6.3. Their measured vertical hydraulic head profiles are illustrated on Charts 14 to 19 on stratigraphic sections with piezometer offtakes, average potentiometric head levels and pressure heads. It should be noted that the heads at these bores have potentially been affected to some degree by previous mining at Metropolitan Coal and/or other nearby mines (e.g., North Cliff and Darkes Forest).

In addition, it is recommended that an additional two multi-piezometer bores are installed surrounding the large swamps (Swamp 77 and Swamp 92) at the southern end of longwall mining.

Bore PHGW2A

Bore PHGW2A is located approximately 400 m north of the T1-T5 transect and about 900 m east of Longwalls 311-316. The profiles in Chart 14 show a mild downwards hydraulic gradient over the past decade.

The head in the Lower Hawkesbury Sandstone is about 174 metres Australian Height Datum (m AHD); the head in the Lower Bulgo Sandstone is not measured due to the piezometer at 365 m depth having missing data since 2021. The profiles at various times in Chart 14 show that the heads were not varying with time as mining proceeded, until commencement of Longwall 305 when the two Scarborough Sandstone and one Stanwell Park Claystone piezometers showed a sudden increase, before a sudden decrease after the start of Longwall 306 and again after Longwall 307. These sensors stopped recording in 2022.

The deepest piezometer (470) experienced a rapid depressurisation in early May 2022 of approximately 40 m; this occurred after the start of LW307, which was 288 m from PHGW2A at this time. By early September 2022, three piezometers (389, 411, 437) experienced depressurisation after a period of non-recording.

Bore PHGW1B

Bore PHGW1B is about 500 m due north of PHGW2A and about 800 m north-east of Longwalls 311-316. Due to proximity, it would be expected to have a similar vertical hydraulic gradient to PHGW2A, but in fact it has a steeper vertical gradient (Chart 15). This seems to be due to the naturally higher lateral hydraulic gradient towards the north-east in deeper strata but could be due to the influence of the Metropolitan Fault.

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 192 m AHD and the head in the Lower Bulgo Sandstone is about 111 m AHD. The profiles at various times in Chart 15 show that the heads are generally increasing as mining progresses; this is more evident in the sensors monitoring claystone units. However, these changes are anticipated to be stabilisation effects after installation, with all sensors stabilising after 2014.

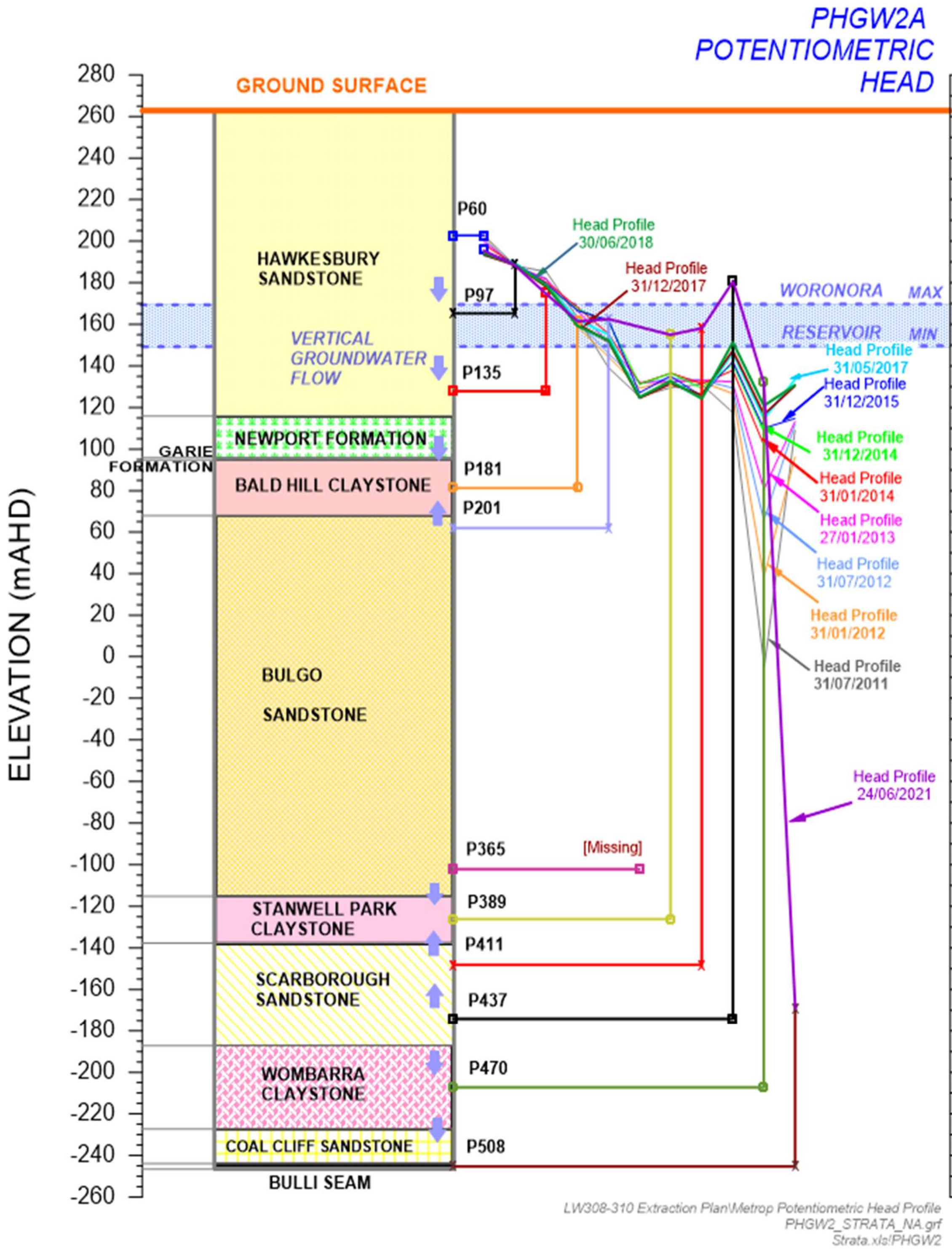


Chart 14 **Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore PHGW2A**

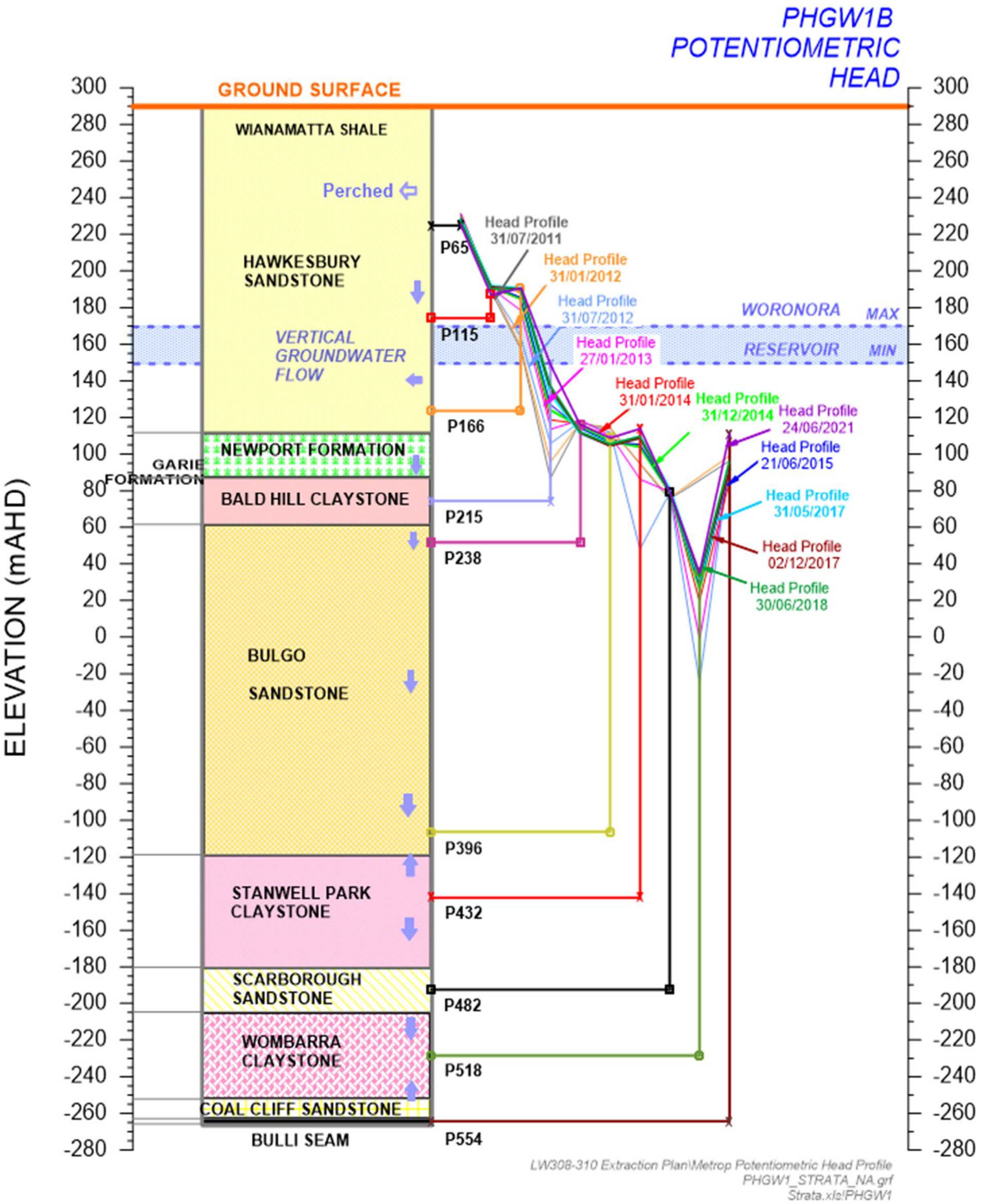


Chart 15 Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore PHGW1B

Bore 9EGW1B

Bore 9EGW1B is located approximately 500 m north of the western end of Longwall 23A and 350 m south of Longwall 316.

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 238 m AHD and the head in the Lower Bulgo Sandstone is about 170 m AHD. The profiles at various times in Chart 16 show that the heads are not varying significantly with time as mining proceeds, but several piezometers have taken time to stabilise. Some depressurisation appears to have occurred in the Lower Bulgo Sandstone and lower formations due to mining to the south (Chart 16).

Bore 9EGW2A and 9EGW2-4

Bore 9EGW2A is located above Longwall 310. The vibrating wire piezometers indicate substantial depressurisation at depth, but the records are erratic and not consistent (Chart 17). The vibrating wire piezometers in and beneath the lower Bulgo Sandstone had unreliable data from 14 October 2014.

An additional hole (9EGW2-4) with five piezometers (P407, P454, P484, P517 and P557) was installed in close proximity to 9EGW2A on 18 December 2017. Piezometers 484, 517, and 557 all showed a significant decline in late 2021 and a rapid increase at the end of 2022. Although the decrease at Piezometer 557 (Bulli Seam) was expected, the decrease of water levels at piezometers 454, 484 and 517 was larger than expected. This decrease could be attributed to in-seam gas drainage holes, which arrived at this location. Geophysics showed an unusually high pore space in the respective claystone formations above the Bulli Seam, which is thought to be the reason for those declines. Piezometers 484 and 517 have shown an oscillation response over 2022, with rapid recovery towards the end of 2022.

Bore PM01 (9DGW1B)

Bore PM01 (9DGW1B) is located above Longwall 316. This site has a similar vertical head gradient to that observed at PHGW1B.

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 240 m AHD and the head in the Lower Bulgo Sandstone is about 131 m AHD. The profiles at various times in Chart 18 show that the heads are not varying significantly with time as mining proceeds, but the Scarborough Sandstone piezometer (P482) has been unstable with increasing heads.

Bore PM02

Bore PM02 is located above Longwall 315. Chart 19 indicates that all potentiometric heads are high and within 40 m of the maximum level of the Woronora Reservoir. As there is a minor difference in head between the Lower Bulgo Sandstone and the Lower Scarborough Sandstone, it is inferred that there is no substantial change in vertical hydraulic gradient (at depth) due to mining.

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 185 m AHD and the head in the Lower Bulgo Sandstone is about 125 m AHD. The profiles at various times in Chart 19 show that the heads are not varying significantly with time as mining proceeds.

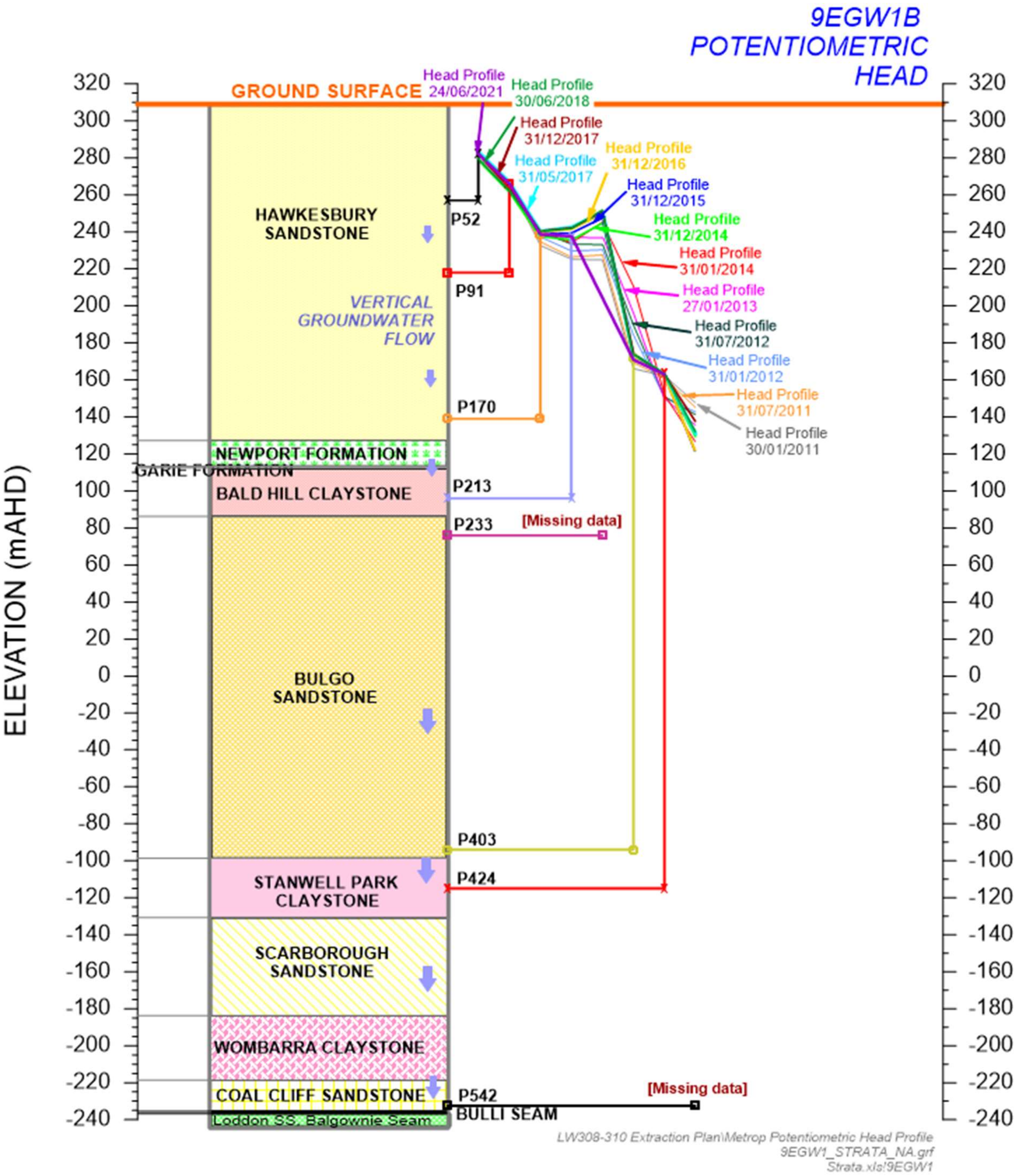


Chart 16 Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore 9EGW1B

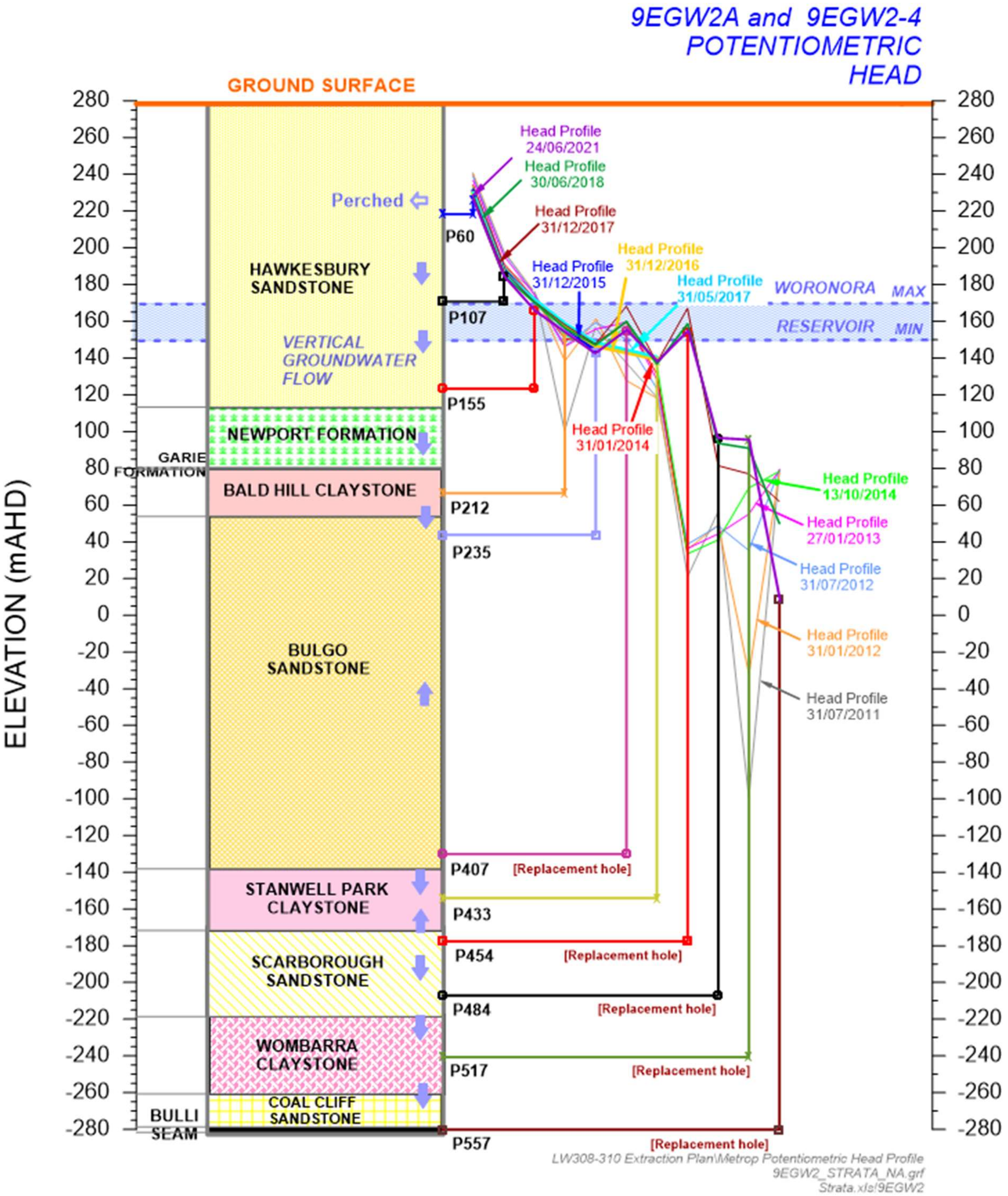


Chart 17 Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bores 9EGW2A and 9EGW2-4

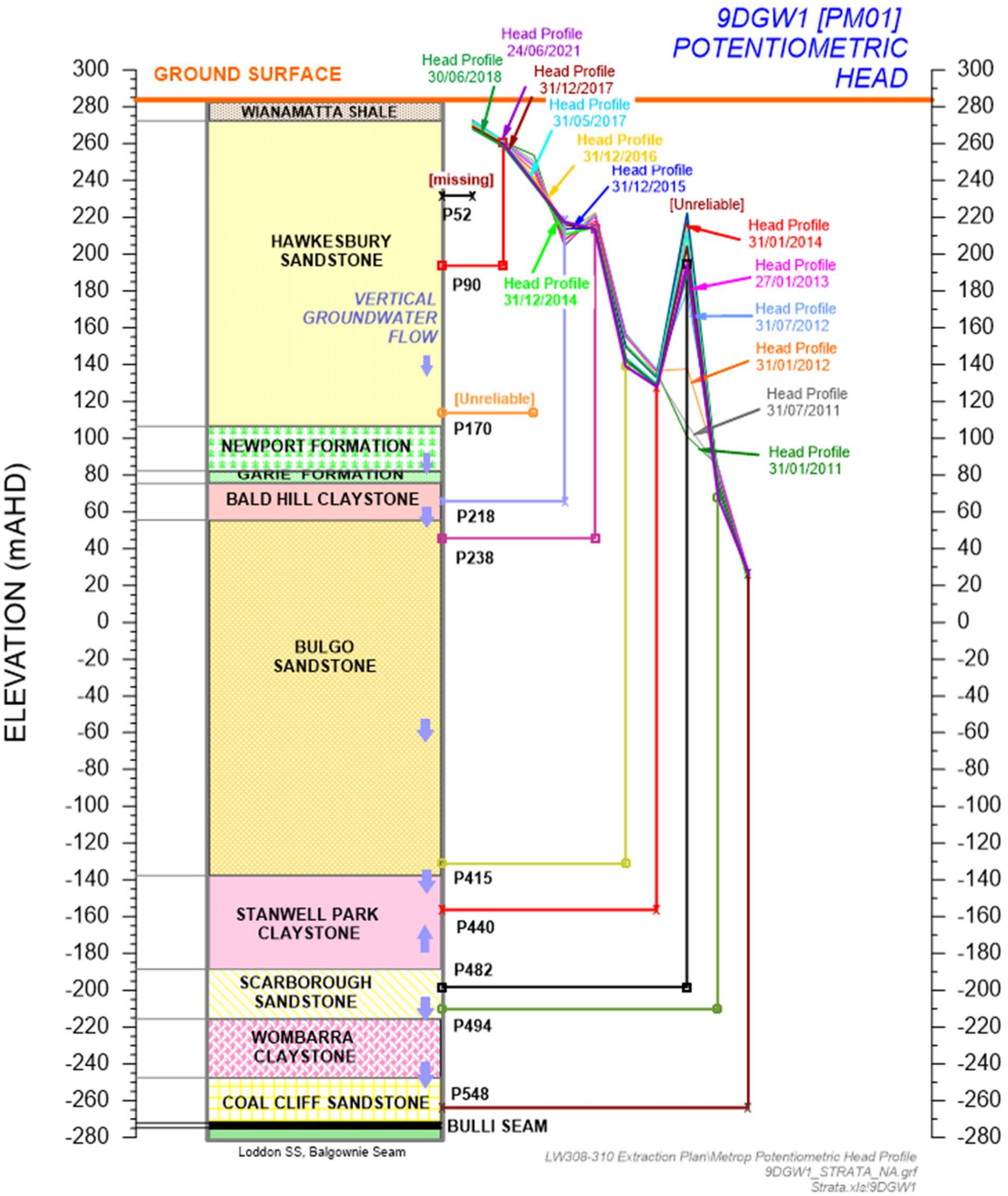


Chart 18 Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore PM01 (9DGW1B)

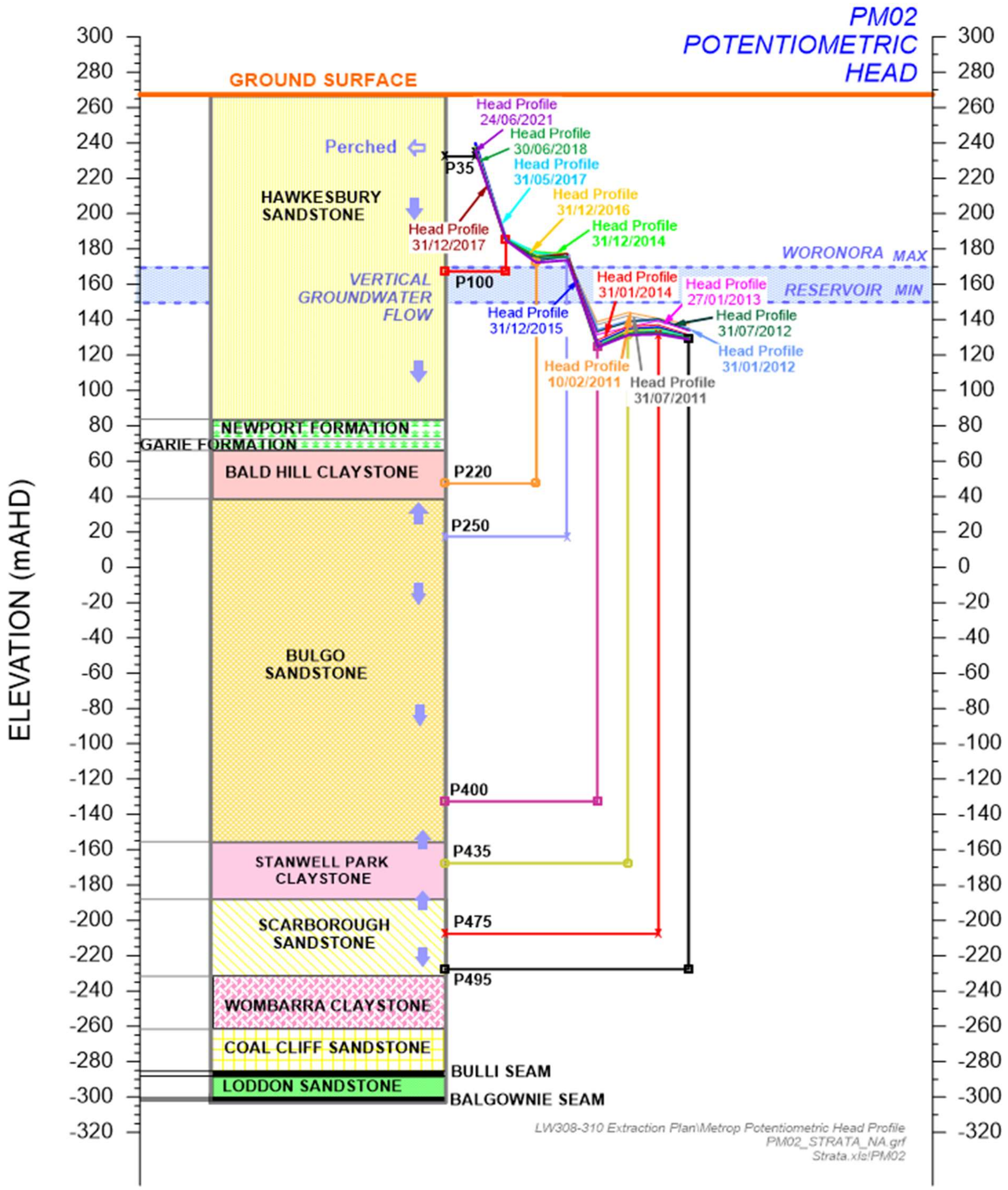


Chart 19 Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore PM02

7.3.5 Mine Water Make

Mine water make (i.e. groundwater that has seeped into the mine through the strata) is calculated from the difference between total mine inflows (reticulated water into the mine, moisture in the downcast ventilation, moisture in backfill delivery pipe and the Run-of-Mine [ROM] coal *in-situ* moisture content) and mine outflows (reticulated water out of the mine, moisture in the exhaust ventilation, and moisture in the ROM coal).

Charts 3a and 3b in Section 4.2 show the mine water make results to August 2023. The 20-day average daily mine water make has consistently been less than 0.5 ML/day (Chart 3a). From January 2009 to August 2023, the mine water make has averaged 0.02 ML/day, which is less than that predicted by groundwater modelling for the Project.

The predicted groundwater take from the Sydney Basin Central Groundwater Source of the Water Sharing Plan for the *Greater Metropolitan Region Groundwater Sources 2023* for each year from 2023 to 2030 is presented in Table 21.

Table 21
Predicted Groundwater Take Volume

Year	Water Take Volume (ML)
2023	35.3
2024	35.5
2025	36.4
2026	36.4
2027	37.5
2028	34.7
2029	32.7
2030	31.1

Metropolitan Coal holds WAL 36475 with sufficient entitlements to account for the maximum predicted take associated with inflows to the underground workings.

7.3.6 Groundwater Quality

Groundwater quality data is available from a number of sites with installed piezometers, as summarised in Table 22. The locations of the groundwater quality sites are shown on Figure 11.

The groundwater quality sampling sites are detailed in Table 23 and shown on Figure 11.

Groundwater quality sites in the vicinity of Longwalls 20-27, namely sites SWGW1, RTGW1A, FGGW1, FGGW2, FGGW3, UTGW1, UTGW2 and UTGW3 were installed within the Metropolitan Coal Mine mining area to monitor groundwater levels and quality as part of previous monitoring programs, however, will be removed from regular monitoring and reporting for Longwalls 311-316 as the monitoring sites are located more than 1 km from Longwalls 311-316 and are expected to experience negligible impacts.

Table 22
Shallow Groundwater Quality Sites

Site Number	Location	Easting (m)	Northing (m)	RL (m AHD)	Commencement Date
SWGW1	Swamp S06	307893	6214226	343.7	12 March 2009
WRGW1	Waratah Rivulet	309886	6214360	207.8	16 February 2007
WRGW2	Waratah Rivulet	309868	6214335	207.9	16 February 2007
WRGW3	Waratah Rivulet	309629	6214072	215.0	16 February 2007
WRGW4	Waratah Rivulet	309579	6214090	217.8	16 February 2007
WRGW5	Waratah Rivulet	309393	6212890	225.4	4 April 2007
WRGW6	Waratah Rivulet	309361	6212871	226.1	4 April 2007
WRGW7	Waratah Rivulet	310717	6215382	184.2	1 September 2010
RTGW1A[1]	Tributary B	309593	6215109	222.0	23 August 2007
UTGW 1	Tributary D	309520	6214151	218.2	16 February 2007
UTGW 2	Tributary D	309097	6214012	237.6	7 March 2007
UTGW 3	Tributary D	308833	6213951	247.2	7 March 2007
FGGW1	Forest Gully	308951	6213200	232.4	8 March 2007
FGGW2	Forest Gully	308816	6213158	240.5	4 April 2007
FGGW3	Forest Gully	308682	6213113	250.4	4 April 2007
ETGW1[2]	Eastern Tributary	312129	6215644	172.6	1 September 2010
ETGW2	Eastern Tributary	312134	6215664	172.1	1 September 2010

1 Due to bore failure as a result of subsidence, groundwater quality at RTGW1A has not been sampled since December 2013.

2 Site ETGW1 was unable to be sampled from January to March 2017, and since August 2017.

Table 23
Deep Groundwater Chemistry Sites

EES (2014) Bore Name	Metropolitan Coal Site Number	Easting (m)	Northing (m)	Collar (m AHD)	Depth (m)	Elevation (m AHD)	Lithology	Sampling Type	Status
9F2-50E	9FGW2	308717.4	6217210.3	289.8	50	239.8	Upper Hawkesbury Sandstone	Chemical and Static Water Level	Operational
9F2-130C		308740.7	6217240.7	289.8	130	139.8	Lower Hawkesbury Sandstone	Chemical and Static Water Level	Operational (recovered from initial grout impact)
9F2-250D		308720.5	6217223.8	289.8	250	39.8	Bulgo Sandstone	Chemical and Static Water Level	Operational (recovered from initial grout impact)
PH2-25E	PHGW2	312316.1	6217761.1	263.0	25	238	Upper Hawkesbury Sandstone	Chemical and Static Water Level	Operational
PH2-110C		312322.3	6217782.3	263.1	110	153	Lower Hawkesbury Sandstone	Chemical and Static Water Level	Operational (recovered from initial grout impact)
PH2-230D		312327.1	6217772.3	262.2	230	33	Bulgo Sandstone	Chemical and Static Water Level	Operational
PM03-25E	PM03	311640.8	6219766.2	265.7	25	242.7	Upper Hawkesbury Sandstone	Chemical and Static Water Level	Operational
PM03-105C		311665.2	6219754.9	265.7	105	160.7	Lower Hawkesbury Sandstone	Chemical and Static Water Level	Operational
PM03-230D		311647.6	6219776.1	265.7	230	35.7	Bulgo Sandstone	Chemical and Static Water Level	Operational (recovered from initial grout impact)

Table 23 (Continued)
Deep Groundwater Chemistry Sites

EES (2014) Bore Name	Metropolitan Coal Site Number	Easting (m)	Northing (m)	Collar (m AHD)	Depth (m)	Elevation (m AHD)	Lithology	Sampling Type	Status
9E1-36E	9EGW1	309474.7	6216083.5	309.2	36	273.2	Upper Hawkesbury Sandstone	Chemical	Operational (field measurement only)
9E1-80E					80	229.2	Upper Hawkesbury Sandstone	Chemical	Operational (field measurement only)
9E1-108C					108	201.2	Lower Hawkesbury Sandstone	Chemical	Operational (field measurement only)
9E1-250D					250	59.2	Bulgo Sandstone	Chemical	No longer operational (drilling fluid but no water recovered)
9H1-35E	9HGW1	308171.8	6214592.5	350.3	35	315.3	Upper Hawkesbury Sandstone	Chemical	Operational (field measurement only)
9H1-82E					82	268.3	Upper Hawkesbury Sandstone	Chemical	No longer operational (no recovery)
9H1-150C					150	200.3	Lower Hawkesbury Sandstone	Chemical	No longer operational (no recovery)
9H1-233D					233	117.3	Bulgo Sandstone	Chemical	No longer operational (no recovery)
9G1-70C	9GGW1	310980.5	6214309.1	286.0	70	216.0	Lower Hawkesbury Sandstone	Chemical and Static Water Level	Operational (field measurement only)
9G1-45E		310986.2	6214305.4	287.0	45	242.0	Upper Hawkesbury Sandstone	Chemical	No longer operational (no recovery)
9G1-140C				287.0	140	147.0	Lower Hawkesbury Sandstone	Chemical	No longer operational (no recovery)
9G1-190D				287.0	190	97.0	Bulgo Sandstone	Chemical	No longer operational (no recovery)

Table 23 (Continued)
Deep Groundwater Chemistry Sites

EES (2014) Bore Name	Metropolitan Coal Site Number	Easting (m)	Northing (m)	Collar (m AHD)	Depth (m)	Elevation (m AHD)	Lithology	Sampling Type	Status
9G3-32E	9GGW3	311581.3	6215044.6	260.0	32	228.0	Upper Hawkesbury Sandstone	Chemical and Static Water Level	Operational (recovered from initial grout impact)
9G3-117C		311588.0	6215040.3	260.0	117	143.0	Lower Hawkesbury Sandstone	Chemical and Static Water Level	Operational (recovered from initial grout impact) (field measurement only)
9G3-216D		311609.7	6215024.9	260.0	216	44.0	Bulgo Sandstone	Chemical and Static Water Level	Operational (still grout impacted) (field measurement only)
F6GW3-85C	F6GW3	312849.0	6215533.9	243.5	85	158.5	Lower Hawkesbury Sandstone	Chemical and Static Water Level	Operational (recovered from initial grout impact)
F6GW4-36E	F6GW4	312524.1	6216670.7	265.0	36	229.0	Upper Hawkesbury Sandstone	Chemical and Static Water Level	Operational
F6GW4-104C		312527.7	6216681.3	265.0	104	161.0	Lower Hawkesbury Sandstone	Chemical and Static Water Level	Operational
F6GW4-208D		312528.4	6216686.0	265.0	208	57.0	Bulgo Sandstone	Chemical and Static Water Level	Operational

Source: after Environmental Earth Sciences (EES) (2014) *Assessment and Interpretation of Deep Groundwater Sampling Program – June 2009 to February 2014 – Woronora Catchment Area, Helensburgh, NSW* and Brienen Environment & Safety (BES) (2019) *Deep Groundwater Sampling Program – January – March 2019 – Woronora Catchment Area, Helensburgh, NSW.*

8 MONITORING PROGRAM

Subsidence parameters will be measured in accordance with the Metropolitan Coal Longwalls 311-316 Subsidence Monitoring Program (Figure 3). In summary, surveys will be conducted to measure subsidence movements in three dimensions using a total station survey instrument and real time GNSS monitoring stations. Subsidence movements will be measured along subsidence lines that have been positioned across the general landscape.

A monitoring program will be implemented to monitor the impacts and environmental performance of the Project on water resources and watercourses during the mining of Longwalls 311-316. The monitoring program is described in Sections 8.1 to 8.8.

Section 8.9 provides detailed TARPs to assess the water resource and watercourse subsidence impact performance indicators and measures.

8.1 METEOROLOGY

Rainfall data will be monitored using pluviometers at the following locations (Figure 15):

- Waratah Rivulet catchment (sites PV1 and PV6);
- Woronora River catchment (site PV2);
- Honeysuckle Creek catchment (site PV5);
- Eastern Tributary catchment (site PV7); and
- Woronora Reservoir catchment (site PV8).

A pan evaporimeter at site PV1 (Figure 15) will monitor evaporation in the Waratah Rivulet catchment.

This data will be supplemented by rainfall and/or climate data from nearby Bureau of Meteorology stations or WaterNSW owned monitoring equipment, as required.

The meteorology data will input to the catchment models described in Section 8.3.1.

8.2 STREAM FEATURES

Visual inspections and photographic surveys of the Waratah Rivulet from the full supply level of the Woronora Reservoir to Pool P will be conducted at annual intervals.

The visual and photographic surveys will record:

- the location, approximate dimensions (length, width and depth), and orientation of surface cracks (specifically whether cracks are developed perpendicular to the stream flow or are controlled by rock joints or other factors, etc.);
- the nature of iron staining (e.g. whether isolated or across the entire streambed);
- the extent of iron staining (e.g. the length of stream affected);
- a description of gas release (e.g. isolated bubbles or continuous stream, and type of gas [methane or carbon dioxide]);
- the nature of scouring, for example the depth of scouring, type of soil exposed, any obvious vegetation impact, potential for severe erosion, etc.;

- water discoloration or opacity if present;
- rock bar characteristics such as extent of cracking, seepage, underflow;
- whether any actions are required (e.g. implementation of management measures, incident notification, implementation of appropriate safety controls, review of public safety, etc.); and
- any other relevant information.

Global Positioning System (GPS) coordinates will be recorded where appropriate (e.g. of particular observations and associated photographs).

The visual inspections on the Waratah Rivulet and Eastern Tributary will record the above parameters by exception (i.e. where they differ to the baseline visual and photographic record).

Any gas releases identified as occurring on the Waratah Rivulet and Eastern Tributary to the Woronora Reservoir full supply level by the visual inspections during the mining of Longwalls 311-316 (either during the visual and photographic surveys or other catchment monitoring) will be monitored weekly to determine the nature of the gas releases, gas concentration (samples taken for the analysis for carbon dioxide and methane content) and any observable environmental effects (e.g. impacts to riparian vegetation or fish kills). Weekly monitoring will be conducted at pools observed with gas releases, until no gas releases have been observed at the pool for three consecutive weeks.

8.3 SURFACE WATER QUANTITY

8.3.1 Surface Water Flow

Surface water flow monitoring will include continuous flow monitoring at (Figure 6):

- the WaterNSW owned gauging station on the Waratah Rivulet, close to the inundation limits of the Woronora Reservoir (GS 2132102);
- the Metropolitan Coal owned gauging station on the Eastern Tributary, close to the inundation limits of the Woronora Reservoir (GS 300078);
- the WaterNSW owned gauging station on the Woronora River, close to the inundation limits of the Woronora Reservoir (GS 2132101) (control site);
- the Metropolitan Coal owned gauging station on Honeysuckle Creek (GS 300077) (control site);
- the WaterNSW gauging station on O’Hares Creek at Wedderburn (GS 213200) (control site);
- the Metropolitan Coal owned gauging station on a tributary of the Woronora Reservoir (Swamp 92 Flume [GS 300143]); and
- the Metropolitan Coal owned gauging station on a tributary of the Woronora Reservoir (Swamp 76 Flume [GS 300142]).

Data from the WaterNSW owned gauging stations will continue to be downloaded monthly by WaterNSW and provided to Metropolitan Coal in accordance with a data exchange agreement.

Metropolitan Coal will source flow data for the O’Hares Creek gauging station at Wedderburn from WaterNSW.

A modified catchment model (Gilbert & Associates, 2015b) will be used to assess the quantity of water resources reaching the Woronora Reservoir from the Waratah Rivulet and Eastern Tributary. Details of the modified catchment models are provided in the Metropolitan Coal Catchment Monitoring Program.

Metropolitan Coal will monitor the Swamp 76 and Swamp 92 streamflow monitoring stations during the extraction of Longwalls 311-316.

Metropolitan Coal installed cameras that capture images at a daily frequency at the Swamp 92 Gauging Station (S92-GS) and Swamp 76 Gauging Station (G76-GS) in March 2024. The images captured by the cameras will be used to verify/validate data collected at the gauging station and assist Metropolitan Coal with identifying potential debris that may influence data records.

8.3.2 Pool Water Levels and Drainage Behaviour

The water level in Pools B, C, E, G, G1, H and I on Waratah Rivulet will be manually monitored daily, or monitored using a continuous water level sensor and logger (Figure 6).

Pool water levels and drainage behaviour will be monitored using a continuous water level sensor and logger in (Figure 6):

- Pools A, F, J, K, L, M, N, O, P, Q, R, S, T, U, V and W on Waratah Rivulet;
- Pools ETG, ETJ, ETM, ETO, ETU, ETW, ETAF, ETAG, ETAH, ETAI/ETAJ/ETAK[26], ETAL, ETAM, ETAN, ETAO, ETAP, ETAQ, ETAR, ETAS/ETAT[27] and ETAU on the Eastern Tributary;
- Pools SR1, SR2 and SP1 on tributaries of the Woronora Reservoir; and
- control Pools WRP1, WRP2, WRP3 and WRP4 on the Woronora River.

Data from these water level meters will be downloaded monthly.

Pools situated on the Waratah Rivulet from Pool P to the full supply level of the Woronora Reservoir will be visually inspected at the time of download of the pool water level data (i.e. monthly) when longwall extraction is within 450 m of the stream and again at the completion of Longwalls 311, 312, 313, 314, 315 and 316 to observe whether the pool water level has fallen below the cease to flow level or whether any changes to the natural drainage behaviour have occurred. Pools P and T on the Waratah Rivulet terminate by flowing through and below their respective rock bars. Pools U and W on the Waratah Rivulet terminate in boulder fields and are not characterised by flow over rock bars. Pool V on the Waratah Rivulet terminates in a rock bar characterised by partial flow over the rock bar and partial flow through and below the rock bar. Pools Q, R and S on the Waratah Rivulet terminate at rock bars.

Pools ETAS, ETAT and ETAU on the Eastern Tributary will be visually inspected at the completion of Longwalls 311, 312, 313, 314, 315 and 316 to observe whether any changes to the natural drainage behaviour have occurred. Pool ETAS is a rock bar controlled pool. Water enters the pool as surface flow from boulder field ETAR. The downstream rock bar is permeable (allowing both underflow and surface flow), and appears to be mainly detached blocks and boulders. Due to the nature of Rock Bar ETAS, Pool ETAS and Pool ETAT typically sit at the same level. Pool ETAT is a rock bar controlled pool. Water enters the pool as surface flow or underflow through Rock Bar ETAS. The downstream rock bar is effectively impermeable. Pool ETAU flows through Eastern Tributary gauging station, over a rock bar/waterfall, into ETAU boulder field.

[26] Only small rock bars separate Pools ETAI, ETAJ and ETAK. Pools join to become the one large pool. Pool ETAK is controlled by a rock bar. The water level meter situated in Pool ETAI and is considered to be representative of the water level in Pools ETAJ and ETAK.

[27] Due to the nature of rock bar ETAS, Pool ETAS and Pool ETAT typically sit at the same level. The water level meter situated in Pool ETAT is considered to be representative of the water level in Pool ETAS.

Observations will include:

- evidence of new cracking within the stream bed or rock bar;
- whether the pools continue to flow over, through and/or below the rock bars (where relevant); and
- whether surface flow is evident along the length of the pools prior to flowing over/through/below the rock bars or boulder fields.

8.4 SURFACE WATER QUALITY

Surface water quality will be sampled monthly at the following sites (Figure 7):

- sites WRWQ 2, WRWQ 6, WRWQ 8, WRWQ 9, WRWQ M, WRWQ N, WRWQ P, WRWQ R, WRWQ T, WRWQ U, WRWQ V, and WRWQ W on the Waratah Rivulet;
- site RTWQ 1 on Tributary B;
- sites ETWQ F, ETWQ J, ETWQ N, ETWQ U, ETWQ W, ETWQ AF, ETWQ AH, ETWQ AQ and ETWQ AU on the Eastern Tributary;
- site FEWQ 1 on the Far Eastern Tributary;
- site HCWQ 1 on Honeysuckle Creek;
- site BCWQ 1 along Bee Creek;
- sites SR1, SR2 and SP1 on Woronora Reservoir tributaries; and
- control sites WOWQ 1 and WOWQ 2 on the Woronora River.

Water quality parameters will include electrical conductivity (EC), pH, redox potential (Eh), dissolved oxygen (DO), turbidity, calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), chloride (Cl), sulphate (SO_4), bicarbonate (HCO_3), total nitrogen (Ntot), total phosphorous (Ptot), nitrate (NO_3), barium (Ba), strontium (Sr), manganese (Mn), iron (Fe), zinc (Zn), cobalt (Co) and aluminium (Al). Samples collected for metal analysis will be field filtered.

Unfiltered water quality samples will also be collected monthly at the following sites and analysed for total iron, total aluminium and total manganese, in addition to the filtered concentrations (Figure 7):

- sites WRWQ 2, WRWQ 6, WRWQ 8, WRWQ 9, WRWQ M, WRWQ N and WRWQ P on the Waratah Rivulet;
- sites ETWQ F, ETWQ J, ETWQ N, ETWQ AF and ETWQ AQ on the Eastern Tributary;
- sites SR1 and SR2 downstream of Swamp 77 and sites S92-GS and SP1 downstream of Swamp 92; and
- control site WOWQ 2 on the Woronora River, control site BCWQ 1 on Bee Creek and control site HCWQ 1 on Honeysuckle Creek.

Monitoring of water quality in areas subject to mining indicates that the effects of subsidence on water quality have been most noticeable in iron, manganese and, to a lesser extent, aluminium (Gilbert & Associates, 2008). These parameters will be used to trigger further assessment of subsidence impacts on water quality as outlined in the TARP provided in Table 25 (Section 8.9).

Metropolitan Coal will continue to monitor site ETAU and a minimum of three downstream sites (site ETFSL 0, site ETFSL 100, ETFSL 200, site ETFSL 300, site ETFSL 400, site ETFSL 500, site CONFLU1, site WDFS1 and/or site WDFS1+100) (Figure 7) weekly until the site ETWQ AU monitoring results are at Level 1 or Level 2 of the TARP for the quality of water resources reaching the Woronora Reservoir (Tables 25-A and 25-B, Section 8.9) for four consecutive assessment periods.

Subject to access arrangements with WaterNSW, Metropolitan Coal will monitor the depth profiles of water quality of the Woronora Reservoir at WDFS1, or another suitable site with agreement from WaterNSW on an annual basis until the completion of Longwall 316.

The downstream sites will be selected in consideration of the Woronora Reservoir water level and safe access to the sites. Sampling of site ETAU and three downstream sites will continue monthly once the site ETWQ AU monitoring results have returned to Level 1 or Level 2 TARP levels for four consecutive assessment periods, unless the TARP level returns to Level 3.

Metropolitan Coal is investigating the installation of an automatic sampler at ETWQ AU to support analysis of contaminant loads and inclusion of additional surface water monitoring parameters such as electrical conductivity, pH, redox potential and turbidity. Metropolitan Coal has prepared a Surface Works Assessment Form (SWAF) and pending approval and suitable weather conditions, is anticipating installation of the automatic sampler, if required, in 2025.

Metropolitan Coal will monitor WARARM5 at the same frequency described above when the sites downstream of site CONFLU1 can be accessed for sampling (i.e. when the Woronora Reservoir water levels are suitably low).

Metropolitan Coal commenced monthly water quality sampling at the Swamp 92 Gauging Station (S92-GS) as of December 2023.

8.5 WORONORA RESERVOIR WATER QUALITY

Metropolitan Coal will source water quality data for the Woronora Reservoir (site DW01, measurements taken from 0 to 9 m below the water surface level), the Nepean Reservoir and the Cataract Reservoir from WaterNSW in accordance with a data exchange agreement.

Consistent with the monitoring described in Section 8.4, the water quality data will comprise key water quality parameters of relevance to water supply and effects of subsidence, namely: total iron; total manganese; and total aluminium. These parameters will be used to trigger further assessment of subsidence impacts on reservoir water quality as outlined in the TARP provided in Table 27 (Section 8.9).

8.6 GROUNDWATER LEVELS

Metropolitan Coal will provide a groundwater impact verification in the Annual Review including an interpretation of multi-aquifer drawdown for the relevant monitoring piezometers.

8.6.1 Swamp Groundwater Levels

Monitoring of upland swamp groundwater levels will be conducted in accordance with the Metropolitan Coal Longwalls 311-316 Biodiversity Management Plan. In summary, groundwater monitoring of upland swamps will include the monitoring of paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 1 m and one sandstone piezometer to a depth of approximately 10 m). Each piezometer has been equipped with a data logger for continuous water level monitoring.

Upland swamp groundwater monitoring will continue to be conducted in Swamp 20 for Longwalls 20-22, Swamp 28 for Longwalls 23-27, Swamps 40, 41, 46, 51, 52 and 53 for Longwalls 301-303, Swamp 50 for Longwall 304, Swamps 71a and 72 for Longwalls 305-307, Swamps 62, 64, 82, and 92 for Longwalls 308-310 and in control Swamps 101, 137a, 137b, Bee Creek Swamp, and Woronora River 1 (WRSWAMP 1) (Figure 9).

Upland swamp groundwater monitoring will be conducted in Swamps 74, 75, 76, 77, 78, 79, 80, 81, 83, 89, 90, 91, 92, 106, 113, 115 and 119 for Longwalls 311-316 (Figure 9).

As of October 2024, the groundwater piezometer sites installed and collecting data are as follows:

- S76-1 (10 m piezometer).
- S76-3 (10 m piezometer).
- S77-1 (10 m piezometer).
- S77-3 (10 m piezometer).
- S92-3 (10 m piezometer).

(the sites to be installed in November 2024 subject to suitable weather and access)

- S92-1 (10 m piezometer).
- 106-1 (1 m and 10 m piezometers).
- 106-2 (1 m and 10 m piezometers).
- 106-3 (1 m and 10 m piezometers).
- S14 (1 m and 10 m piezometers).
- S74 (1 m and 10 m piezometers).
- S75 (1 m and 10 m piezometers).
- S113 (1 m and 10 m piezometers).
- S115 (1 m and 10 m piezometers).
- S119 (1 m and 10 m piezometers).
- Bee Creek Swamp-1 (1 m and 10 m piezometers) (control swamp).
- Bee Creek Swamp-2 (1 m and 10 m piezometers) (control swamp).

Metropolitan Coal has identified a potential location (S77-0) for a new substrate-only monitoring site at the downstream end of Swamp 77. The feasibility of installing a substrate piezometer at S77-0 is being investigated as access for installation equipment is heavily constrained and substrate thickness in the downstream section of the swamp is limited in areas (e.g. approximately 0.5 m).

8.6.2 Shallow Groundwater Levels Near Streams

Continuous water level monitoring of shallow groundwater will be conducted along streams at (Figure 10):

- sites WRGW1, WRGW2, WRGW3, WRGW5, WRGW6 and WRGW7 along Waratah Rivulet;
- site ETGW1 along Eastern Tributary; and
- sites ETO1, ETO2, ETO3 and ETO4 adjacent to Pool ETO on the Eastern Tributary.

These shallow boreholes contain a piezometer at the base of each hole. Data will be downloaded monthly.

8.6.3 Groundwater Levels/Pressures

Continuous groundwater level monitoring will also be conducted at an approximately east-west transect of bores (sites T1, T2, T3-R, T5 and T6)[28] located to the east of Longwalls 311-316 (Figure 10). Bore T3 ceased recording in December 2020 and was replaced by a redrilled bore T3-R, approximately 10 m north of the original T3 location. T3-R ceased recording in March 2024. Data from the divers in the standpipes will be downloaded monthly and the measured water levels at these bores will be compared against the water level in the Woronora Reservoir.

Additional groundwater standpipes have been installed as a component of the Woronora Reservoir Impact Strategy, namely bores TBS02-15 (pre-mining Longwall 302), bore TBS03-15 (pre-mining Longwall 303), bore TBS02-90 (post-mining Longwall 302), and bore TBS02-190 (post-mining Longwall 302) (Figure 10).

Continuous groundwater level/pressure monitoring will be conducted at (Figure 10):

- site 9HGW0 (Longwall 10 post-mining);
- site 9EGW1B;
- site 9FGW1A;
- site 9GGW2B;
- site 9HGW1B;
- site PM02;
- site 9GGW1-3;
- site 9GGW1-80;
- site PM01 (9DGW1B);
- site 9EGW2A;

[28] The water level data obtained at bore T4 is anomalous and unreliable as its head is higher than the head at upgradient site T5. This is considered unlikely to be a groundwater divide as it is not related to the topographic ridge well upgradient (SLR Consulting, 2021).

- site 9EGW2-4;
- site PM03;
- site PHGW1B;
- site PHGW2A;
- site F6GW3A;
- site F6GW4A;
- site LW305GW (Longwall 305 post-mining);
- site TBS02-90;
- site TBS02-190;
- site TBS02-250R;
- site TBS02-15; and
- site TBS03-15.

The following sites are planned to be installed in early 2025 (subject to approval and suitable weather conditions):

- site S92-GW-02;
- site 9E-GW-77;
- site 9D-GW-76-90; and
- site 9D-GW-76-150.

Data from the piezometers will be downloaded monthly.

Vertical profiles of potentiometric head are effective monitors of the capacity of an aquifer system to maintain pressure during the formation of deformation zones caused by caving and subsidence. Head profiles show a characteristic reduction in head with depth due to mining. That is, as mining moves closer, groundwater pressures can fall. Vertical groundwater head profiles will be used to assess the potential for connective cracking between the surface and the mine. The measured vertical hydraulic head profiles for six bores[29] (those most relevant to Longwalls 311-316, as listed in Section 7.3.3 and shown in Charts 14 to 19) will be compared against the predicted vertical hydraulic head profiles for each bore as outlined in the TARPs provided in Section 8.9.

Metropolitan Coal will review VWPs that are performing poorly and assess whether sufficient groundwater data is being collected by the remaining VWPs. In the event mine subsidence results in the loss of a deep monitoring bore, Metropolitan Coal will assess whether sufficient groundwater data is being collected by the remaining deep monitoring bores.

8.6.4 Woronora Reservoir Leakage

Continuous groundwater level/pressure monitoring will be conducted at bores PM02, 9GGW2B, PHGW2A, 9EGW2A and F6GW4A and data from the piezometers will be downloaded monthly (Figure 10). The water levels in Hawkesbury Sandstone at depths similar to reservoir level, measured at Bores PM02, PHGW2A and 9EGW2A, will be compared against the full supply level of Woronora Reservoir to assess reductions in hydraulic gradient from the bores to the Woronora Reservoir as detailed in the TARPs in Section 8.9.

[29] This includes bore site 9EGW2A; not site 9EGW2-4.

As described in Section 8.6.3, continuous groundwater level monitoring will also be conducted at an approximately east-west transect of bores (sites T1, T2, T3-R, T5 and T6) overlying Longwalls 305-307 (Figure 10). Data from the water level sensors in the standpipes will be downloaded monthly. The water tables measured at transect bores T2 and T5 will be used to assess the hydraulic gradient to the reservoir as detailed in the TARP in Section 8.9.

8.7 MINE WATER MAKE

Metropolitan Coal has an In-rush Hazard Management Plan to manage the potential risk of in-rush from:

- water lodgement in external (from adjacent mines) workings;
- water stored in existing Metropolitan workings;
- mining under surface water bodies; and
- intersection with boreholes or gas drainage holes.

In addition to shift inspections conducted by statutory officials that report on any abnormal conditions at the working face and in outbye areas, Metropolitan Coal conducts statutory weekly inspections of development workings to identify water accumulations.

In the event the statutory inspection identifies the potential for in-rush, an investigation is conducted by the Senior Mine Supervisor on that shift and reported to the Mining Engineering Manager.

Monitoring of the mine water balance will comprise monitoring of water flows into and out of the mine.

Water flows into the mine:

- Clean water reticulated into the mine (recorded continuously and downloaded monthly).
- Backfill water used to assist pumping into the mine (recorded continuously and downloaded monthly).
- Ventilation moisture content entering the mine at the intake points by manual measurement using a digital psychrometer. The frequency of readings will be as follows:
  - every hour over a 9 hour period on two occasions during a 12 month period;
  - daily (week day) except public holidays or other circumstances (access) that prevent readings to be taken; and
  - once per week as a minimum.
- Measurement of the in-situ moisture content of the coal during channel sampling for coal quality.

Water flows out of the mine:

- Return water reticulated out of the mine (recorded continuously and downloaded monthly).
- Moisture content of the raw coal conveyed out of the mine at the drift portal using an automated moisture scanner. Recorded continuously and downloaded monthly.
- Moisture content of gas stream reticulated out of the mine to the gas drainage plant (recorded continuously and downloaded monthly).
- Ventilation moisture content exiting the mine at the upcast shaft by manual measurement using a digital psychrometer. The frequency of readings will be as follows:
  - every hour over a 9 hour period on two occasions during a 12 month period;

- daily (weekday) except public holidays or other circumstances (access, fan maintenance) that prevent readings to be taken; and
- once per week as a minimum.

The inferred water make (i.e. groundwater that has seeped into the mine through the strata) will be calculated from the difference between total mine inflows (reticulated water into the mine, moisture in the downcast ventilation, moisture in the backfill process and the *in-situ* coal moisture content) and total mine outflows (reticulated water out of the mine, moisture in the exhaust ventilation, reticulated gas moisture out of the mine and moisture in the ROM coal). Given the large fluctuations in daily water usage and the cycle period for water entering the mine, being used by machinery, and draining to sumps for return pumping to the surface, a 20-day average will be used to provide a more reliable estimate of water make.

Metropolitan Coal will report in the Annual Review on the total volume of groundwater taken as inflows to the underground mine as a component of the underground water balance. In addition, the following volumes of surface water will be measured: water taken by means of the weir on Camp Gully, water discharged into Camp Gully and Sydney Water usage. Other meters will measure usage on site (e.g. stockpile sprays and recycled water).

8.8 GROUNDWATER QUALITY

Shallow groundwater quality sampling will be conducted monthly at the following sites (Figure 11):

- sites WRGW1, WRGW2 and WRGW7 along the Waratah Rivulet.

Water quality parameters will include EC, pH, Eh, Ca, Mg, Na, K, Cl, SO_4, HCO_3, Ba, Sr, Mn, Fe, Zn, Co and Al. The samples collected for the analysis of metals will be field filtered.

To identify trends in water quality parameters (i.e. Fe, Mn and pH) over the length of the Waratah Rivulet, groundwater quality sampling will also be conducted at sites WRGW1, WRGW2, WRGW3, WRGW5[30], WRGW6 and WRGW7.

Unfiltered water quality samples will also be collected monthly at site WRGW7 on the Waratah Rivulet and analysed for total iron.

8.9 TRIGGER ACTION RESPONSE PLANS AND ASSESSMENT OF PERFORMANCE INDICATORS AND MEASURES

The monitoring results will be used to assess the Project against the performance indicators and performance measures using the TARPs detailed in Tables 24 to 29.

30 Site WRGW4 was sheared in 2011 and subsequently has not been sampled.

Table 24
Trigger Action Response Plan – Negligible Reduction to the Quantity of Water Resources Reaching the Woronora Reservoir

Performance Measure	Performance Indicator	Monitoring Site(s)	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers		Action/Response
Negligible reduction to the quantity of water resources reaching the Woronora Reservoir.	*Changes in the quantity of water entering Woronora Reservoir are not significantly different post-mining compared to pre-mining, that are not also occurring in the control catchment.*	WaterNSW gauging station on Waratah Rivulet (GS 2132102). WaterNSW gauging station on O'Hares Creek at Wedderburn (GS 213200) (control site).	Surface water flow.	Monthly download of continuous data-logger.	Analysis of measured flow versus modelled flows in Waratah Rivulet using catchment model, specifically: - Monitored flows will be filtered in order to assess low flows (i.e. flows of 1 mm/day or less)[1]. - The filtered monitored flows on Waratah Rivulet will be integrated over successive 14 day periods to produce a smoothed set of data for comparison with the corresponding integrated flows (14 day totals) predicted by the modified AWBM model for the Waratah Rivulet. - The ratio of filtered monitored flows divided by the modified AWBM predicted flows will be calculated at 14 day intervals commencing at the beginning of the baseline period and advancing beyond the commencement of Longwall 20 secondary extraction. The median of the ratios will be analysed over a sliding window of 1 year. Analysis of measured flow versus modelled flows in Waratah Rivulet, six monthly, within one month of download.	Accuracy of flow measurements which depend on measuring water level and conversion of water level (stage) to flow using a flow versus stage (rating curve). Accuracy of catchment flow modelling.	Baseline data (prior to commencement of Longwall 20) is available from the gauging station on Waratah Rivulet from March 2007 to May 2010. Estimated minimum daily flow recorded during baseline period was 0.048 ML/day. Baseline data for O'Hares Creek is available over the same period. Estimated minimum daily flow during adopted baseline period was 0.0063 ML/day.	Level 1	The median of the ratios does not fall below the 35th percentile of the baseline data	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	The median of the ratios falls below the 35th percentile but does not fall below the 20th percentile of the baseline data	Increase the frequency of data analysis to quarterly (until such time that data analysis indicates a return to Level 1). Annual reporting.
								Level 3	The median of the ratios falls below the 20th percentile of the baseline data	Conduct the same analysis of measured flow versus modelled flows for the control catchment, specifically: - The filtered monitored flow rates on O'Hares Creek and Woronora River will be integrated over successive 14 day periods to produce a smoothed set of data for comparison with the corresponding integrated flows (14 day totals) predicted by the modified AWBM models of the same catchments. - The ratio of the filtered monitored flow divided by the modified AWBM predicted flow will be calculated at 14 day intervals commencing at the beginning of the baseline period and advancing beyond the commencement of Longwall 20 secondary extraction. The median of the ratios will be analysed over a sliding window of 1 year. If the same has occurred in the control catchment, continue monitoring and six monthly analysis and annual reporting. If the same has not occurred in the control catchment: • Increase the frequency of data analysis to quarterly (until such time that data analysis indicates a return to Level 1). • Undertake investigation and assess against the performance measure. Report to DPHI, WaterNSW, NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW) – Water and BCS within one month of assessment completion. • Consider the need for management measures, in accordance with Sections 9 and 10.

1 Monitored flows will be filtered numerically (in order to remove the effect of high flows) by setting monitored flows that are greater than 1mm/day to equal modelled flows.

Table 25-A
Trigger Action Response Plan – Negligible Reduction to the Quality of Water Resources Reaching the Woronora Reservoir

Performance Measure	Performance Indicator	Monitoring Site(s)	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/Triggers		Action/Response[1]
Negligible reduction to the quality of water resources reaching the Woronora Reservoir.	*Changes in the quality of water entering Woronora Reservoir are not significantly different post-mining compared to pre-mining concentrations that are not also occurring at control site WOWQ2.*	Site WRWQ9 on the Waratah Rivulet. Site ETWQ AU on the Eastern Tributary. Control site WOWQ2 on the Woronora River.	Iron (Fe). Manganese (Mn). Aluminium (Al). [Field filtered].	Monthly.	Water quality data analysed quarterly, following the receipt of laboratory data[1]: • Adjusted baseline mean plus two standard deviations[2, 3] have been calculated for each water quality parameter and are provided in Table 24-B. • Adjusted baseline mean plus one standard deviation[4, 5] has been calculated for each water quality parameter and are provided in Table 24-B. The six month mean metal concentration will also be calculated at the end of each six month review period.	Potential for sampling, laboratory and data management errors.	<u>WRWQ9</u> • Fe (0.03 to 0.39 mg/L). • Mn (0.01[6] to 0.069 mg/L). • Al (0.001[6] to 0.15 mg/L). <u>ETWQ AU</u> • Fe (0.1 to 0.5 mg/L). • Mn (0.005[6] to 0.033 mg/L). • Al (0.03 to 0.11 mg/L). <u>WOWQ2</u> • Fe (0.05[6] to 1.3 mg/L). • Mn (0.01[6] to 0.1 mg/L). • Al (0.0005[6] to 0.11 mg/L).	Level 1	Data analysis indicates no water quality parameter exceeds the adjusted baseline mean plus two standard deviations.	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	Data analysis indicates any water quality parameter exceeds the adjusted baseline mean plus two standard deviations for one month.	Increase the frequency of data analysis to quarterly (until such time that data analysis indicates a return to Level 1). Annual reporting.
								Level 3	Data analysis indicates: • any water quality parameter exceeds the adjusted baseline mean plus two standard deviations for two consecutive months; or • over a three month period the water quality parameter exceeds the adjusted mean plus two standard deviations in the first month, the adjusted mean plus one standard deviation in the next month and the adjusted mean plus two standard deviations in the third month; or • the six month mean exceeds the adjusted baseline mean plus one standard deviation for two consecutive assessment periods (i.e. over two six monthly reports); and • there was not a similar exceedance of the trigger at the control site.	Increase the frequency of data analysis to quarterly (until such time that data analysis indicates a return to Level 1). If the water quality parameter is greater than the historical maximum, then undertake an investigation and assess against the performance measure. If the water quality parameter is less than the historical maximum, then undertake an investigation and assess against the performance measure at the end of the quarter[7]. The assessment would include consideration of relevant data that is available, or is made available by WaterNSW (e.g. water quality samples taken at various depths at or near site WDFS1, Woronora Reservoir sediment samples, load estimates, hydrodynamic and contaminant transport model results). The assessment is to be finalised without this information if it is unavailable. Report to DPHI, WaterNSW, DCCEEW – Water and BCS within one month of assessment completion. Consider the need for management measures, in accordance with Sections 9 and 10.

1 If data analysis indicates a performance indicator has been exceeded, an assessment is to be made against the performance measure. The assessment against the performance measure would consider <u>total</u> Fe, Mn and Al concentrations at relevant monitoring sites (in addition to dissolved) for the record available.

2 Log transformations (i.e. base 10 logs of the water quality concentrations) will be used to calculate the arithmetic means and standard deviations. Log transformations are commonly applied to concentrations as part of statistical analyses in water resources studies as is evidenced by the following statement from a US Geological Survey publication regarding such analyses: "In order to make an asymmetric distribution become more symmetric, the data can be transformed or re-expressed into new units. These new units alter the distances between observations on a line plot. The effect is to either expand or contract the distances to extreme observations on one side of the median, making it look more like the other side. The most commonly-used transformation in water resources is the logarithm. Logs of water discharge, hydraulic conductivity, or concentration are often taken before statistical analyses are performed." Techniques of Water-Resources Investigations of the United States Geological Survey Book 4, Hydrologic Analysis and Interpretation Chapter A3 Statistical Methods By D.R. Helsel and R.M. Hirsch in Water Resources (September 2002), section 1.7.1, page 12.

3 Baseline is considered to be prior to subsidence effects occurring from Longwall 20 on the relevant environmental feature. In this case, baseline data at site WRWQ9 includes data from September 2006 to 18 May 2010 (i.e. prior to the commencement of Longwall 20). The baseline period for site ETWQ AU includes data from January 2010 to 25 May 2011 on the basis of negligible subsidence effects. Comparable means plus two standard deviations have been calculated at control site WOWQ2 using concurrent monitoring data i.e. a comparable mean plus two standard deviations has been calculated for the control site WOWQ2 using monitoring data over the same period of time used to calculate the baseline mean plus two standard deviations at WRWQ9. Similarly, a comparable mean plus two standard deviations has been calculated for the control site WOWQ2 using monitoring data over the same period of time used to calculate the baseline mean plus two standard deviations at ETWQ AU.

4 The maximum percentage increase in the mean plus two standard deviations at the control site (WOWQ2) since the end of the baseline period to December 2014 has been calculated as described in 2. Above. The maximum percentage increase at the control site has been used to factor up the baseline mean plus two standard deviations values for WRWQ9 and ETWQ AU to account for increasing trends in water quality at the control site. This has resulted in adjusted mean plus two standard deviation values for each site (where appropriate).

5 Baseline is considered to be prior to subsidence effects occurring from Longwall 20 on the relevant environmental feature. In this case, baseline data at site WRWQ9 includes data from September 2006 to 18 May 2010 (i.e. prior to the commencement of Longwall 20). The baseline period for site ETWQ AU includes data from January 2010 to 25 May 2011 on the basis of negligible subsidence effects. Comparable mean plus one standard deviation values have been calculated at control site WOWQ2 using concurrent monitoring data i.e. a comparable mean plus one standard deviation has been calculated for the control site WOWQ2 using monitoring data over the same period of time used to calculate the baseline mean plus one standard deviations at WRWQ9. Similarly, a comparable mean plus one standard deviation has been calculated for the control site WOWQ2 using monitoring data over the same period of time used to calculate the baseline mean plus one standard deviation at ETWQ AU.

6 The maximum percentage increase in the mean plus one standard deviation at the control site (WOWQ2) since the end of the baseline period to December 2014 has been calculated as described in 4. Above. The maximum percentage increase at the control site has been used to factor up the baseline mean plus one standard deviation values for WRWQ9 and ETWQ AU to account for increasing trends in water quality at the control site. This has resulted in adjusted mean plus one standard deviation values for each site (where appropriate).

7 Results reported as < (detection limit) have been set equal to nominated detection limit.

8 Based on historical assessments of the performance measure, Professor Barry Noller (The University of Queensland) has recommended (February 2021) that the assessment against the performance measure be undertaken quarterly where the measured concentrations are less than the historical maximum (The University of Queensland, 2021j – 2021n).

Table 25-B
Adjusted Baseline Mean plus Standard Deviations for Sites WRWQ9, ETWQ AU and WOWQ2

Assessment	Site	Water Quality Indicator	Baseline Mean Plus Two Standard Deviations (mg/L)	Adjusted Baseline Mean Plus Two Standard Deviations (mg/L)	Baseline Mean Plus One Standard Deviation (mg/L)	Adjusted Baseline Mean Plus One Standard Deviation (mg/L)
Waratah Rivulet water quality post-mining versus baseline, and compared to control site WOWQ2	**WRWQ9**	Filtered Iron	0.544	0.706	0.284	0.337
		Filtered Aluminium	0.097	0.100	0.041	0.047
		Filtered Manganese	0.092	0.117	0.055	0.066
	WOWQ2 (using same baseline period as WRWQ9 to allow comparison)	Filtered Iron	0.741	0.961	0.324	0.385
		Filtered Aluminium	0.244	0.250	0.094	0.109
		Filtered Manganese	0.064	0.082	0.042	0.051
Eastern Tributary water quality post-mining versus baseline, and compared to control site WOWQ2	**ETWQ AU**	Filtered Iron	0.543	0.543	0.336	0.336
		Filtered Aluminium	0.094	0.188	0.065	0.106
		Filtered Manganese	0.029	0.030	0.017	0.020
	WOWQ2 (using same baseline period as ETWQ AU to allow comparison)	Filtered Iron	1.657	1.657	0.555	0.555
		Filtered Aluminium	0.075	0.151	0.061	0.100
		Filtered Manganese	0.090	0.094	0.052	0.058

Table 26
Trigger Action Response Plan – No Connective Cracking Between the Surface and the Mine and Negligible Leakage from Woronora Reservoir

Performance Measure	Performance Indicator	Monitoring Site(s)	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers		Action/Response
No connective cracking between the surface and the mine.	*Significant departure from the predicted envelope of the vertical potentiometric head profile at Bore PM02 does not occur.*	Bore PM02.	Groundwater pressures/levels.	Monthly download of continuous datalogging.	Analysis of vertical head profiles, six-monthly, within one month of download.	Datalogger instrumentation precision to 1 mm; error is +/- 0.5 mm.	Predicted profile for longwall panel relevant to longwall status.	Level 1	PM02 Head Profile is consistent with the shape and magnitude of the predicted Model Curve[2].	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	PM02 Head Profile is consistent with the shape of, and does not lie significantly to the left of the predicted Model Curve[2].	Increase the frequency of data analysis to quarterly (until such time that data analysis indicates a return to Level 1). Annual reporting.
								Level 3	PM02 Head Profile is inconsistent with the shape of, or lies significantly to the left of the predicted Model Curve[2].	Increase the frequency of data analysis to quarterly (until such time that data analysis indicates a return to Level 1). Undertake investigation and assess against the performance measure. Report to DPHI, WaterNSW, DCCEEW – Water and BCS within one month of assessment completion. Consider the need for management measures, in accordance with Sections 9 and 10.
	Significant departure from the predicted envelope of the vertical potentiometric head profile at Bore PM01 does not occur.	Bore PM01.	Groundwater pressures/levels.	Monthly download of continuous datalogging.	Analysis of vertical head profiles, six-monthly, within one month of download.	Datalogger instrumentation precision to 1 mm; error is +/- 0.5 mm.	Predicted profile for longwall panel relevant to longwall status.	Level 1	PM01 Head Profile is consistent with the shape and magnitude of the predicted Model Curve[2].	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	PM01 Head Profile is consistent with the shape of, and does not lie significantly to the left of the predicted Model Curve[2].	Increase the frequency of data analysis to quarterly (until such time that data analysis indicates a return to Level 1). Annual reporting.
								Level 3	PM01 Head Profile is inconsistent with the shape of, or lies significantly to the left of the predicted Model Curve[2].	Increase the frequency of data analysis to quarterly (until such time that data analysis indicates a return to Level 1). Undertake investigation and assess against the performance measure. Report to DPHI, WaterNSW, DCCEEW – Water and BCS within one month of assessment completion. Consider the need for management measures, in accordance with Sections 9 and 10.
No connective cracking between the surface and the mine. **Negligible leakage from the Woronora Reservoir.**	*The hydraulic gradient to the Woronora Reservoir at full supply level from Bore PHGW2A is reduced by no more than 40% from that measured to 30 June 2017[5].*	Bore PHGW2A (97.5 m).	Groundwater pressures/levels.	Monthly download of continuous datalogging.	Analysis of water tables quarterly, within one month of download.	Datalogger instrumentation precision to 1 mm; error is +/- 0.5 mm.	PHGW2A > 186.92 m AHD[2].	Level 1	PHGW2A[4] >= 186.92 m AHD.	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	PHGW2A[4] < 186.92 m AHD and > 179.71 m AHD.	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Annual reporting.
								Level 3	PHGW2A[4] =< 179.71 m AHD.	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Undertake investigation and assess against the performance measures. Report to DPHI, WaterNSW, DCCEEW – Water and BCS within one month of assessment completion. Consider the need for management measures, in accordance with Sections 9 and 10.

Table 26 (Continued)
Trigger Action Response Plan – No Connective Cracking Between the Surface and the Mine and Negligible Leakage from Woronora Reservoir

Performance Measure	Performance Indicator	Monitoring Site(s)	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers		Action/Response
Negligible leakage from the Woronora Reservoir.	*The hydraulic gradient to the Woronora Reservoir at full supply level from Bore 9EGW2A is reduced by no more than 40% from that measured to 30 June 2017[5].*	Bore 9EGW2A (107.5 m).	Groundwater pressures/levels.	Monthly download of continuous datalogging.	Analysis of water tables quarterly, within one month of download.	Datalogger instrumentation precision to 1 mm; error is +/- 0.5 mm.	9EGW2A > 186.32 m AHD[3].	Level 1	9EGW2A[4] >= 186.32 m AHD.	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	9EGW2A[4] < 186.32 m AHD and > 179.35 m AHD.	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Annual reporting.
								Level 3	9EGW2A[4] =< 179.35 m AHD.	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Undertake investigation and assess against the performance measure. Report to DPHI, WaterNSW, DCCEEW – Water and BCS within one month of assessment completion. Consider the need for management measures, in accordance with Sections 9 and 10.
	The hydraulic gradient to the Woronora Reservoir at full supply level from Bore PM02 is reduced by no more than 40% from that measured to 30 June 2017[5].	Bore PM02 (100 m).	Groundwater pressures/levels.	Monthly download of continuous datalogging.	Analysis of water tables, quarterly, within one month of download.	Datalogger instrumentation precision to 1 mm; error is +/- 0.5 mm.	PM02 > 183.86 m AHD[3].	Level 1	PM02[4] >= 183.86 m AHD.	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	PM02[4] < 183.86 m AHD and > 177.88 m AHD.	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Annual reporting.
								Level 3	PM02[4] =< 177.88 m AHD.	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Undertake investigation and assess against the performance measure. Report to DPHI, WaterNSW, DCCEEW – Water and BCS within one month of assessment completion. Consider the need for management measures, in accordance with Sections 9 and 10.
	The hydraulic gradient from transect bore T5 to bore T2 does not reduce outside the range seen during the baseline period [7].	Bores T2 and T5	Groundwater levels	Monthly download of continuous datalogging.	Analysis of water tables quarterly, within one month of download.	Datalogger instrumentation precision to 1 mm; error is +/- 0.5 mm	T5 - T2 = 7.82 m[7]	Level 1	T5 - T2>= 7.82 m	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	T5 - T2 < 7.82 m and > 6.20 m	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Annual reporting.
								Level 3	T5 – T2 =< 6.20 m	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Undertake investigation and assess against the performance measure. Report to DPHI, WaterNSW, DCCEEW – Water and BCS within one month of assessment completion. Consider the need for management measures, in accordance with Sections 9 and 10.

Table 26 (Continued)
Trigger Action Response Plan – No Connective Cracking Between the Surface and the Mine and Negligible Leakage from Woronora Reservoir

Performance Measure	Performance Indicator	Monitoring Site(s)	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers		Action/Response
Negligible leakage from the Woronora Reservoir.	*The hydraulic gradient from transect bore T2 to the Woronora Reservoir remains positive (towards the Reservoir).*	Bore T2	Groundwater levels	Monthly download of continuous datalogging.	Analysis of water tables quarterly, within one month of download.	Datalogger instrumentation precision to 1 mm; error is +/- 0.5 mm	T2 - Woronora Reservoir Level > 0 m	Level 1	T2 - Woronora Reservoir Level > 0 m	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	T2 - Woronora Reservoir Level <= 0 m AND T2 shows a lagged response to changes in Woronora Reservoir Level.	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Annual reporting.
								Level 3	T2 - Woronora Reservoir Level <= 0 m AND T2 remains stable and shows no response to changes in Woronora Reservoir Level.	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Undertake investigation and assess against the performance measure. Report to DPHI, WaterNSW, DCCEEW – Water and BCS within one month of assessment completion. Consider the need for management measures, in accordance with Sections 9 and 10.

1 Given the large fluctuations in daily water usage and the cycle period for water entering the mine, being used by machinery, and draining to sumps for return pumping to the surface, a 20 day average will be used to provide a more reliable estimate of water make.

2 Based on the measured potentiometric head profile (averaged over the preceding month). In forming the vertical head profile from vibrating-wire piezometer measurements, unreliable data points are to be excised. A data point will be considered unreliable for any of the following reasons: the piezometer response has not yet stabilised (common in claystones); a piezometer head is inconsistent with overlying and underlying measurements; or the piezometer head has an unreasonably low pressure head component (to be recognised by proximity to the line of unsaturation).

3 Minimum measurement to 30 June 2017.

4 7-Day Average Potentiometric Head at the mid Hawkesbury Sandstone Piezometer

5 As mining approaches bores they will be subject to localised subsidence effects (i.e. due to tilts and strains), which may result in compromised VWP pressure measurements. These will be considered during the implementation of the TARP. The purpose of the TARP is not to monitor for localised subsidence effects; rather it is to measure the hydraulic gradient in the groundwater to the Woronora Reservoir.

6 As at 31 March 2019, the water level in the Woronora Reservoir was 155.9 m AHD, some 13 m below the Woronora Reservoir full supply level, and some 23 m below the Level 3 trigger of 178.9 m AHD.

7 Baseline period between 21 December 2022 to 29 February 2024 (end of Longwall 307 onwards) and considered the new baseline for T5-T2 after mining at Longwall 305 to Longwall 308 passed directly over the transect bores.

Table 27
Trigger Action Response Plan – Negligible Reduction to the Quality of Water Resources in the Woronora Reservoir

Performance Measure	Performance Indicator	Monitoring Site(s)	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers		Action/Response
Negligible reduction in the water quality of Woronora Reservoir.	*Changes in the quality of water in the Woronora Reservoir are not significantly different post-mining compared to pre-mining concentrations.*	Woronora Reservoir (site DW01) (subject to data availability from WaterNSW). Nepean Reservoir (subject to data availability from WaterNSW). Cataract Reservoir (subject to data availability from WaterNSW).	Total Iron (Fe). Total Manganese (Mn). Total Aluminium (Al). Samples recorded at various depths below surface would be considered, where data is available.	Sampling frequency is variable.	Water quality data analysed annually, following the receipt of data from WaterNSW. Water quality parameters, measured in the same location on the same day will be geometrically averaged. The parameter records will be interpolated to provide daily records. Concentration exceedance duration curves will be calculated for each parameter by determining the concentration exceeded at each location by percentages of days of the year covering the full range from 0% to 100%, at 5% intervals. Baseline data[1] will be analysed in an annual format to determine concentration exceeded with an estimated average recurrence interval (ARI[2]) curve of 20 years by percentages of days in the year from 0% to 100%. For each percentage of time selected from this range, an ARI curve will be calculated by fitting a log Generalised Extreme Value distribution to the concentration exceeded each year of the baseline record by that percentage of days. For each water quality parameter, the concentration exceedance curve for the current year of monitoring and the 20 year ARI exceedance curve calculated from the baseline records will be plotted on a graph.	Potential for sampling, laboratory and data management errors.	Baseline 10 and 20 year ARI exceedance curve.	Level 1	The current year's duration exceedance curve for a water quality parameter in Woronora Reservoir (total iron, total manganese and total aluminium) is below the baseline 10 year ARI exceedance curve for any range of the duration percentages from 0% to 75%.	Continue monitoring. Annual reporting.
								Level 2	The current year's duration exceedance curve for a water quality parameter in Woronora Reservoir (total iron, total manganese and total aluminium) is above the baseline 10 year ARI but below the baseline 20 year ARI exceedance curve for any range of the duration percentages from 0% to 75%.	Plot and qualitatively assess the Woronora Reservoir, Nepean Reservoir and Cataract Reservoir water quality data every six months (until such time that data analysis indicates a return to Level 1). Annual reporting.
								Level 3	The current year's duration exceedance curve for a water quality parameter in Woronora Reservoir (total iron, total manganese and total aluminium) is above the baseline 20 year ARI exceedance curve for any range of the duration percentages from 0% to 75%.	Plot and qualitatively assess the data from the Nepean Reservoir and Cataract Reservoir. Undertake investigation and assess against the performance measure. The assessment would include consideration of relevant data that is available, or is made available by WaterNSW (e.g. data collected at various depths at WaterNSW water quality and sediment monitoring sites including any control sites) and other data collected by Metropolitan Coal, where permission is granted by WaterNSW. The assessment is to be finalised without this information if it is unavailable. Report to DPHI, WaterNSW, DCCEEW – Water and BCS within one month of assessment completion. Consider the need for management measures, in accordance with Sections 9 and 10.

1 Baseline data includes data prior to 19 May 2010 (i.e. prior to the commencement of Longwall 20).

2 Average Recurrence Interval. This term has been used here for consistency with previous Annual Reviews and Water Management Plans. Based on recommendations by the Institution of Engineers Australia, the preferred terminology now involves the term Annual Exceedance Probability (AEP) expressed as a percentage probability. This is to avoid confusion that the term ARI has caused within the industry, community and other stakeholders. A 20 year ARI is equivalent to a 5% AEP.

Table 28
Trigger Action Response Plan – Negligible Environmental Consequences on Waratah Rivulet

Performance Measure	Performance Indicator	Monitoring Site(s)	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers		Action/Response
No Diversion of Flows, No Change in the Natural Drainage Behaviour										
Negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P).	*No change to the natural drainage behaviour of Pools T, U, V and W.*	Pools T to W on Waratah Rivulet. Control pools on the Woronora River.	Streambed cracking and drainage behaviour.	Monthly, during download of pool water level data.	Visual inspections of Pools T to W for streambed cracking and changes to the natural drainage behaviour.	Limitations of visual observations.	No mine-induced surface cracking present at Pools T, U, V or W within the stream bed or rock bar. Pool T flows through and below the rock bar. Pools U and W terminate in a boulder field (i.e. no flow over a rock bar). Pool V terminates in a rock bar characterised by partial flow over the rock bar and partial flow through and below the rock bar.	Level 1	No mine-induced surface cracking or impacts to natural drainage behaviour observed	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	Mine-induced surface cracking observed. No impacts to natural drainage behaviour observed.	Initiate survey of the relevant subsidence cross line. Assess pool water level data. Six monthly analysis and annual reporting.
								Level 3	There appear to be impacts to natural drainage behaviour such that: - a pool does not continue to flow over, through and/or below the rock bars (where relevant); or - surface flow is not evident along the length of Pool T prior to flowing through/below the rock bars; - surface flow is not evident along the length of Pool V prior to flowing over/through/below the rock bar; and - surface flow is not evident along the length of Pools U or W prior to flowing through the downstream boulder field.	Initiate survey of the relevant subsidence cross line. Assess pool water level data. Undertake investigation and assess against the performance measure. Report to DPHI, WaterNSW, DCCEEW – Water and BCS within one month of assessment completion. Consider the need for management measures, in accordance with Sections 9 and 10.
Negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P).	*Analysis of water level data for Pools T, U, V and W indicates the water level is at or above the pool's previous minimum.*	Pools T, U, V and W on Waratah Rivulet. Control pools on the Woronora River.	Pool water level.	Monitored continuously, with a data logger and downloaded monthly.	Analysis of Pools T, U, V and W water level data against the pool's previous minimum, quarterly, within one month of download.	Water level sensor precision, data logger malfunction and download error.	Pool water level hydrographs to 31 December 2018[1].	Level 1	The water level in Pools T, U, V or W has not been below the pool's previous minimum.	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	The water level in Pools T, U, V or W has been below the pool's previous minimum, however, is considered to be due to an error type.	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Annual reporting.
								Level 3	The water level in Pools T, U, V or W has been below the pool's previous minimum and does not appear to be due to an error type; and the same is not occurring in control pool(s).	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Initiate survey of the relevant subsidence cross line. Undertake investigation (including assessment of control pools) and assess against the performance measure. Report to DPHI, WaterNSW, DCCEEW – Water and BCS within one month of assessment completion. Consider the need for management measures, in accordance with Sections 9 and 10.

Table 28 (Continued)
Trigger Action Response Plan – Negligible Environmental Consequences on Waratah Rivulet

Performance Measure	Performance Indicator	Monitoring Site(s)	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers		Action/Response
Minimal Iron Staining										
Negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P).	*Visual inspection of the Waratah Rivulet from Pool T to the full supply level of the Woronora Reservoir does not show significant changes in the extent or nature of iron staining that isn't also occurring in the Woronora River (control site).*	Waratah Rivulet, from Pool T to the full supply level of the Woronora Reservoir.	Nature and extent of iron staining.	Monthly.	Visual inspections of Waratah Rivulet.	Subjective nature of visual observations.	Iron staining present (dark in colour [crystalline goethite]), apparent in the baseline stream mapping photographs. Natural seeps and associated iron staining also occur (as recorded by baseline mapping).	Level 1	The extent or nature of iron staining in the Waratah Rivulet from Pool T to the full supply level of the Woronora Reservoir has not changed.	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	The extent or nature of iron staining in the Waratah Rivulet from Pool T to the full supply level of the Woronora Reservoir has changed significantly, as a result of climatic conditions.	Record the nature and extent of the changes in the Waratah Rivulet. Inspect the nature and extent of iron staining on the Woronora River (control site). Increase the frequency of visual inspections on the Waratah Rivulet and Woronora River to weekly (until such time that data analysis indicates a return to Level 1). Six monthly analysis and annual reporting.
								Level 3	The extent or nature of iron staining in the Waratah Rivulet from Pool T to the full supply level of the Woronora Reservoir has changed significantly, not as a result of climatic conditions (i.e. a similar change has not occurred in the Woronora River [control site]).	Record the nature and extent of the changes in the Waratah Rivulet. Inspect the nature and extent of iron staining on the Woronora River (control site). Increase the frequency of visual inspections on the Waratah Rivulet and Woronora River to weekly (until such time that data analysis indicates a return to Level 1). Undertake investigation and assess against the performance measure. Report to DPHI, WaterNSW, DCCEEW - Water and BCS within one month of assessment completion. Consider the need for management measures, in accordance with Sections 9 and 10.

Table 28 (Continued)
Trigger Action Response Plan – Negligible Environmental Consequences on Waratah Rivulet

Performance Measure	Performance Indicator	Monitoring Site(s)	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers		Action/Response
					Minimal Gas Releases					
Negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P).	*Gas releases in Waratah Rivulet from Pool T to the full supply level of the Woronora Reservoir have not increased beyond those observed up to the commencement of Longwall 301 extraction.*	Waratah Rivulet, from Pool T to the full supply level of the Woronora Reservoir.	Free Carbon Dioxide as CO_2 (mg/L). Methane (mg/L).	Visual inspections for gas releases monthly. Weekly at pools that have been observed with gas releases, until no gas releases have been observed at the pool for three consecutive weeks.	Visual inspections, and where gas releases occur, water quality sampling. Analysis of water quality results, quarterly, within one month of the receipt of laboratory results.	Free Carbon Dioxide as CO_2 (mg/L) ALS Method APHA 4500 CO_2-D Detection limit is 1 mg/L[4]. Methane (mg/L) ALS Method EPO33: Methane Detection limit is 0.01 mg/L[5].	No gas releases observed in Waratah Rivulet from Pool T to the full supply level of the Woronora Reservoir prior to the mining of Longwall 20. Pool U – gas releases observed in August 2016 to June 2017. Pool W – gas releases observed in January to May 2016; October 2016. Assessment of gas releases in pools to 30 June 2017 indicates the performance measure has been met.	Level 1	Free carbon dioxide concentrations are equal to or less than 4 mg/L[2] in Waratah Rivulet pools from Pool T to the full supply level of the Woronora Reservoir. Methane concentrations are equal to or less than 0.159 mg/L[2] in Waratah Rivulet pools from Pool T to the full supply level of the Woronora Reservoir.	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	Free carbon dioxide concentrations are above 4 mg/L and equal to or less than 13 mg/L[3] in Waratah Rivulet pools from Pool T to the full supply level of the Woronora Reservoir. Methane concentrations are above 0.159 mg/L and equal to or less than 0.478 mg/L[3] in Waratah Rivulet pools from Pool T to the full supply level of the Woronora Reservoir.	Increase the frequency of data analysis to monthly in pools subject to gas releases (until such time that data analysis indicates a return to Level 1). Annual reporting.
								Level 3	Free carbon dioxide concentrations are above 13 mg/L in Waratah Rivulet pools from Pool T to the full supply level of the Woronora Reservoir. Methane concentrations are above 0.478 mg/L in Waratah Rivulet pools from Pool T to the full supply level of the Woronora Reservoir.	If the gas concentration parameter is greater than the historical maximum, then undertake an investigation and assess against the performance measure. If the gas concentration parameter is less than historical maximum, then undertake an investigation report and assess against the performance measure at the end of the quarter[6], Report to DPHI, WaterNSW, DCCEEW – Water and BCS within one month of assessment completion. Consider the need for management measures, in accordance with Sections 9 and 10.

1 Hydro Engineering & Consulting (2023) Metropolitan Coal Surface Water Review 1 January to 31 December 2022.

2 This value is the 80th percentile of the free carbon dioxide or methane results for gas releases recorded in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir and in Eastern Tributary pools downstream of the Longwall 26 maingate to 30 June 2017. For the calculation of the 80th percentile, values less than the detection limit (< 1 mg/L for free carbon dioxide and < 0.01 mg/L for methane) have been taken as the value of the detection limit (i.e. as 1 mg/L or 0.01 mg/L).

3 This value is the 99th percentile of the free carbon dioxide or methane results for gas releases recorded in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir and in Eastern Tributary pools downstream of the Longwall 26 maingate to 30 June 2017. For the calculation of the 99th percentile, values less than the detection limit (< 1 mg/L for free carbon dioxide and < 0.01 mg/L for methane) have been taken as the value of the detection limit (i.e. as 1 mg/L or 0.01 mg/L).

4 For 4 mg/L and 13 mg/L in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir, the error for 2X the Detection Limit (DL) is 50% and 15.4%, respectively.

5 For 0.159 mg/L and 0.478 mg/L in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir, the error for 2X the Detection Limit (DL) is 11.2% and 4.2%, respectively.

6 Based on historical assessments of the performance measure, Professor Barry Noller (The University of Queensland) has recommended (February 2021) that the assessment against the performance measure be undertaken quarterly where the measured concentrations are less than the historical maximum (The University of Queensland, 2021b – 2021e).

Table 29
Trigger Action Response Plan – Negligible Environmental Consequences on Eastern Tributary

Performance Measure	Performance Indicator	Monitoring Site(s)	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers		Action/Response
No Diversion of Flows, No Change in the Natural Drainage Behaviour										
Negligible environmental consequences over at least 70% of the stream length (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26[1].	*No change to the natural drainage behaviour of Pools ETAS, ETAT and ETAU.*	Pools/rock bars ETAS, ETAT and ETAU on the Eastern Tributary.	Stream cracking and drainage behaviour.	Monthly.	Visual inspections of pools/rock bars ETAS, ETAT and ETAU on the Eastern Tributary for stream cracking and changes to natural drainage behaviour.	Limitations of visual observations.	No mine-induced surface cracking observed to date at Pools ETAS or ETAT. Two separate cracks at downstream end of rock bar ETAU. Crack 1; approximately 2 m in length and 1-7 mm wide, Crack 2; approximately 3m in length and 1-7 mm wide (with a 150 mm x 80 mm section sheared). Pool ETAS is a rock bar controlled pool. Water enters the pool as surface flow from boulder field ETAR. The downstream rock bar is permeable (allowing both underflow and surface flow), and appears to be mainly detached blocks and boulders. Due to the nature of rock bar ETAS, Pool ETAS and Pool ETAT typically sit at the same level. Pool ETAT is a rock bar controlled pool. Water enters the pool as surface flow or underflow through rock bar ETAS. The downstream rock bar is effectively impermeable. Pool ETAU flows through Eastern Tributary gauging station, over a rock bar/waterfall.	Level 1	No mine-induced surface cracking at Pool ETAS or Pool ETAT; no increase in previous cracking at Pool ETAU. No impacts to natural drainage behaviour observed.	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	Mine-induced surface cracking observed at Pool ETAS or Pool ETAT, or increase observed in previous cracking at Pool ETAU. No impacts to natural drainage behaviour observed.	Assess the monitoring results from the relevant subsidence cross lines (ETAT and ETAU). Six monthly analysis and annual reporting.
								Level 3	There appear to be impacts to natural drainage behaviour such that there is not continual surface flow along the length of Pools ETAS, ETAT or ETAU.	Assess the monitoring results from the relevant subsidence cross lines. Assess pool water level data for ETAU. Undertake investigation and assess against the performance measure. Report to DPHI, WaterNSW, DCCEEW – Water and BCS within one month of assessment completion. Consider the need for management measures, in accordance with Sections 9 and 10.
Negligible environmental consequences over at least 70% of the stream length (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26[1].	*Analysis of water level data for Pool ETAS/ETAT and Pool ETAU indicates the water levels are above that required to maintain water over the downstream rock bar.*	Pool ETAS/ETAT[2] and ETAU on the Eastern Tributary.	Pool water level.	Monitored continuously, with a data logger and downloaded monthly.	Analysis of Pool ETAS/ ETAT and Pool ETAU water level data, quarterly (within one month of download).	Water level sensor precision, Data logger malfunction and download error.	Pool water level hydrographs to 31 December 2018[3].	Level 1	The water levels in Pool ETAS/ETAT and Pool ETAU have been above that required to maintain water over the downstream rock bar[4].	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	The water levels in Pool ETAS/ETAT and Pool ETAU has been below that required to maintain water over the downstream rock bar, however, appears to be due to an error type [4].	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Annual reporting.
								Level 3	The water levels in Pool ETAS/ETAT and Pool ETAU has been below that required to maintain water over the downstream rock bar and does not appear to be due to an error type [4].	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Assess the monitoring results from the Pool ETAS/ETAT and Pool ETAU subsidence cross lines. Initiate Incident Reporting and Contingency Plan in the event the performance measure has been exceeded.

Table 29 (Continued)
Trigger Action Response Plan – Negligible Environmental Consequences on Eastern Tributary

Performance Measure	Performance Indicator	Monitoring Site(s)	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers		Action/Response
					Minimal Iron Staining					
Negligible environmental consequences over at least 70% of the stream length (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26[5].	N/A	Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26.	Nature and extent of iron staining.	Within three months of the completion of Longwall 311, Longwall 312, Longwall 313, Longwall 314, Longwall 315 and Longwall 316.	Visual inspections of Eastern Tributary.	Subjective nature of visual observations.	On 14 October 2016, Metropolitan Coal reported the exceedance of the Eastern Tributary performance measure in relation to iron staining to the DPE and other relevant agencies. Iron staining/flocculent is present at a number of stream features between the maingate of Longwall 26 and the full supply level of the Woronora Reservoir.	N/A	N/A	Metropolitan Coal to monitor the nature and extent of iron staining on the Eastern Tributary during the mining of Longwalls 311-316. Metropolitan Coal to implement stream remediation in accordance with the Metropolitan Coal Stream Remediation Plan.

[1] The *no diversion of flows, no change in natural drainage behaviour* component of this performance measure was exceeded during the mining of Longwalls 23-37, triggering contingency measures for the impacted pools. This TARP monitors pools not impacted during the mining of Longwalls 23-27.

[2] Due to the nature of rock bar ETAS, Pool ETAS and Pool ETAT typically sit at the same level.

[3] Hydro Engineering & Consulting (2023) Metropolitan Coal Surface Water Review 1 January to 31 December 2022.

[4] The performance indicator will be considered to have been exceeded if the water level in Pool ETAS/ETAT and/or Pool ETAU has been below that required to maintain water over the downstream rock bar, except where subsidence causes a local change in stream bed profile that affects the level of the pool, but not the natural behaviour of the pool.

[5] The minimal iron staining component of this performance measure was exceeded during the mining of Longwalls 23-37, triggering contingency measures for the impacted pools. The nature and extent of iron staining on the Eastern Tributary will continue to be monitored during the mining of Longwalls 311-316.

Table 29 (Continued)
Trigger Action Response Plan – Negligible Environmental Consequences on Eastern Tributary

Performance Measure	Performance Indicator	Monitoring Site(s)	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline[1]	Significance Levels/ Triggers		Action/Response
Minimal Gas Releases										
Negligible environmental consequences over at least 70% of the stream length (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26.	*Gas releases in Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26 have not increased beyond those observed up to the commencement of Longwall 301 extraction.*	Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26.	Free Carbon Dioxide as CO_2 (mg/L). Methane (mg/L).	Visual inspections for gas releases monthly. Weekly at pools that have been observed with gas releases, until no gas releases have been observed at the pool for three consecutive weeks.	Visual inspections, and where gas releases occur, water quality sampling. Analysis of water quality results, quarterly, within one month of the receipt of laboratory results.	<u>Free Carbon Dioxide as CO_2 (mg/L)</u> ALS Method APHA 4500 CO_2-D Detection limit is 1 mg/L[4]. <u>Methane (mg/L)</u> ALS Method EPO33: Methane Detection limit is 0.01 mg/L[5].	No gas releases observed in Eastern Tributary prior to the mining of Longwall 20. Pool ETAG – gas releases observed in February 2017. Pool ETAI – gas releases observed in March 2017. Pool ETAL – gas releases observed from January to March 2016. Pool ETAM – gas releases observed from January to June 2016. Assessment of gas releases in pools to 30 June 2017 indicates the performance measure has been met.	Level 1	Free carbon dioxide concentrations are equal to or less than 4 mg/L[2] in Eastern Tributary pools between the full supply level of the Woronora Reservoir and the maingate of Longwall 26. Methane concentrations are equal to or less than 0.159 mg/L[2] in Eastern Tributary pools between the full supply level of the Woronora Reservoir and the maingate of Longwall 26.	Continue monitoring. Six monthly analysis and annual reporting.
								Level 2	Free carbon dioxide concentrations are above 4 mg/L and equal to or less than 13 mg/L[3] in Eastern Tributary pools between the full supply level of the Woronora Reservoir and the maingate of Longwall 26. Methane concentrations are above 0.159 mg/L and equal to or less than 0.478 mg/L[3] in Eastern Tributary pools between the full supply level of the Woronora Reservoir and the maingate of Longwall 26.	Increase the frequency of data analysis to monthly in pools subject to gas releases (until such time that data analysis indicates a return to Level 1). Annual reporting.
								Level 3	Free carbon dioxide concentrations are above 13 mg/L[3] in Eastern Tributary pools between the full supply level of the Woronora Reservoir and the maingate of Longwall 26. Methane concentrations are above 0.478 mg/L[3] in Eastern Tributary pools between the full supply level of the Woronora Reservoir and the maingate of Longwall 26.	If the gas concentration parameter is greater than the historical maximum, then undertake an investigation and assess against the performance measure. If the gas concentration parameter is less than historical maximum, then undertake an investigation report and assess against the performance measure at the end of the quarter[6], Report to DPHI, WaterNSW, DCCEEW – Water and BCS within one month of assessment completion. Consider the need for management measures, in accordance with Sections 9 and 10.

1 Consistent with the previously approved Longwalls 301-303 WMP, 'baseline' includes gas releases in pools to 30 June 2017.

2 This value is the 80th percentile of the free carbon dioxide or methane results for gas releases recorded in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir and in Eastern Tributary pools downstream of the Longwall 26 maingate to 30 June 2017. For the calculation of the 80th percentile, values less than the detection limit (< 1 mg/L for free carbon dioxide and < 0.01mg/L for methane) have been taken as the value of the detection limit (i.e. as 1 mg/L or 0.01 mg/L).

3 This value is the 99th percentile of the free carbon dioxide or methane results for gas releases recorded in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir and in Eastern Tributary pools downstream of the Longwall 26 maingate to 30 June 2017. For the calculation of the 99th percentile, values less than the detection limit (< 1 mg/L for free carbon dioxide and < 0.01mg/L for methane) have been taken as the value of the detection limit (i.e. as 1 mg/L or 0.01 mg/L).

4 For 4 mg/L and 13 mg/L in Eastern Tributary pools between the full supply level of the Woronora Reservoir and the maingate of Longwall 26, the error for 2X the Detection Limit (DL) is 50% and 15.4%, respectively.

5 For 0.159 mg/L and 0.478 mg/L in Eastern Tributary pools between the full supply level of the Woronora Reservoir and the maingate of Longwall 26, the error for 2X the Detection Limit (DL) is 11.2% and 4.2%, respectively.

6 Based on historical assessments of the performance measure, Professor Barry Noller (The University of Queensland) has recommended (February 2021) that the assessment against the performance measure be undertaken quarterly where the measured concentrations are less than the historical maximum (The University of Queensland, 2021b – 2021e).

8.10 WARATAH RIVULET MONITORING AND ADAPTIVE MANAGEMENT

As described in Section 4.1, Metropolitan Coal has established a comprehensive monitoring and adaptive management program to identify subsidence related movements at the Waratah Rivulet to minimise the risk of exceedance of the Waratah Rivulet performance measure. A similar Valley Closure TARP has been successfully implemented by Metropolitan Coal at the Eastern Tributary for Longwalls 303 to 307 and is in place for Waratah Rivulet during the extraction of 308 to 310.

As Longwalls 311, 312, 313, 314, 315 and 316 will move progressively further away from the Waratah Rivulet, Metropolitan Coal will maintain the TARP for Longwall 311 to confirm that incremental valley closure has diminished to below measurable survey tolerances, < ±10 mm[31]. The Waratah Rivulet Valley Closure TARP (Table 30) is designed to monitor the development of subsidence effects on the Waratah Rivulet. The longwall layouts have been designed for a low likelihood of impacts based on a predicted total valley closure of 200 mm or less. With the conservative nature of valley closure predictions, observed valley closure is typically lower than predicted valley closure. The Waratah Rivulet Valley Closure TARP has therefore been designed to suit observed valley closure movements. The TARP defines four status levels. Level 1 and 2 status represent observed movement at reduced percentages (50% and 75% respectively) of the design criteria for the Waratah Rivulet, which is based on a predicted valley closure of 200 mm. Level 3 status represents a significant level of observed valley movement but with no observed pool impacts. Level 4 represents a confirmed pool impact.

A Technical Committee, comprising industry and technical representatives, will review the monitoring data in accordance with the TARP. The key outcomes of the Technical Committee review will be reported to DPE, WaterNSW and the Metropolitan Coal General Manager monthly if the results are at TARP Level 2 status.

In the event the results are at TARP Level 3 status, monitoring, review and reporting to DPE, WaterNSW and the Metropolitan Coal General Manager will be conducted weekly. A Level 4 status will initiate procedures to cease extraction of the current longwall and notification to DPE and WaterNSW will be within 24 hours.

[31] Each GNSS monitor is accurate to ±5 mm, valley closure requiring 2 monitors therefore the error band is the sum of both monitors at ±10 mm.

Table 30
Longwall 311 Waratah Rivulet Valley Closure Trigger Action Response Plan
TARP Zone – extraction within 600 m of Waratah Rivulet

Valley Closure[1] (*Total Closure*)	Monitoring Method and Measure	TARP LEVEL				
			Level 1	**Level 2**	**Level 3**	**Level 4**
Longwall 311	Telemetered real time data GNSS *# 43,44* Absolute 3D movement and closure	***Trigger***	Baseline to no greater than **40 mm[2]**	Greater than Level 1 (**40 mm**) and no greater than **125 mm[3]**. Measurements over three consecutive epochs (days)	Greater than Level 2 (**125 mm**) and no type 3 impact[4] (loss of pool water level). Measurements over three consecutive epochs (days).	Type 3 impact confirmed, being a diversion of flows or change in natural drainage behaviour of pools in performance measure zone.
		Action	Monthly monitoring[5]: • GNSS data[6] • Pool level data[7] • Visual inspections End of Panel: • Rock bar closure survey[8]	Monthly monitoring: • As per Level 1, and • rock bar closure surveys	Weekly monitoring: • All data gathering increased to weekly frequency • Weekly review of GNSS and rock bar closure line data[9]	Immediate action: • Metropolitan Coal to initiate procedures to cease extraction of current longwall panel at next available cut through
		Response and Reporting	Reporting: • Monthly to Technical Committee Technical Committee: • End of panel meeting • Key outcomes reported to DPHI and WaterNSW following the end of panel meeting	Reporting: • Monthly to Technical Committee Technical Committee: • Monthly meeting • Key outcomes reported to DPHI and WaterNSW following each meeting	Reporting: • Weekly to Technical Committee Technical Committee: • Weekly meeting • Metropolitan Coal to determine need to cease longwall mining operations at Level 3 in consultation with Technical Committee • Key outcomes of Technical Committee reported to DPHI and WaterNSW following each meeting • Notify DPHI and WaterNSW of Level 3 status and associated actions	Response: • Immediate Technical Committee meeting and reporting to review all relevant data (within 24hrs) • Immediate reporting (24hrs) to Metropolitan Coal General Manager • Immediate notification (24hrs) of the Level 4 status and associated actions to DPHI and WaterNSW • Commence Stream Remediation Plan.

1 Waratah Rivulet will be monitored for total closure (cumulative value) as measured from the commencement of Longwall 307 (i.e. the "baseline" period) to the completion of Longwall 311.

2 Observed closure no greater than 40 mm. No previous Type 3 impacts have been recorded on Waratah Rivulet for measured closure of less than 40 mm.

3 Observed closure no greater than predicted closure of 125 mm at the completion of Longwall 308.

4 Type 3 impacts (loss of pool water level) are not recorded on Waratah Rivulet, where rock bars are more than 170 m distance from a longwall void. Longwall 311 will be greater than 500 m from rock bar V at its closet approach.

5 Monitoring and review frequency can be increased at any time as determined by the Technical Committee.

6 GNSS valley closure monitoring is representative of closure at Rock Bars U, V and W that are greater than 500 m of extraction of Longwall 311.

7 Pool water level monitoring equipment and loggers are installed at Pools P, Q, R, S, T, U and V.

8 Rock bar V is to be monitored for Longwall 311 at its terrestrial survey closure line.

9 Weekly review to include observations of closure, strain, vertical subsidence, horizontal movement.

8.11 WARATAH RIVULET GAUGING STATION TRIGGER ACTION RESPONSE PLAN

WaterNSW owns a gauging station (GS 2132102) on the Waratah Rivulet at Pool Q, close to the inundation limits of the Woronora Reservoir (Figure 6). Table 31 describes the TARP used to identify and manage subsidence related movements at GS 2132102.

Table 31
Trigger Action Response Plan – Waratah Rivulet Gauging Station

Level	Monitoring frequency	Trigger	Action
Level 1	Quarterly Review (Recorded daily)	Absolute horizontal movement at GNSS monitoring site Q Line is less than or equal to 50 mm.	Continue Monitoring. End of panel survey and inspection of rock bar.
Level 2	Monthly	Absolute horizontal movement at GNSS monitoring site Q Line is greater than 50 mm. There is no visible damage to the gauging station observed.	Survey and visual inspection of rock bar Q at monthly frequency until the longwall panel being mined is completed.
Level 3	Weekly	Visible damage to the gauging station is observed.	Report to WaterNSW within one week of inspection. Weekly survey and inspections until movement stabilised. Liaise with WaterNSW to agree long-term solution for Gauging Station (e.g. recalibration of flows, repairs or replacement). Review and update the 2016 Contingency Plan for Monitoring Waratah Rivulet Stream Flows, as necessary.

9 MANAGEMENT MEASURES

9.1 SUBSIDENCE MANAGEMENT APPROACH

Potential environmental consequences during the mining of Longwalls 311-316 will be managed in accordance with the relevant requirements of the Project Approval and other approvals, through:

- **Mine Planning and Design** – The design of the mine, including avoidance and subsidence mitigation measures (Section 9.2).
- **Subsidence Monitoring** – Monitoring to confirm predictions of subsidence effects and potential subsidence impacts and environmental consequences (Sections 8 and 9.3).
- **Management Measures and Remediation** – Implementation of management measures and/or remediation, as required, to address subsidence impacts and/or environmental consequences (Section 9.4).
- **Adaptive Management** – The implementation of adaptive management where appropriate (Section 9.5).
- **Contingency Plans** – Implementation of Contingency Plans in the event an exceedance of a subsidence impact performance measure or an unexpected impact is detected (Section 10), including consideration of identified potential contingency measures (Sections 10.1).

9.2 MINE PLANNING AND DESIGN

Mine planning and design considerations have included mining geometry, geology and stratigraphy and avoidance and subsidence mitigation measures, as described below.

Since the commencement of longwall mining methods at the Metropolitan Colliery in 1995, Metropolitan Coal has adopted a conservative mining geometry with significantly narrower longwall panels than the industry norm to minimise potential impacts on the environmental values of the area. As a result of the narrower longwall panels, the extracted seam thickness, substantial depths of cover and alteration of thick sandstone/claystone lithologies, there is a constrained zone in the overburden at Metropolitan Coal. The risk of connective cracking between the mine and the surface is very low.

As described in Section 5, a number of risk assessments have been conducted including a risk assessment to assess the potential for Longwalls 311-316 mining effects on lineaments, joints, faulting, basal shear planes and dykes to impact on the quantity of water to the Woronora Reservoir, including the potential for water to be diverted out of Woronora Reservoir and into other catchments. Metropolitan Coal considers all risk control measures and procedures to be reasonable to manage all identified risks.

Longwalls 301 to 310 were shortened at the northern commencing ends as a result of the thinning of the coal seam and/or prohibitive carbon dioxide gas content. Avoidance and subsidence mitigation measures that have been incorporated into the longwall layouts have included:

- The finishing end of Longwall 301 was shortened to reduce potential subsidence effects at Bridge 2 (M1 Princes Motorway).
- The commencing ends of Longwalls 302, 303, 304 and 305 were shortened to reduce potential subsidence effects at the Garrawarra Centre Complex.
- The finishing ends of Longwalls 303, 304 and 305 were shortened to reduce predicted valley closure on the Eastern Tributary.

Metropolitan Coal has developed a monitoring and adaptive management approach for the Waratah Rivulet as described in Sections 8.10 and 9.5.

9.3 ADDITIONAL MONITORING

Where a performance indicator and/or measure has been exceeded, it may be appropriate to conduct additional monitoring (e.g. increase the frequency of monitoring or the parameters monitored) or conduct additional test work.

9.4 MANAGEMENT MEASURES AND REMEDIATION

This section describes the implementation of management measures and/or remediation for water resources and watercourses. Management measures will be implemented, as appropriate, to comply with the relevant statutory requirements and the subsidence impact performance measure.

As described in Section 4.1, the magnitudes of the systematic and/or valley related movements predicted for the Project were considered likely to result in the fracturing and dilation of the underlying strata of streams above and immediately adjacent to the longwalls. Cracking and dilation of bedrock would likely result in the localised diversion of a portion of the surface flow into subterranean flows or leakage from pools. Stream remediation measures will be implemented as described in Section 9.4.1.

Other potential subsidence impacts such as impacts on aesthetic values, stream bank erosion, cliff falls and swamps and the associated management measures are described in Section 9.4.2.

Management and rehabilitation measures for surface disturbance areas are described in Section 9.4.3.

Follow-up inspections will be conducted to assess the effectiveness of implemented management measures and the requirement for any additional management measures. Management measures will be reported in the Annual Review (Section 12).

9.4.1 Stream Remediation

Metropolitan Coal is required to achieve the rehabilitation objective specified in Table 11 of Condition 1, Schedule 6 of the Project Approval for the Waratah Rivulet and the Eastern Tributary watercourses.

Table 11: Rehabilitation Objectives

Domain	***Rehabilitation Objective***
Waratah Rivulet, between the downstream edge of Flat Rock Swamp and the full supply level of the Woronora Reservoir *Eastern Tributary, between the maingate of Longwall 26 and the full supply level of the Woronora Reservoir*	*Restore surface flow and pool holding capacity as soon as reasonably practicable*

Metropolitan Coal is also required to achieve the subsidence impact performance measures specified in Table 1 of Condition 1, Schedule 3 of the Project Approval in relation to the Waratah Rivulet and Eastern Tributary watercourses.

Table 1: Subsidence Impact Performance Measures

Watercourses	
Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P).	*Negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases)*
Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26	*Negligible environmental consequences over at least 70% of the stream length (that is no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining and minimal gas releases)*

9.4.1.1 Waratah Rivulet Stream Remediation

The location of pools/rock bars along the Waratah Rivulet are shown on Figure 5 and on the detailed mapping in Appendix 1.

As described in Section 9.4.1, Metropolitan Coal is required to restore surface flow and pool holding capacity on the Waratah Rivulet between the downstream edge of Flat Rock Swamp and the full supply level of the Woronora Reservoir (i.e. Pools A to W). Metropolitan Coal is also required not to exceed the Waratah Rivulet watercourse subsidence impact performance measure, which is applicable to Pools T to W.

Stream remediation on the Waratah Rivulet at pools/rock bars overlying the Longwalls 1-13 mining area, at pools/rock bars downstream of the Longwalls 1-13 mining area to the Longwall 23 maingate, and pools/rock bars downstream of the Longwall 23 maingate to the full supply level of the Woronora Reservoir, is described below.

Longwalls 1-13 Mining Area (Downstream of Flat Rock Swamp to Longwall 20 Tailgate)

As described in Section 8.3.2, Pools B, C, E, G, G1, H and I will be manually monitored on a daily basis, or continuously with water level sensors and data loggers, while Pools A and F will be monitored continuously with water level sensors and data loggers.

As a result of previous mining, the water levels in pools upstream of Flat Rock Crossing (i.e. Pools A to G) and immediately downstream of Flat Rock Crossing (Pools G1) have been impacted by mine subsidence.

Stream remediation activities have been conducted at Pools A, F and G. The rock bars at Pools A and F are considered to largely control the pools located upstream of these rock bars. As a result, Metropolitan Coal anticipates that the restoration of surface flow and pool holding capacity at Pools A and F will restore the surface flow and pool holding capacity of pools between Flat Rock Swamp and Pool F. Metropolitan Coal considers the pool remediation efforts to have largely been successful but continues to monitor the performance of these works.

In 2021, Hydro Engineering & Consulting (2021a) assessed the effectiveness of pool remediation measures undertaken by Metropolitan Coal for restoring the water holding capacity of pools on the Waratah Rivulet. Hydro Engineering & Consulting (2021a) found that for Pool G1, water level recession behaviour was consistent with pre-impact behaviour, and for Pools B, C, E, F and G, water levels during low flow conditions were consistent with the water levels of similar, un-impacted pools. For Pool A, recorded water levels during low flow conditions were not consistent with the water levels of similar, unimpacted pools.

In the event stream remediation activities are required at any additional pools/rock bars, Metropolitan Coal will prepare stream remediation plans in consultation with the DPE, Resources Regulator and WaterNSW and include the plans in the Metropolitan Coal Stream Remediation Plan (Metropolitan Coal, 2019) (Appendix 7). Metropolitan Coal will also provide the DPE, Resources Regulator and WaterNSW with 14 days' notice of their intention to commence stream remediation activities at each pool/rock bar.

Metropolitan Coal will advise the DPE, Resources Regulator, WaterNSW, BCS, DPE – Water and Department of Primary Industries – Fisheries (DPI – Fisheries) if the stream remediation process has been triggered.

Downstream of Longwalls 1-13 Mining Area (Longwall 20 Tailgate to Longwall 23 Maingate)

Pools J, K, L, M, M1, N and O on the Waratah Rivulet are situated downstream of the completed Longwalls 1-13 mining area, between the Longwall 20 tailgate and Longwall 23 maingate (Figure 5). Pools J to O will be monitored continuously with water level sensors and data loggers (Section 8.3.2).

As a result of mining, the water levels in Pool N were impacted by mine subsidence in early September 2012. A stream remediation plan for Pool N is provided in the Metropolitan Coal Stream Remediation Plan (Appendix 7). To date (September 2021), Pool N has overflowed its rock bar since December 2014, with the exception of relatively short periods when pools on the Woronora River also stopped flowing in 2021, Hydro Engineering & Consulting (2021a) assessed the effectiveness of pool remediation measures undertaken by Metropolitan Coal for restoring the water holding capacity of pools on the Waratah Rivulet. Hydro Engineering & Consulting (2021a) found that for Pool N, water level recession behaviour was consistent with pre-impact behaviour. Monitoring of Pool N will continue to be conducted.

Downstream of the Maingate of Longwall 23

Pools P, Q, R, S, T, U, V and W on the Waratah Rivulet are situated between the Longwall 23 maingate and the full supply level of the Woronora Reservoir (Figure 5). Pools T to W will be monitored continuously with water level sensors and data loggers (Section 8.3.2).

Although not anticipated to be required, stream remediation will be triggered at Pools T, U or, V if the assessment of monitoring results indicates the performance measure:

> *negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, …….) on the Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P)*

has been exceeded.

9.4.1.2 Eastern Tributary Stream Remediation

The location of pools/rock bars along the Eastern Tributary are shown on Figure 5 and on the detailed mapping in Appendix 2.

As described in Section 9.1, the Project Approval required Metropolitan Coal to have negligible environmental consequences over at least 70% of the stream length on the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26 (which includes Pools ETAG to ETAU).

Monitoring conducted in accordance with the Metropolitan Coal Longwalls 23-27 Water Management Plan identified that the Eastern Tributary watercourse performance measure was exceeded in relation to *minimal iron staining* and *no diversion of flows, no change in the natural drainage behaviour of pools*. The exceedance of the Eastern Tributary watercourse performance measure (referred to as the Eastern Tributary Incident) was reported to the DPE and other relevant agencies in October 2016.

Metropolitan Coal provided the DPE with a proposed course of action in relation to the exceedance of the Eastern Tributary subsidence impact performance measure, focused on the implementation of stream remediation measures.

In accordance with Condition 1, Schedule 6 of the Project Approval, Metropolitan Coal is required to restore surface flow and pool holding capacity on the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26.

Between the Woronora Reservoir Full Supply Level and the Maingate of Longwall 26

Pools ETAG to ETAU on the Eastern Tributary are situated between the full supply level of the Woronora Reservoir and the maingate of Longwall 26 (Figure 5).

The drainage behaviour of 12 pools on the Eastern Tributary (Pools ETAG to ETAR) were impacted by mine subsidence during the mining of Longwalls 23-27. The drainage behaviour of Pools ETAS, ETAT and ETAU on the Eastern Tributary have not been impacted.

Within the performance measure reach of the Eastern Tributary, Metropolitan Coal have conducted stream remediation activities at pools ETAH, ETAK, ETAL, and ETAM following the approval of the Stream Remediation Plan. The selection of future stream remediation locations will be informed by the pool drainage behaviour response to remediation to date and ongoing water level monitoring.

These stream remediation works have been conducted in accordance with the Metropolitan Coal Stream Remediation Plan (Appendix 7).

Upstream of the Reach Subject to the Eastern Tributary Performance Measure

From July to September 2019, Metropolitan Coal conducted stream remediation on the Eastern Tributary at Pool ETO (immediately upstream of the Fire Road 9J crossing and upstream of the Longwall 26 maingate) (Figure 5). Permeability testing has confirmed a significant reduction in hydraulic conductivity of rock bar ETO and both pool level data and visual observations have confirmed that pool holding capacity has been restored and water is flowing over the rock bar for significantly longer periods post remediation.

9.4.1.3 Stream Remediation Activities

Metropolitan Coal is committed to stream remediation at the earliest opportunity. The specific timing of stream remediation activities will be influenced by practical considerations. For example, the catchment may be closed due to rainfall, bushfire risk or stream remediation activities are unable to be conducted as a result of high stream flows. It is anticipated that remediation activities would generally follow mining in a downstream direction however additional remediation efforts may be required for some pools.

Metropolitan Coal will provide the DPE, Resources Regulator and WaterNSW with 14 days' notice of its intention to commence stream remediation activities at each pool/rock bar.

The Metropolitan Coal Stream Remediation Plan describes the implementation and management of stream restoration works. Stream remediation activities typically include fracture characterisation, stream grouting, environmental management and monitoring.

9.4.2 Other Subsidence Impact Management Measures

9.4.2.1 Aesthetic Values

Potential aesthetic restoration measures include:

- Manual application of coloured cement to the stream bed to reduce the appearance of subsidence-induced cracking. A colour that will blend in with the local stream bed colouration will be selected. A range of potentially suitable products are available from landscape suppliers and/or businesses. The product and landscaper proposed to be used will be selected in consultation with WaterNSW.
- The injection of polyurethane at key iron seep locations to reduce the extent of iron staining.

9.4.2.2 Stream Bank Erosion

Visual monitoring (particularly along Waratah Rivulet and the Eastern Tributary) will be conducted to identify areas subject to excessive erosion and sedimentation. Where monitoring indicates the potential for excessive erosion or sediment migration, specific mitigation measures will be employed.

Potential management measures include:

- filling of cracks and minor erosion holes in the bed or banks of watercourses;
- installation of sediment fences downslope of subsidence-induced erosion areas;
- stabilisation of erosion areas using rock or other appropriate materials;
- stabilisation of banks subject to soil slumping; and
- implementation of vegetation management measures.

To date, limited erosion and sedimentation has been identified. Sediment controls (coir logs and sandbags) have been used at previous stream remediation sites Pools A and F for erosion control.

There is potential for the riparian areas that have been subject to increased ponding as a result of subsidence to experience stream bank erosion. The potential for excessive erosion and sedimentation will be monitored at these locations. However, it is anticipated that a new stream bank will be established that will be colonised in due course by native vegetation adapted to the new conditions.

9.4.2.3 Cliff Falls

Cliff and overhang sites COH7, COH8, COH9, COH10, COH11, COH12, COH13, COH16, COH17, COH18 and COH19 will be monitored to record evidence of potential subsidence impacts in accordance with the Metropolitan Coal Longwalls 311-316 Land Management Plan. The monitoring results will be used to assess the potential environmental consequences of the recorded subsidence impact and identify management measures, where appropriate.

In relation to impacts on water resources, potential management measures include:

- the implementation of erosion and sediment control measures (e.g. the installation of sediment fences downslope of erosion areas, the stabilisation of erosion areas using rock or other appropriate materials); and
- stabilisation techniques (e.g. installation of artificial rock support, installation of standing supports, or scaling/dislodgement/removal of remaining loose rock).

The implementation of management measures will be considered with regard to the specific circumstances of the subsidence impact (e.g. the location, nature and extent of the impact) and the assessment of the environmental consequences in accordance with the Metropolitan Coal Longwalls 311-316 Land Management Plan (Figure 3).

9.4.2.4 Swamp Remediation Measures

In accordance with the Metropolitan Coal Longwalls 311-316 Biodiversity Management Plan (Figure 3), in the event remediation measures are proposed to be implemented in an upland swamp, Metropolitan Coal will prepare a swamp remediation plan for the swamp in consultation with the DPE, BCS, WaterNSW, DPI – Fisheries and Resources Regulator.

Potential remediation measures for impacts on upland swamps include:

- installation of coir log dams (i.e. erosion control structures) at any knick points in a swamp;
- use of water spreading techniques, involving long lengths of coir logs and hessian ‘sausages’ linked together across a swamp contour such that water flow builds up behind them and slowly seeps through the water spreaders to maintain swamp moisture; and
- injection grouting.

The implementation of management measures will be considered with regard to the specific circumstances of the subsidence impact (e.g. the location, nature and extent of the impact) and the assessment of the environmental consequences in accordance with the Metropolitan Coal Longwalls 311-316 Biodiversity Management Plan (Figure 3).

9.4.3 Surface Disturbance

The Metropolitan Coal Construction Management Plan (Figure 3) will describe the management measures that will be implemented for surface construction works (excluding remediation or rehabilitation works) in the Woronora Special Area. The management measures will include measures to minimise impacts on water resources and watercourses (e.g. implementation of fuel management measures and erosion and sediment control measures).

The Metropolitan Coal Rehabilitation Management Plan (Figure 3) details the rehabilitation of surface disturbance areas (including those associated with surface exploration activities, vehicular access tracks, environmental monitoring activities and other minor Project-related surface activities).

9.5 ADAPTIVE MANAGEMENT

Metropolitan Coal will implement an adaptive management approach for the Project. Adaptive management involves:

- Planning – developing management strategies to meet performance measures; identifying performance indicators to assess performance; and establishing monitoring programs to monitor against the performance measures.
- Implementation – implementing management strategies and monitoring impacts against performance indicators.
- Review – reviewing and evaluating the effectiveness of management strategies by analysis of monitoring data against predicted impacts, performance indicators and performance measures.
- Contingency Response – implementing the contingency plan in the event a subsidence impact water resource or watercourse performance measure has been exceeded (Section 10).
- Adjustment – adjusting management strategies to improve performance.

Examples of adaptive management measures include the potential to step-around a longwall, stand-offs (environmental pillar) from a particular location, or increasing the setback of the longwalls already subject to stand-off.

10 CONTINGENCY PLAN

In the event a subsidence impact water resource or watercourse performance measure detailed in Section 6 is considered to have been exceeded, Metropolitan Coal will implement the following Contingency Plan:

- The likely exceedance will be reported to the Technical Services Manager and/or the Environment & Community Superintendent within 24 hours of assessment completion.
- The Technical Services Manager and/or the Environment & Community Superintendent will report the likely exceedance to the General Manager as soon as practicable after becoming aware of the exceedance.
- Metropolitan Coal will report the likely exceedance of the water resource or watercourse performance measure to the DPE, DPE – Water, WaterNSW and BCS as soon as practicable after Metropolitan Coal becomes aware of the exceedance.
- Metropolitan Coal will identify an appropriate course of action with respect to the identified impact(s), in consultation with specialists and relevant agencies, as necessary. For example:
  - proposed contingency measures;
  - a program to review the effectiveness of the contingency measures; and
  - consideration of adaptive management under circumstances where a water resource or watercourse performance measure detailed in Table 1 of the Project Approval has been exceeded.

  Contingency measures will be developed in consideration of the specific circumstances of the exceedance and the assessment of environmental consequences. Potential contingency measures are described in Section 10.1 below.
- Metropolitan Coal will submit the proposed course of action and a program to review the effectiveness of the contingency measures to the DPE for approval.
- Metropolitan Coal will implement the approved course of action to the satisfaction of the DPE.

In accordance with Condition 6, Schedule 6 of the Project Approval, Metropolitan Coal will provide a suitable offset to compensate for the impact to the satisfaction of the Secretary of the DPE if either the contingency measures implemented by Metropolitan Coal have failed to remediate the impact or the Secretary of the DPE determines that it is not reasonable or feasible to remediate the impact.

10.1 POTENTIAL CONTINGENCY MEASURES

Potential contingency measures for an exceedance of the water resource or watercourse performance measures include:

- The conduct of additional monitoring (e.g. increase in monitoring frequency or additional sampling) to inform the proposed contingency measures.
- The implementation of stream remediation measures to restore surface water flow/pool holding capacity.
- The implementation of revegetation measures to remediate impacts of gas releases on riparian vegetation.
- The purchase of water from Sydney Water in accordance with a license agreement established to the satisfaction of WaterNSW and the DPE.
- The provision of a suitable offset(s) to compensate for the reduction in the quantity of water resources reaching the Woronora Reservoir. Examples of potential offsets include improvement works in the Woronora Reservoir water supply catchment.
- The implementation of adaptive management measures. Examples of adaptive management measures include stepping-around a longwall, the use of stand-offs (environmental pillar) from a particular location, or increasing the setback of the longwalls already subject to stand-off.

11 FUTURE EXTRACTION PLANS AND INVESTIGATIONS

Metropolitan Coal is required to collect baseline data for the next Extraction Plan in accordance with Condition 7, Schedule 3 of the Project Approval. However, the currently approved Longwall 317 is too short to economically mine and, therefore, Metropolitan Coal is seeking to modify Project Approval (08_0149) to extend Longwall 317 and add an additional longwall (i.e. Longwall 318). Metropolitan Coal will collect baseline data for water resources and watercourses as part of the Modification process to inform the impact assessments and for use in future Extraction Plans.

Metropolitan Coal will also address a number of recommendations made by the IEAPM that are relevant to the monitoring and management of water resources as part of this Extraction Plan.

A summary of the additional monitoring, data collection and investigations are provided below.

11.1 SURFACE WATER

Visual Inspections

Visual inspection and photographic survey (e.g. drone survey) of the streams associated with the large swamps located over Longwalls 311-316 will be conducted prior to the commencement of Longwall 311.

Metropolitan Coal is investigating the installation of a fixed camera to be mounted at the discharge point of Swamp 77 and at the gauging stations of Swamp 76 and Swamp 92 to record once daily still images of any changes to water colour and detect the presence of iron staining. The proposed locations of the fixed cameras are shown on Figure 7.

Contaminant Load Assessment

Subject to the availability of suitable and complete data, Metropolitan Coal will prepare a Contaminant Load Assessment generally consistent with the recommendations in IEAPM (2023a). The assessment would investigate flow-concentration relationships for watercourses discharging to the Woronora Reservoir and the Woronora Reservoir itself and assess whether these have changed as mining has progressed. The Contaminant Load Assessment would aim to improve impact analysis including consideration of pre-impact data, where it is available. The scope of the Contaminant Load Assessment would be tailored to the available data.

Based on the outcomes of the Contaminant Load Assessment, any changes required to the monitoring regime would be identified. This may include the installation of automatic samplers at sites along the Eastern Tributary, Waratah Rivulet and Woronora Reservoir to support analysis of contaminant loads and inclusion of additional surface water monitoring parameters such as electrical conductivity, pH, redox potential and turbidity, as recommended by IEAPM (2023a).

Woronora Reservoir Water Quality and Sampling at Depth

Metropolitan Coal will investigate introducing a short-term sampling program in the upper Woronora Reservoir to obtain temperature and water quality data at various depths through the water column. This data would be used to assess temperature stratification behaviour and water quality. Metropolitan Coal will consult with WaterNSW to identify opportunities to undertake these works.

Metropolitan Coal will undertake a comparison of water quality data to the WaterNSW water quality incident management trigger levels for selected parameters at the point of supply to the Woronora Water Filtration Plant. The results will be reported in future Annual Reviews.

Metropolitan Coal will investigate surface water plume modelling (e.g. CORMIX) to further understand the significance (if any) of temperature stratification within the upper Woronora Reservoir.

The modelling and Woronora Reservoir data analysis would be undertaken in consultation with Associated Professor Barry Noller. An update on the analysis will be reported in the Annual Review.

Sediment Cores

Discussions with WaterNSW in January 2024 have revealed that sediment cores have previously been attempted in Woronora Reservoir with limited success due to the powdery nature of the material. An alternate program was completed using grab samples at multiple locations with results yet to be published by WaterNSW.

Metropolitan Coal will investigate the suitability of gathering sediment cores within the Woronora Reservoir in consultation with WaterNSW. This would be subject to access arrangements with WaterNSW.

A study of the extent of any increase in iron, manganese and aluminium concentrations in Reservoir sediments will be designed that incorporates sampling sites from upper Woronora Reservoir and its key tributaries and down into the Reservoir.

The selection of sampling sites in the lower Woronora Reservoir will be undertaken in consultation with WaterNSW. Subject to access and collection of samples, the study would incorporate collection of sediment cores that are preserved at the time of collection to prevent changes to physico-chemical properties of constituents, particularly iron and manganese that may be modified by change in redox condition (i.e. reducing to oxidising), and used to provide data for concentrations of metals and major physico-chemical characteristics, leaching and release characteristics of iron and manganese in particular, major mineral compositions, morphology and particle size distributions and dating of discrete layers and other related data collection for interpretation purposes. This data can provide a historical record of changes to inputs to the Reservoir and be used to understand the nature of sediment and water dispersal from upstream mining activities and any release characteristics of iron, manganese and aluminium to the water column at the place of deposition in the Woronora Reservoir.

The outcomes of the investigation will be reported in the Annual Review.

Honeysuckle Creek

The collection of baseline data and establishment of regular monitoring along Honeysuckle Creek, in addition to that currently undertaken, would be considered as part of the Modification application process. Where able to be collected, this data would enable a before-after-control-impact analysis to be conducted during and following the extraction of Longwalls 317 and 318 (as proposed by the Modification).

Eastern Tributary Rating Curve

Consistent with the IEAPM (2023a) recommendations, Metropolitan Coal will investigate suitable methods for improving the extension of the Eastern Tributary rating curves to improve high flow measurement accuracy as a part of the Longwalls 311-316 Extraction Plan. The revised rating curve would be used once finalised.

Metropolitan Coal will also consult with WaterNSW regarding the extension of the rating curve at the Waratah Rivulet and the implementation of flow gauges with validated rating curves, or alternative estimation methods, in future mining areas.

The outcomes of the investigation will be reported in the Annual Review.

11.2 GROUNDWATER

In regards to the IEAPM recommendation for an additional bore at the T5 location, Metropolitan Coal installed groundwater site LW305GW in late 2022. This adjacent monitoring site has multi-level piezometers at similar horizons to T5.

A proposed location has been identified for a substrate monitoring piezometer in the downstream end of Swamp 77 (S77-0). Metropolitan Coal is investigating the feasibility of installation in consideration of accessibility limitations.

The installation of any new monitoring sites and collection of data would be subject to suitable access arrangement with WaterNSW.

12 ANNUAL REVIEW AND IMPROVEMENT OF ENVIRONMENTAL PERFORMANCE

In accordance with Condition 3, Schedule 7 of the Project Approval, Metropolitan Coal will conduct an Annual Review of the environmental performance of the Project by the end of March each year.

The Annual Review will specifically address the environmental performance of the WMP and will:

- describe the works that were carried out in the past calendar year, and the works that are proposed to be carried out over the current calendar year;
- include a comprehensive review of the monitoring results and complaints records of the Project over the past year, including a comparison of these results against the:
  - relevant statutory requirements, limits or performance measures/criteria;
  - monitoring results of previous years; and
  - relevant predictions in the Project EA, Preferred Project Report and Extraction Plan;
- identify any non-compliance over the last year, and describe what actions were (or are being) taken to ensure compliance;
- identify any trends in the monitoring data over the life of the Project;
- analyse historical water quality trends in Woronora Reservoir and their relation to mining development;
- identify any discrepancies between the predicted and actual impacts of the Project, and analyse the potential cause of any significant discrepancies; and
- describe what measures will be implemented over the next year to improve the environmental performance of the Project.

As described in Section 2, this WMP will be reviewed within three months of the submission of an Annual Review, and revised where appropriate.

13 INCIDENTS

An incident is defined as a set of circumstances that causes or threatens to cause material harm to the environment, and/or breaches or exceeds the limits or performance measures/criteria in the Project Approval.

The reporting of incidents will be conducted in accordance with Condition 6, Schedule 7 of the Project Approval. Metropolitan Coal will notify the Secretary of the DPE and any other relevant agencies of any incident associated with the Project as soon as practicable after Metropolitan Coal becomes aware of the incident. Within seven days of the date of the incident, Metropolitan Coal will provide the Secretary and any relevant agencies with a detailed report on the incident.

14 COMPLAINTS

A protocol for the managing and reporting of complaints has been developed as a component of Metropolitan Coal's Environmental Management Strategy and is described below.

The Environment & Community Superintendent is responsible for maintaining a system for recording complaints.

Metropolitan Coal will maintain public signage advertising the telephone number on which environmental complaints can be made. The Environment & Community Superintendent is responsible for ensuring that the currency and effectiveness of the service is maintained. Notifications of complaints received are to be provided as quickly as practicable to the Environment & Community Superintendent.

Complaints and enquiries do not have to be received via the telephone line and may be received in any other form. Any complaint or enquiry relating to environmental management or performance is to be relayed to the Environment & Community Superintendent as soon as practicable. All employees are responsible for ensuring the prompt relaying of complaints. All complaints will be recorded in a complaints register.

For each complaint, the following information will be recorded in the complaints register:

- date and time of complaint;
- method by which the complaint was made;
- personal details of the complainant which were provided by the complainant or, if no such details were provided, a note to that effect;
- nature of the complaint;
- the action(s) taken by Metropolitan Coal in relation to the complaint, including any follow-up contact with the complainant; and
- if no action was taken by Metropolitan Coal, the reason why no action was taken.

The Environment & Community Superintendent is responsible for ensuring that all complaints are appropriately investigated, actioned and that information is fed back to the complainant, unless requested to the contrary.

In accordance with Condition 10, Schedule 7 of the Project Approval, the complaints register will be made publicly available on the Peabody website and updated on a monthly basis. A summary of complaints received and actions taken will be presented to the Community Consultative Committee as part of the operational performance review.

15 NON-COMPLIANCES WITH STATUTORY REQUIREMENTS

A protocol for the managing and reporting of non-compliances with statutory requirements has been developed as a component of Metropolitan Coal's Environmental Management Strategy and is described below.

Compliance with all approvals, plans and procedures will be the responsibility of all personnel (staff and contractors) employed on or in association with Metropolitan Coal, and will be developed through promotion of Metropolitan Coal ownership under the direction of the General Manager.

The Technical Services Manager and/or Environment & Community Superintendent will undertake regular inspections, internal audits and initiate directions identifying any remediation/rectification work required, and areas of actual or potential non-compliance.

As described in Section 13, Metropolitan Coal will notify the Secretary of the DPE and any other relevant agencies of any incident associated with Metropolitan Coal as soon as practicable after Metropolitan Coal becomes aware of the incident. Within seven days of the date of the incident, Metropolitan Coal will provide the Secretary of the DPE and any relevant agencies with a detailed report on the incident.

A review of Metropolitan Coal's compliance with all conditions of the Project Approval, mining leases and all other approvals and licences will be undertaken prior to (and included within) each Annual Review. The Annual Review will be made publicly available on the Peabody website.

Additionally, in accordance with Condition 8, Schedule 7 of the Project Approval, an independent environmental audit was undertaken by the end of December 2011, and is undertaken a minimum of once every three years thereafter. A copy of the audit report will be submitted to the Secretary of the DPE and made publicly available on the Peabody website. The independent audit will be undertaken by an appropriately qualified, experienced and independent team of experts whose appointment has been endorsed by the Secretary of the DPE.

16 REFERENCES

Boughton, W.C. (2004) The Australian Water Balance Model, *Environmental Modelling and Software*, Vol 19, pp. 943–956.

Brienen Environment & Safety (2019) *Deep Groundwater Sampling Program – January – March 2019 – Woronora Catchment Area, Helensburgh, NSW*.

Department of Planning (2008) *Southern Coalfield Panel Report.*

Department of Planning (2009) *Major Project Assessment Metropolitan Coal Project.* Director-General's Environmental Assessment Report. June 2009.

Department of Planning and Environment and NSW Trade & Investment – Division of Resources and Energy (2015) *Guidelines for the Preparation of Extraction Plans Required under Conditions of Development Consents, Project Approvals and Mining Lease Conditions for Underground Coal Mining.* Version 5. Draft.

Ditton, S. and Merrick, N. (2014) *A New Subsurface Fracture Height Prediction Model for Longwall Mines in the NSW Coalfields.*

Eco Logical Australia (2018a) *Metropolitan Coal Vegetation Monitoring, Longwalls 23-27 – Autumn 2017.*

Eco Logical Australia (2018b) *Metropolitan Coal Vegetation Monitoring, Longwalls 23-27 – Spring 2017.*

Eco Logical Australia (2019a) *Metropolitan Coal Vegetation Monitoring, Longwalls 23-27 – Autumn 2018.*

Eco Logical Australia (2019b) *Metropolitan Coal Vegetation Monitoring, Longwalls 23-27 – Spring 2018.*

Eco Logical Australia (2020a) *Metropolitan Coal Vegetation Monitoring, Longwalls 23-27 – Autumn 2019.*

Eco Logical Australia (2020b) *Metropolitan Coal Vegetation Monitoring, Longwalls 23-27 – Spring 2019.*

Eco Logical Australia (2021a) *Metropolitan Coal Vegetation Monitoring, Longwalls 23-27 – Autumn 2020.*

Eco Logical Australia (2021b) *Metropolitan Coal Vegetation Monitoring, Longwalls 23-27 – Spring 2020.*

Environmental Earth Sciences (2014) *Assessment and Interpretation of Deep Groundwater Sampling Program – June 2009 to February 2014 – Woronora Catchment Area, Helensburgh, NSW.*

Gilbert & Associates (2008) *Metropolitan Coal Project Surface Water Assessment*, Appendix C in Helensburgh Coal Pty Ltd (2008) *Metropolitan Coal Project Environmental Assessment.*

Gilbert & Associates (2014) *Assessment of Performance Measure of Minimal Gas Releases – Pool P.*

Gilbert & Associates (2015a) *Metropolitan Coal – Revised Rating Curves for Waratah Rivulet (GS 2132102), Woronora River (GS 2132101) and O'Hares Creek at Wedderburn (GS 213200).*

Gilbert & Associates (2015b) *AWBM Model Calibration – Waratah Rivulet, Woronora River and O'Hares Creek.*

Golder Associates Pty Ltd (2020) *2020EX02 Summary Report.*

Hebblewhite, B., Kalf, F and McMahon, T. (2017) *Woronora Reservoir Impact Strategy – Stage 1 Report.*

Hebblewhite, B., Kalf, F and McMahon, T. (2019) *Woronora Reservoir Impact Strategy – Stage 2 Report.*

Helensburgh Coal Pty Ltd (2008) *Metropolitan Coal Project Environmental Assessment*.

Helensburgh Coal Pty Ltd (2009) *Metropolitan Coal Project Preferred Project Report.*

Helsel, D. and Hirsch, R. (2002) *Techniques of Water-Resources Investigations of the United States Geological Survey Book 4, Hydrologic Analysis and Interpretation Chapter A3 Statistical Methods*. In Water Resources (September 2002), section 1.7.1, pp. 12.

Heritage Computing (2008) *Metropolitan Coal Project Groundwater Assessment*, Appendix B in Helensburgh Coal Pty Ltd (2008) *Metropolitan Coal Project Environmental Assessment.*

Hydro Engineering & Consulting (2021a) *Metropolitan Coal Waratah Rivulet Pool Impact Assessment.*

Hydro Engineering & Consulting (2021b) *Metropolitan Coal Surface Water Review 1 January to 30 June 2021*.

Hydro Engineering & Consulting (2022) *Metropolitan Coal Surface Water Review 1 January to 31 December 2022*.

Hydro Engineering & Consulting (2024) *Visual Inspection and Photographic Survey of Streams in the Vicinity of Longwalls 304-310.*

HydroSimulations (2018) *Metropolitan Coal Project Underground Model Calibration.*

HydroSimulations (2019) *Metropolitan Coal Project Significance of Chain Pillars on Simulated Groundwater Pressures [Draft].*

Independent Expert Scientific Committee's (2015) *Advice to decision maker on coal mining – Further advice on impacts to swamps.*

Independent Expert Panel for Mining in the Catchment (2018) *Initial Report on Specific Mining Activities at the Metropolitan and Dendrobium Coal Mines.* 12 November 2018.

Independent Expert Advisory Panel for Mining (2023a) *Water Quality Performance Measures for Metropolitan Coal Mine.* October 2023.

Independent Expert Advisory Panel for Mining (2023b) *Metropolitan Coal Mine: Independent review of environmental performance to 2022.* September 2023.

Metropolitan Coal Pty Ltd (2011) *Metropolitan Coal 2011 Annual Review.*

Metropolitan Coal Pty Ltd (2014) *Metropolitan Coal 2013 Annual Review and Annual Environmental Management Report.*

Metropolitan Coal Pty Ltd (2015) *Metropolitan Coal 2014 Annual Review and Annual Environmental Management Report/Rehabilitation Report.*

Metropolitan Coal Pty Ltd (2019) *Metropolitan Coal Stream Remediation Plan*.

Metropolitan Coal Pty Ltd (2021) *Metropolitan Coal 2020 Annual Review.*

Metropolitan Coal Pty Ltd (2022) *Metropolitan Coal 2021 Annual Review.*

Mine Subsidence Engineering Consultants (2021) *Metropolitan Mine – Longwalls 308-310 Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan (MSEC Report 1199).*

Mine Subsidence Engineering Consultants (2024) *Metropolitan Coal Mine – Longwalls 311-316 Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan (MSEC Report 1340).*

National Health and Medical Research Council (2011) *National Water Quality Management Strategy - Australian Drinking Water Guidelines.*

NSW Planning Assessment Commission (2009) *The Metropolitan Coal Project Review Report.* May 2009.

Operational Risk Mentoring (2019) *Metropolitan Collieries Pty Ltd – Longwalls 305-307 Environmental Risk Assessment Report.*

Raveendran, R., Ashworth, B. and Chatelier, B. (2001) *Manganese removal in drinking water systems*, in Proceedings of the 64th Annual Water Industry Engineers and Operations Conference, pp. 92-100, Bendigo, Australia.

Rayner-Canham, G. (1996) *Descriptive Inorganic Chemistry*; Freeman: New York. Chapter 9.

Risk Mentor (2021) *Metropolitan Collieries Pty Ltd – Longwalls 308-310 Environmental Risk Assessment Report.*

SP Solutions (2008) *Metropolitan Coal Project Environmental Risk Analysis*. Appendix O in the Helensburgh Coal Pty Ltd (2008) *Metropolitan Coal Project Environmental Assessment*.

SLR Consulting Australia Pty Ltd (2020) *Metropolitan Coal Groundwater: Model Calibration Report.*

SLR Consulting Australia Pty Ltd (2021) *Metropolitan Coal Groundwater Monitoring Report 1 January – 30 June 2021.*

The University of Queensland (2014) *Pool P Gas Release – Assessment against Subsidence Impact Performance Measure.*

The University of Queensland (2016a) *Eastern Tributary Iron Staining Incident.*

The University of Queensland (2016b) *Pools W, ETAL and ETAM Gas Releases – Assessment against Subsidence Impact Performance Measure.*

The University of Queensland (2017) *Pool U Gas Releases – Assessment against Subsidence Impact Performance Measure.*

The University of Queensland (2018a) *Assessment against Water Quality Performance Measure, January to March 2018.*

The University of Queensland (2018b) *Pool P and Pool U Gas Releases – Assessment against Subsidence Impact Performance Measure.*

The University of Queensland (2018c) *Pool P Gas Releases – Assessment against Subsidence Impact Performance Measure.*

The University of Queensland (2018d) *Assessment against Water Quality Performance Measure, April 2018.*

The University of Queensland (2018e) *Assessment against Water Quality Performance Measure, May 2018.*

The University of Queensland (2018f) *Assessment against Water Quality Performance Measure, June 2018.*

The University of Queensland (2018g) *Assessment against Water Quality Performance Measure, July 2018.*

The University of Queensland (2018h) *Assessment against Water Quality Performance Measure, August 2018.*

The University of Queensland (2018i) *Assessment against Water Quality Performance Measure, September 2018.*

The University of Queensland (2018j) *Assessment against Water Quality Performance Measure, October 2018.*

The University of Queensland (2018k) *Assessment against Water Quality Performance Measure, November 2018.*

The University of Queensland (2018l) *Assessment against Water Quality Performance Measure, December 2018.*

The University of Queensland (2019a) *Pool U Gas Releases – Assessment against Subsidence Impact Performance Measure.*

The University of Queensland (2019b) *Assessment against Water Quality Performance Measure, January 2019.*

The University of Queensland (2019c) *Assessment against Water Quality Performance Measure, February 2019.*

The University of Queensland (2019d) *Assessment against Water Quality Performance Measure, March 2019.*

The University of Queensland (2020a) *Pool P and Pool U Gas Releases – Assessment against Subsidence Impact Performance Measure.*

The University of Queensland (2020b) *Pool U Gas Releases – Assessment against Subsidence Impact Performance Measure.*

The University of Queensland (2020c) *Pool P Gas Releases – Assessment against Subsidence Impact Performance Measure.*

The University of Queensland (2020d) *Pool P Gas Releases – Assessment against Subsidence Impact Performance Measure.*

The University of Queensland (2020e) *Assessment against Water Quality Performance Measure, January 2020.*

The University of Queensland (2020f) *Assessment against Water Quality Performance Measure, February 2020.*

The University of Queensland (2020g) *Assessment against Water Quality Performance Measure, March 2020.*

The University of Queensland (2020h) *Assessment against Water Quality Performance Measure, April 2020.*

The University of Queensland (2020i) *Assessment against Water Quality Performance Measure, June 2020.*

The University of Queensland (2020j) *Assessment against Water Quality Performance Measure, July 2020.*

The University of Queensland (2020k) *Assessment against Water Quality Performance Measure, August 2020.*

The University of Queensland (2020l) *Assessment against Water Quality Performance Measure, September 2020.*

The University of Queensland (2021a) *Pool P Gas Releases – Assessment against Subsidence Impact Performance Measure.*

The University of Queensland (2021b) *Pool P and Pool U Gas Releases – Assessment against Subsidence Impact Performance Measure.*

The University of Queensland (2021c) *Pool P and Pool U Gas Releases – Assessment against Subsidence Impact Performance Measure.*

The University of Queensland (2021d) *Pool P and Pool U Gas Releases – Assessment against Subsidence Impact Performance Measure.*

The University of Queensland (2021e) *Pool P Gas Releases – Assessment against Subsidence Impact Performance Measure.*

The University of Queensland (2021f) *Assessment against Water Quality Performance Measure, October 2020.*

The University of Queensland (2021g) *Assessment against Water Quality Performance Measure, November 2020.*

The University of Queensland (2021h) *Assessment against Water Quality Performance Measure, December 2020.*

The University of Queensland (2021i) *Assessment against Water Quality Performance Measure, January 2021.*

The University of Queensland (2021j) *Assessment against Water Quality Performance Measure, February 2021.*

The University of Queensland (2021k) *Assessment against Water Quality Performance Measure, March 2021.*

The University of Queensland (2021l) *Assessment against Water Quality Performance Measure, April 2021.*

The University of Queensland (2021m) *Assessment against Water Quality Performance Measure, May 2021.*

The University of Queensland (2021n) *Assessment against Water Quality Performance Measure, June 2021.*

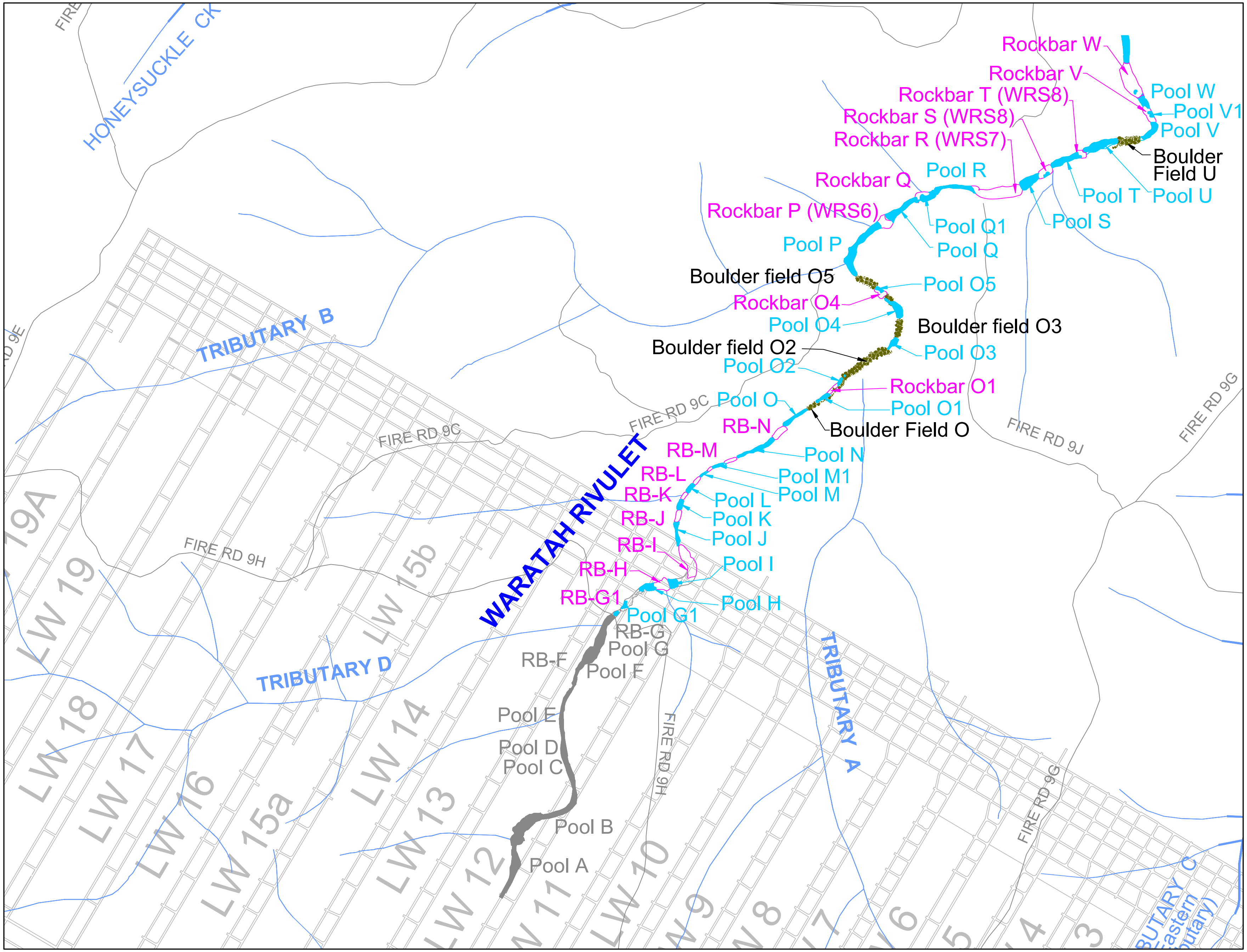
Velseis (2018) *Metropolitan 2D repro. Processing and Interpretation report*.

Yee, N., Shaw, S., Benning, L.G. and Nguyen, T.N. (2006) *The rate of ferrihydrite transformation to goethite via the Fe (II) pathway*. American Mineralogist 91: 92-96.

APPENDIX 1

WARATAH RIVULET STREAM MAPPING AND PHOTOGRAPHIC RECORD

STREAM MAPPING SUMMARY – GENERAL LAYOUT



POOL G1 - STREAM MAPPING SUMMARY

G1-1 Upstream end of Pool G1 looking downstream

G1-2 Downstream end of Pool G1 looking upstream

G1-7 On rockbar G1 looking upstream

G1-8 On rockbar G1 looking downstream

G1-9 South East bank

G1-11 North West bank

G1-5 Cracking in rockbar

G1-6 Cracking in rockbar

G1-10 Iron Staining

G1-14 Crack perpendicular to joint

G1-15 Buckling

G1-3 Cracking aross pool and deposits

G1-4 Cracking in rockbar

G1-12 Crack 20 to 50mm wide

G1-13 Crack

Pool G1 and Rockbar G1 notes (as at 16 Dec 2008)

- Pool length is approximately 15m. Width varies from approximately 6m to 10m. Average depth is approximately 0.4m with a maximum of approximately 0.7m.
- Several cracks observed in the stream bed and in the rockbar downstream of the pool (see photos).
- Base of the pool is sandstone covered in stained sediment. Minor alluvial deposits on north side of pool.
- Pool flows out onto rockbar. Narrow turbulent flow over rockbar and some ponding. Rock shelf both sides of flow to approximately 1m maximum above water level.
- Cross bedding present.
- Rockbar approximately 24m wide u/s end and 32m wide at d/s end.

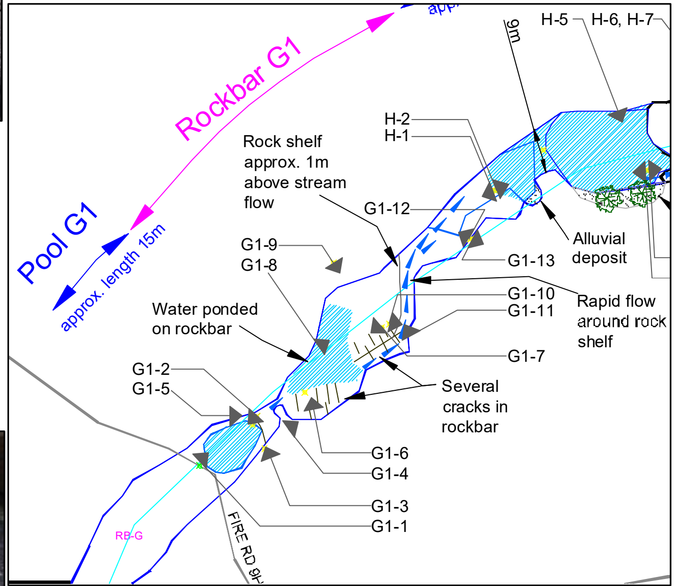


Photo Details

Photo ID	Easting	Northing	Bearing
G1-1	309673	6214194	46
G1-2	309686	6214204	226
G1-3	309688	6214196	335
G1-4	309695	6214202	46
G1-5	309685	6214202	95
G1-6	309698	6214210	348
G1-7	309717	6214226	232
G1-8	309703	6214222	52
G1-9	309705	6214242	140
G1-10	309719	6214227	104
G1-11	309723	6214225	332
G1-12	309739	6214248	350
G1-13	309739	6214248	170
G1-14	309739	6214248	290
G1-15	309739	6214248	130

POOL H - STREAM MAPPING SUMMARY

H-1 Upstream end of Pool H looking upstream

H-2 Upstream end of Pool H looking downstream

H-3 Downstream end of Pool H looking upstream

H-4 Downstream end of Pool H looking downstream

H-5 South East bank

H-8 and H-9 Cracks in rockbar, 5mm wide, 5m apart.

H-7 Flow at downstream end of pool H

Pool H and Rockbar H notes (as at 16 Dec 2008)

- Pool length is approximately 40m. Width is approximately 9m to 20m. Average depth is approximately 1m to 1.5m.
- Algae and alluvial deposits on the southern side of the pool bed.
- Alluvial deposits on southern bank.
- Rockbar H approximately 27 to 37m wide.
- Pool flows out onto rockbar. Narrow turbulent flow over rockbar and some ponding. Rock shelf both sides of flow approximately 1m above water level.
- Cross bedding present. Boulders present along northern side of pool.
- Minor cracking at downstream end of rockbar H.

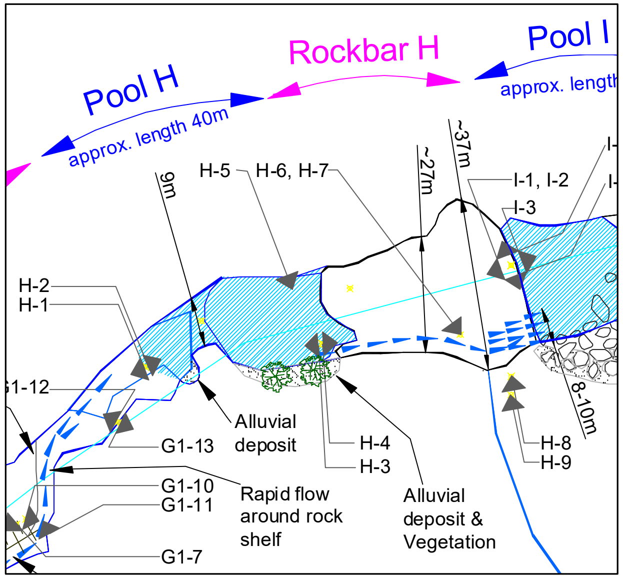


Photo Details

Photo ID	Easting	Northing	Bearing
H-1	309745	6214260	246
H-2	309745	6214260	66
H-3	309783	6214265	266
H-4	309783	6214265	86
H-5	309776	6214278	159
H-7	309813	6214267	174
H-8	309824	6214258	350
H-9	309824	6214254	350

POOL I - STREAM MAPPING SUMMARY

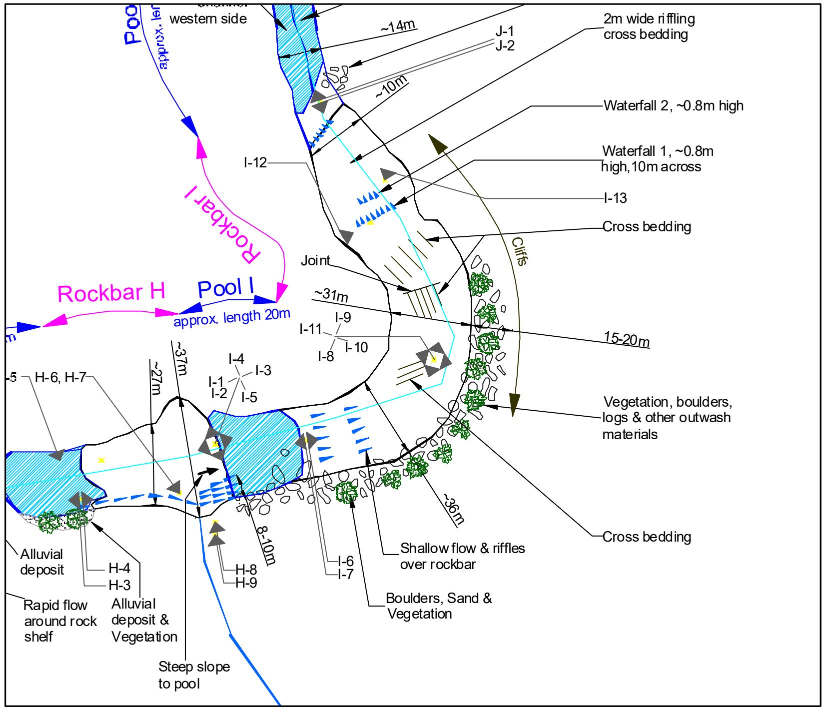

I-1 and I-2 Upstream end of Pool I looking upstream

<u>Pool I notes (as at 16 Dec 2008)</u>

- Pool length is approximately 20m. Width is approximately 21m. Average depth is approximately 1.4m.
- Pool bed is sandstone with sediment covering the rock surface.
- Sandstone cobbles to about 0.3m size at downstream end of pool. Boulders to about 1m size and vegetation along the southern bank.
- Cross bedding present in pool bed.
- Rockbar H rises approximately 1.5m above the u/s end of Pool I.
- Pool I flows out onto Rockbar I to form shallow flow and riffle across most of the width of the rockbar.

I-3 Upstream end of Pool I looking downstream

I-4 Northern bank at u/s end of pool



I-7 Downstream end of Pool I looking upstream

I-5 Southern bank at u/s end of pool

I-6 Downstream end of Pool I looking downstream

Photo Details

Photo ID	Easting	Northing	Bearing
I-1	309824	6214282	250
I-2	309824	6214282	250
I-3	309824	6214282	70
I-4	309824	6214282	340
I-5	309824	6214282	160
I-6	309872	6214350	80
I-7	309872	6214350	260

ROCKBAR I - STREAM MAPPING SUMMARY

I-8 Rockbar I looking upstream

I-9 Rockbar I looking downstream

I-10 Eastern bank

I-12 Waterfall 1

I-11 Western bank

I-13 Waterfalls 1 and 2

Rockbar I notes (as at 16 Dec 2008)

- Width varies from approximately 31m to 36m. Length is approximately 150m.
- Water flows mainly over full width of rockbar as shallow flow and riffles.
- Cliffs located along the eastern edge of the rockbar.
- Two small waterfalls are located on the rockbar as shown on sketch.
- Cross bedding present.
- Approximately 3m vertical change in height from Pool H to Pool I.

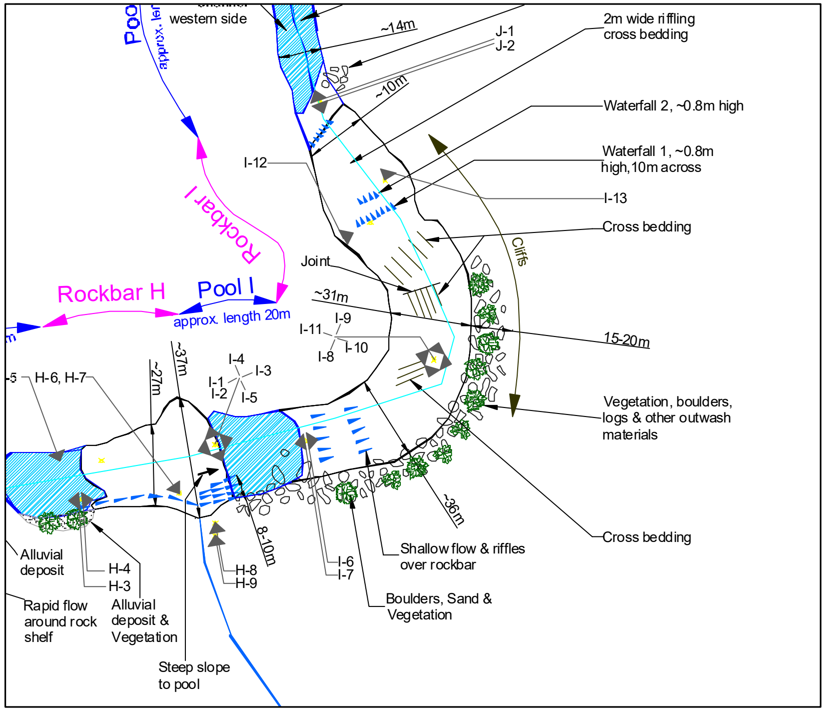


Photo Details

Photo ID	Easting	Northing	Bearing
I-8	309891	6214308	200
I-9	309891	6214308	20
I-10	309891	6214308	110
I-11	309891	6214308	290
I-12	309876	6214363	60
I-13	309876	6214362	195

POOL J - STREAM MAPPING SUMMARY

J-1 Pool J upstream end looking downstream

J-2 Pool J upstream end looking upstream

J-3 Pool J downstream end looking upstream

J-4 Pool J downstream end looking downstream

<u>Pool J and Rockbar J notes (as at 16 Dec 2008)</u>

- Width varies from approximately 12m to 14m. Length is approximately 60m.
- Water depth varies from approximately 0.8m to 1.0m along a deeper channel on the western side of the pool. Sandstone shelf about 0.3m below water surface along the eastern side of the pool.
- Rockbar J width varies from approximately 12m to 21m with an average width of approximately 20m.
- Water flows over most of the rockbar as shallow flow with minor riffles at the u/s and d/s ends of the rockbar.

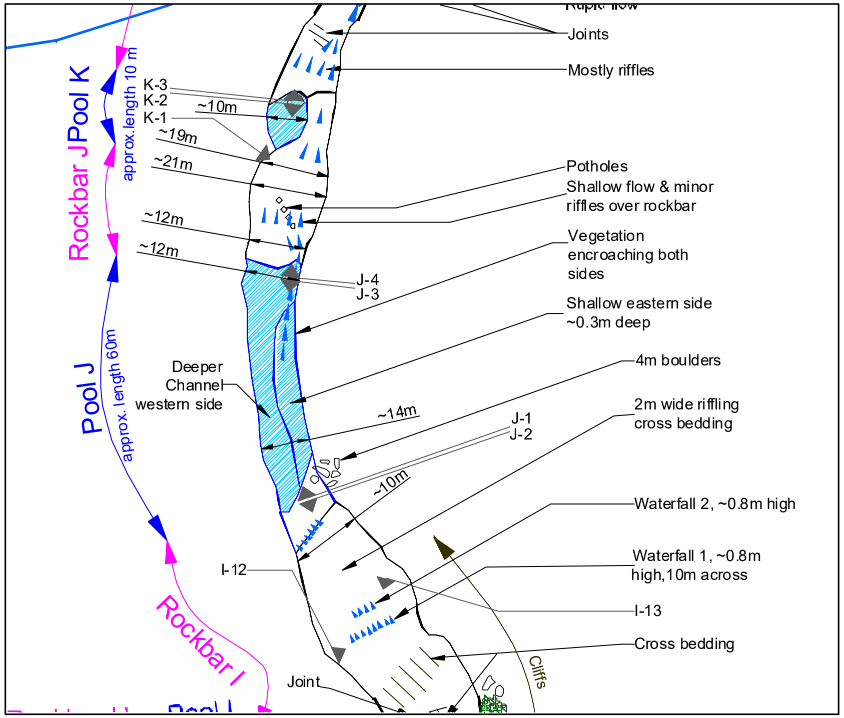


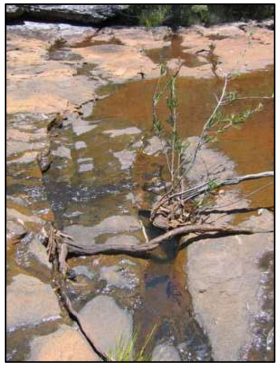
Photo Details

Photo ID	Easting	Northing	Bearing
J-1	309856	6214387	160
J-2	309856	6214387	340
J-3	309853	6214446	185
J-4	309853	6214446	5

POOL K - STREAM MAPPING SUMMARY

K-1 Pool K upstream end looking towards west bank

K-4 Joints across Rockbar K



K-5 Joints across Rockbar K

K-2 Pool K downstream end looking upstream

L-4 Joints across Rockbar K

K-3 Pool K downstream end looking downstream

L-5 Joints across Rockbar K

Pool K and Rockbar K notes (as at 16 Dec 2008)

- Dimensions are approximately 10m wide by 10m long.
- Water depth is approximately 0.9m
- Pool K is located on the west side of the downstream end of Rockbar J. Rockbar J forms an almost continuous rockbar with Rockbar K.
- Joints located across the middle of Rockbar K as shown in sketch.
- Water flows around Pool K and over most of the width of Rockbar K as shallow flow and riffles.

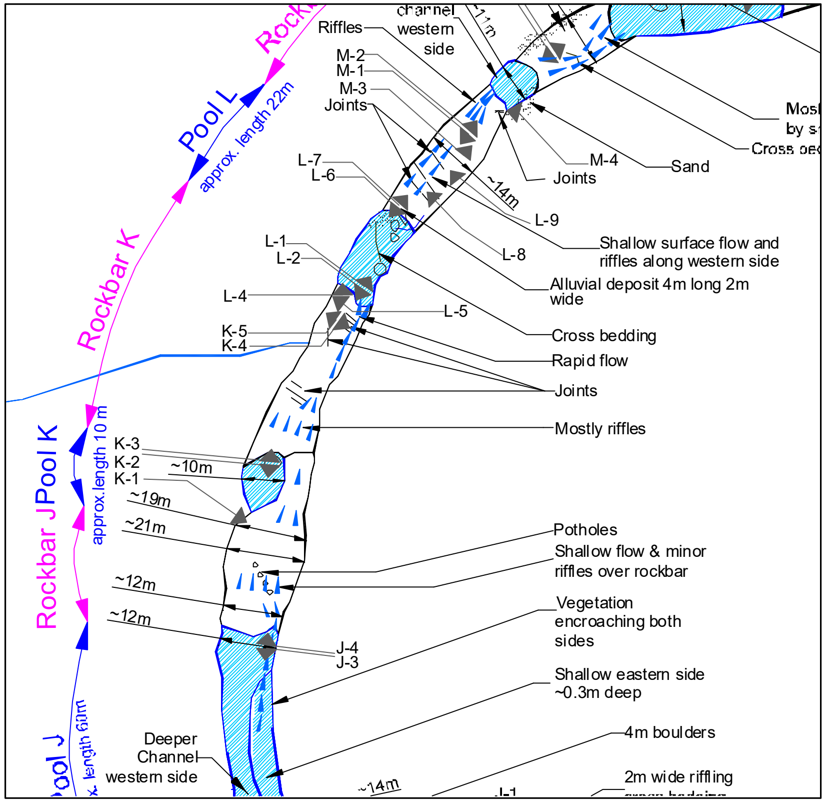


Photo Details

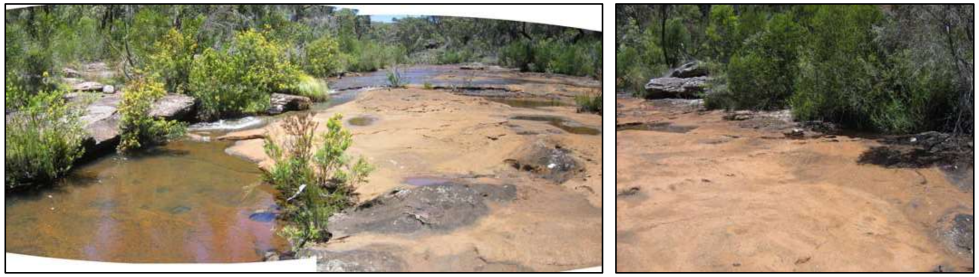
Photo ID	Easting	Northing	Bearing
K-1	309843	6214479	130
K-2	309852	6214493	185
K-3	309852	6214493	5
K-4	309869	6214529	120
K-5	309869	6214529	300
L-4	309871	6214536	0
L-5	309871	6214533	305

POOL L - STREAM MAPPING SUMMARY

L-1 Upstream end of Pool L looking downstream

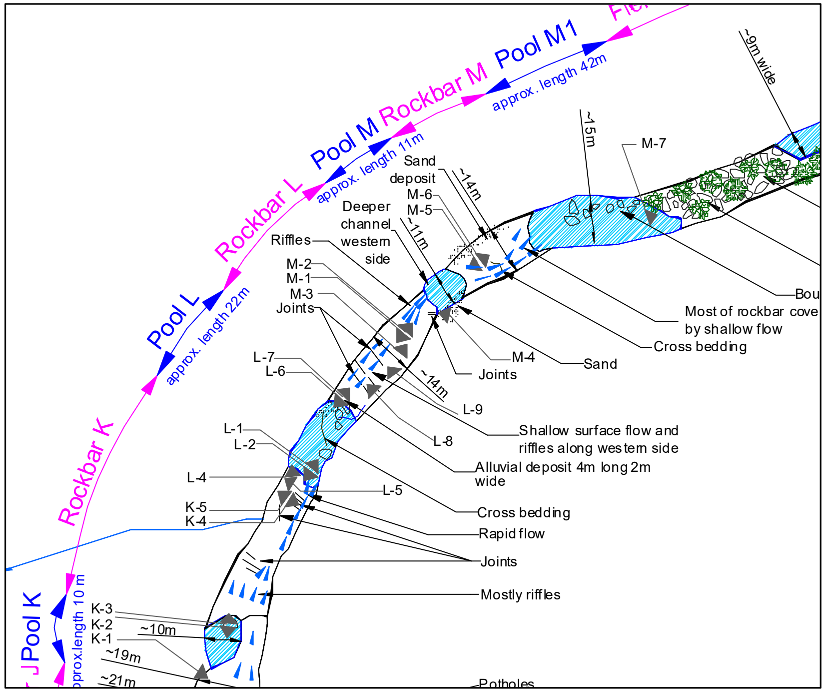
Pool L and Rockbar L notes (as at 16 Dec 2008)

- Pool length is approximately 22m. Width varies from approximately 10m to 12m. Water depth varies from approximately 0.6m to 0.9m.
- Pool bed is sandstone covered with sediment.
- Boulders to about 1m size located on eastern bank and downstream end.
- Alluvial deposit approximately 2m x 4m at downstream end of pool.
- Cross bedding present in pool bed.
- Water flows onto Rockbar L at the western bank then flows over approximately the western half of Rockbar L as shallow flow and riffles.
- Rockbar L width is approximately 13m.

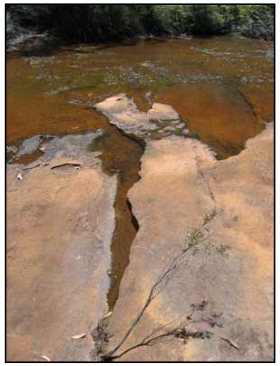


L-2 Upstream end of Pool L looking upstream

L-8 Joints across u/s end of Rockbar L



L-6 Downstream end of Pool L looking upstream



L-9 Joint in Rockbar L

L-7 Downstream end of Pool L looking downstream

Photo Details

Photo ID	Easting	Northing	Bearing
L-1	309876	6214538	40
L-2	309876	6214538	220
L-6	309885	6214559	225
L-7	309885	6214559	40
L-8	309895	6214560	315
L-9	309900	6214566	320

POOL M and M1 - STREAM MAPPING SUMMARY

M-1 Upstream end of Pool M looking upstream

M-3 Riffling at u/s end of Pool M

Pool M and Rockbar M notes (as at 16 Dec 2008)

- Pool M is approximately 11m long and 11m wide. Water depth varies from approximately 0.3m to 0.9m with an average of approximately 0.6m. The deeper flow channel is on the western side of the pool.
- Pool bed is sandstone covered with sediment and sand deposits.
- Rockbar M is approximately 14m wide. Water flows over the rockbar from Pool M to Pool M1; width of flow is approximately 7m.
- Cross bedding present in pool bed and Rockbar M.

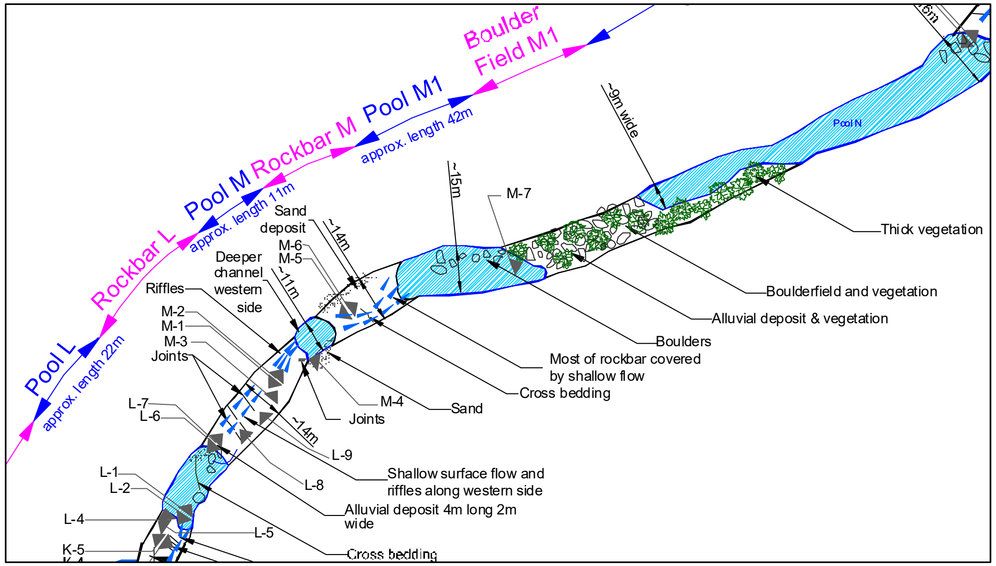
Pool M1 notes (as at 16 Dec 2008)

- Pool M1 is approximately 42m long and width varies from approximately 9m to 15m. Water depth varies from 0.3m to 1m with an average of approximately 1m.
- Base of Pool M1 is sandstone, covered with sediment.
- Boulders and detached blocks located along the north western side of the pool, approximately 1m to 6m in size.
- Pool M1 ends at boulder field consisting of boulders and blocks up to approximately 1m in size, and vegetation. Alluvial deposits and thick vegetation on the south western bank.

M-2 Upstream end of Pool M looking downstream

M-4 Joints in Rockbar M

M-5 Downstream end of Pool M looking upstream



M-6 Downstream end of Pool M looking downstream to Pool M1

M-7 Downstream end of Pool M1 looking downstream to boulder field

Photo Details

Photo ID	Easting	Northing	Bearing
M-1	309903	6214578	220
M-2	309903	6214578	40
M-3	309902	6214572	40
M-4	309916	6214583	270
M-5	309983	6214613	235
M-6	309983	6214613	55
M-7	309973	6214611	70

POOL N (WRS5) - STREAM MAPPING SUMMARY

N-1 Downstream end of Pool N looking upstream

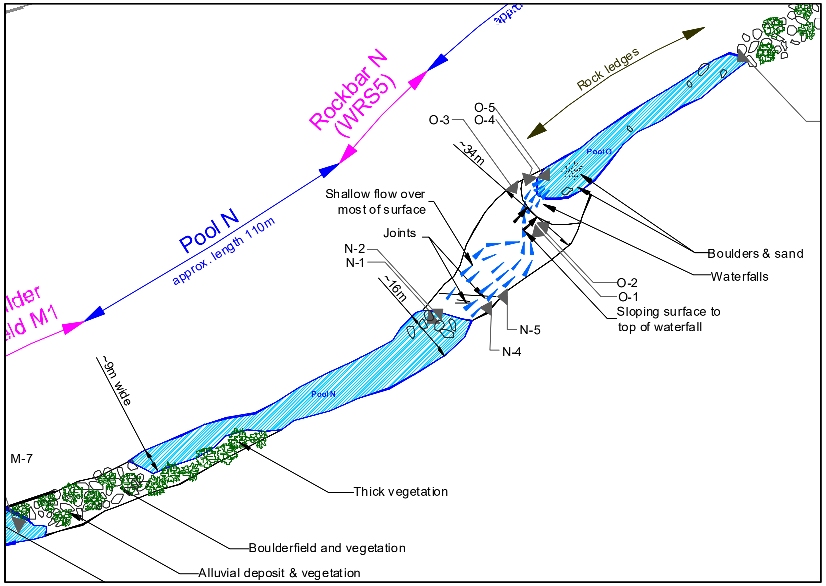
N-4 Joints in rockbar N

N-2 Downstream end of Pool N looking downstream

N-5 Joints in Rockbar N

Pool N and Rockbar N (WRS5) notes (as at 16 Dec 2008)

- Pool N is approximately 110m long and varies from 10m to 16m wide. Average water depth is approximately 1m.
- Pool bed is sandstone covered with sediment and sand deposits.
- Boulders to about 1m size present at the downstream end of the pool extending approximately 15m into the pool.
- Rockbar N (WRS5) varies from approximately 20m wide at the upstream end to approximately 34m wide at the downstream end.
- Water flows over most of the surface of the rockbar from Pool N and enters Pool O via riffles and 4 waterfalls. The slope of the riffles is generally along the sandstone bedding planes.
- The vertical drop in height from the top of Rockbar N to Pool O is approximately 5.5m to 6m.
- Cross bedding present.



O-1 Upstream end of Pool O looking upstream at Rockbar N (WRS5)

Photo Details

Photo ID	Easting	Northing	Bearing
N-1	310109	6214679	230
N-2	310109	6214679	50
N-4	310127	6214681	270
N-5	310132	6214685	270
O-1	310143	6214707	50

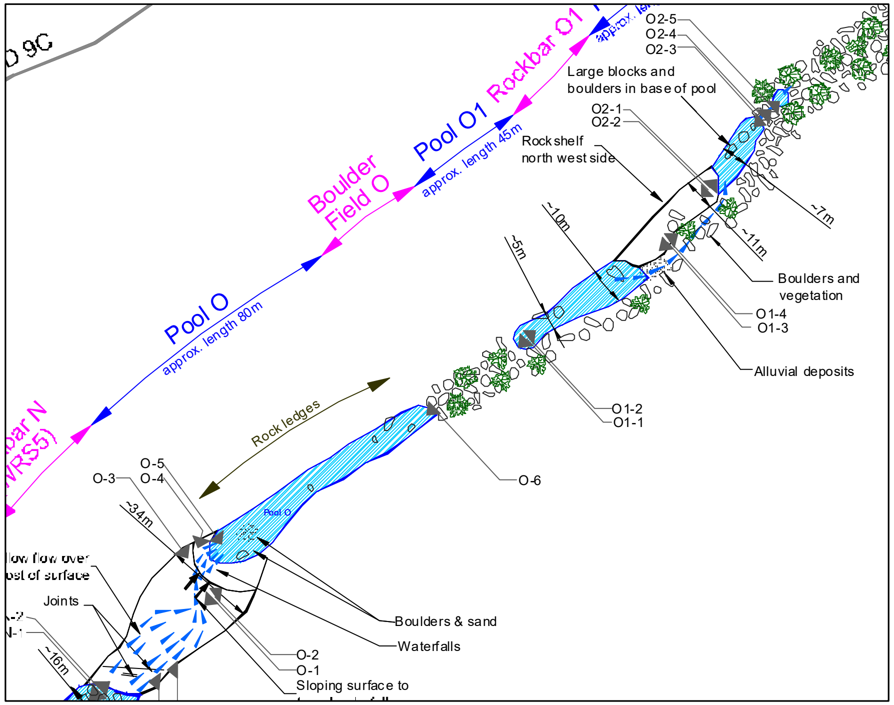
POOL O - STREAM MAPPING SUMMARY

O-1 Upstream end of Pool O looking upstream at Rockbar N (WRS5) and North Western Bank

Pool O notes (as at 16 Dec 2008)

- Pool O is approximately 80m long and varies in width from approximately 8m at the downstream end to 15m at the upstream end. Water depth varies from approximately 0.5m to 1m with an average of approximately 0.8m.
- Pool bed is sandstone covered with sediment and sand deposits.
- Boulders up to about 2m size scattterd through the pool. More boulders are located on the south east side of the pool and there are rock ledges along the north west side.
- The downstream end of the pool flows into a boulder field.
- The boulder field comprises boulders varying up to approximately 5m size, alluvial deposits and vegetation.
- Water flow is audible through the boulder field.

O-2 Upstream end of Pool O looking downstream



O-5 South Eastern Bank at waterfalls

O-4 Looking upstream from base of waterfalls

O-6 Downstream end of Pool O looking upstream

O-3 South Eastern Bank at waterfalls

Photo Details

Photo ID	Easting	Northing	Bearing
O-1	310143	6214707	230
O-2	310143	6214707	50
O-3	310134	6214721	145
O-4	310140	6214724	200
O-5	310144	6214724	145
O-6	310209	6214763	230

POOL O1 - STREAM MAPPING SUMMARY

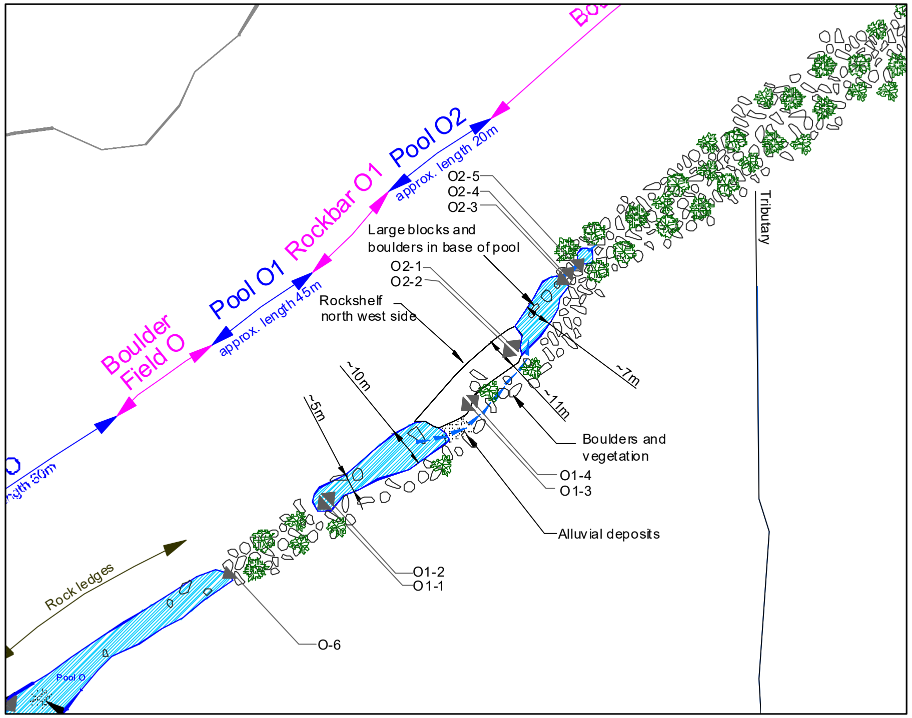
O1-1 Upstream end of Pool O1 looking upstream

O1-2 Upstream end of Pool O1 looking downstream

<u>Pool O1 notes (as at 17 Dec 2008)</u>

- Pool O1 is approximately 40m long and varies in width from approximately 5m to 11m. Water depth varies from approximately 0.3m to 1.2m.
- Pool bed is sandstone with potholes, and sand deposits and aquatic vegetation at the upstream end.
- The pool is surrounded by boulder field on all sides except the north west, which comprises rock ledge/rock shelf.
- The boulder field comprises boulders varying up to approximately 5m size, alluvial deposits and vegetation.
- The boulder field on the south east side of the pool is approximately 6m wide.
- Estimated distance between sandstone ledges on north east and south west banks is approximately 40m.
- Cross bedding present.
- Braided flow is audible through the boulder field.

O1-3 Downstream end of Pool O1 looking upstream



O1-4 Downstream end of Pool O1 looking downstream

Photo Details

Photo ID	Easting	Northing	Bearing
O1-1	310237	6214784	230
O1-2	310237	6214784	50
O1-3	310279	6214813	230
O1-4	310279	6214813	50

POOL O2 - STREAM MAPPING SUMMARY

O2-1 Upstream end of Pool O2 looking downstream

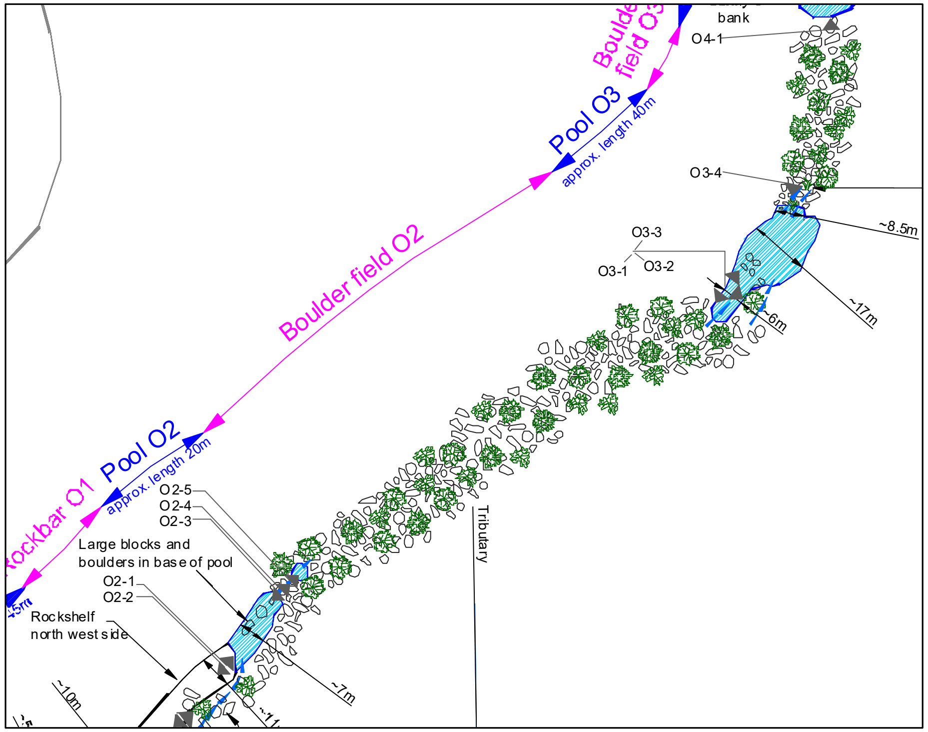
O2-2 Upstream end of Pool O2 looking upstream

Pool O2 notes (as at 17 Dec 2008)

- Pool O2 is approximately 20m long and 7m wide. Water depth varies from approximately 0.3m to 0.5m.
- Pool bed is sandstone with alluvial deposits.
- The pool is located amongst a boulder field and has boulders and detached blocks up to approximately 5m in size in the base of the pool.
- There is a small pool immediately downstream of Pool 02. It is located amongst boulders and vegetation and is approximately 3m to 4m diameter.
- Braided flow is audible through the boulder field.

O2-3 Downstream end of Pool O2 looking upstream

O2-4 Downstream end of Pool O2 looking downstream



O2-5 Small pool downstream of Pool O2

Photo Details

Photo ID	Easting	Northing	Bearing
O2-1	310291	6214829	225
O2-2	310291	6214829	45
O2-3	310307	6214850	225
O2-4	310307	6214850	45
O2-5	310309	6214853	45

POOL O3 - STREAM MAPPING SUMMARY

O3-1 Upstream end of Pool O3 looking upstream

O3-2 Upstream end of Pool O3 looking at east bank

O3-3 Upstream end of Pool O3 looking downstream

O3-4 Downstream end of Pool O3 looking upstream

<u>Pool O3 notes (as at 17 Dec 2008)</u>

- Pool O3 is approximately 40m long and varies in width from approximately 6m to 17m. Water depth varies from approximately 0.3m to 1.5m.
- Pool bed is sandstone with alluvial sand deposits and aquatic vegetation.
- Boulder field located upstream and downstream and comprises boulders varying up to approximately 5m size, alluvial deposits and vegetation.
- Braided flow is audible through the boulder field.

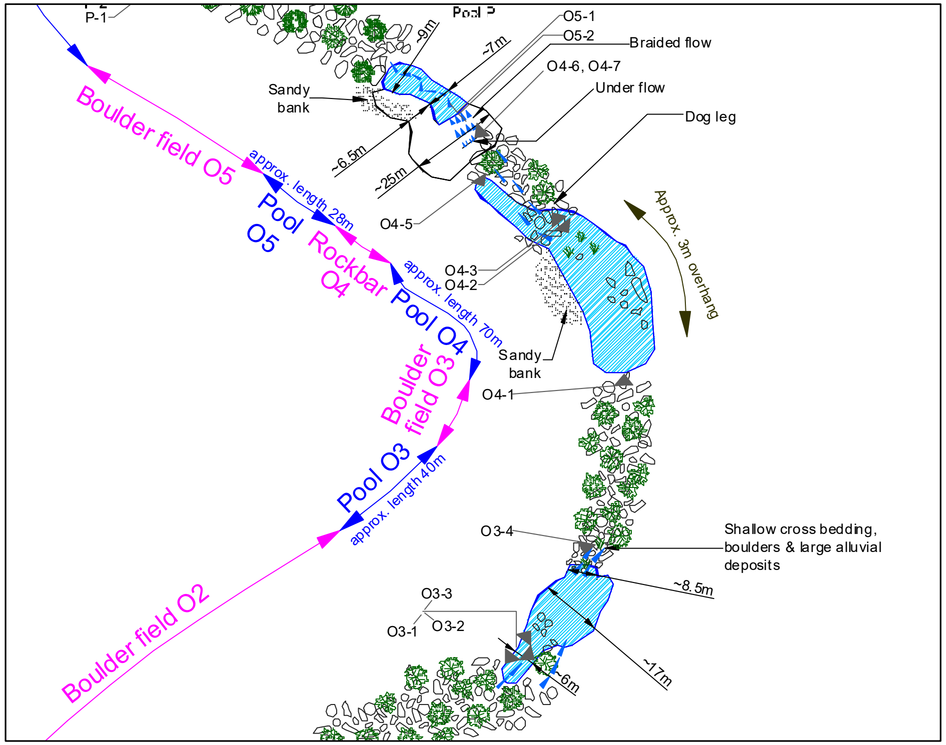


Photo Details

Photo ID	Easting	Northing	Bearing
O3-1	310435	6214938	220
O3-2	310435	6214938	130
O3-3	310435	6214938	40
O3-4	310454	6214966	190

POOL O4 - STREAM MAPPING SUMMARY

O4-1 Upstream end of Pool O4 looking downstream

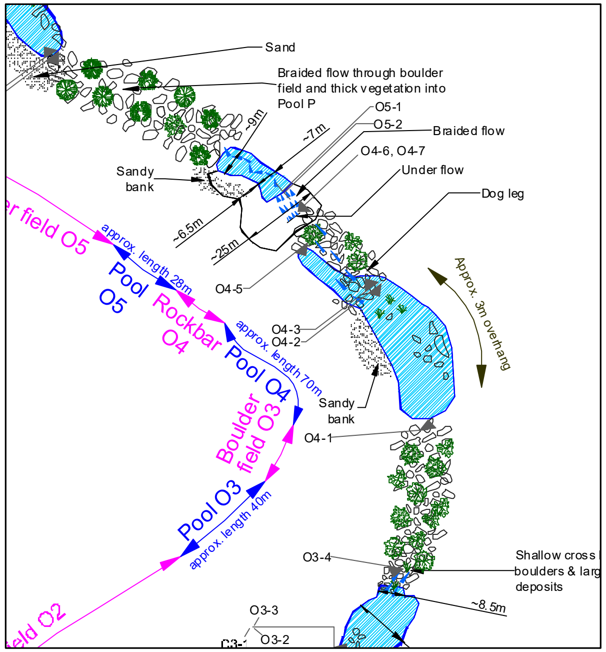
O4-4 Sample of vegetation from base of pool

Pool O4 and Rockbar O4 notes (as at 17 Dec 2008)

- Pool O4 is approximately 70m long overall. The main section of the pool is approximately 55m long and 15m to 20m wide. A narrow section extends downstream of a dog leg, measuring approximately 15m long and 5m wide. Water depth varies from approximately 0.1m to 1m.
- Pool bed is sandstone with alluvial sand deposits, aquatic vegetation and boulders.
- The pool is located amongst a boulder field. The south western bank of the pool is sand.
- The boulder field comprises boulders varying up to approximately 5m size, alluvial deposits and vegetation.
- Rockbar O4 is approximately 25m wide. Underflow emerges onto the rockbar and flows into Pool O5.

O4-2 At dog leg in Pool O4 looking upstream

O4-5 Downstream end of Pool O4 looking upstream



O4-3 At dog leg in Pool O4 looking downstream

O4-6 Flow emerging at upstream end of Rockbar O4

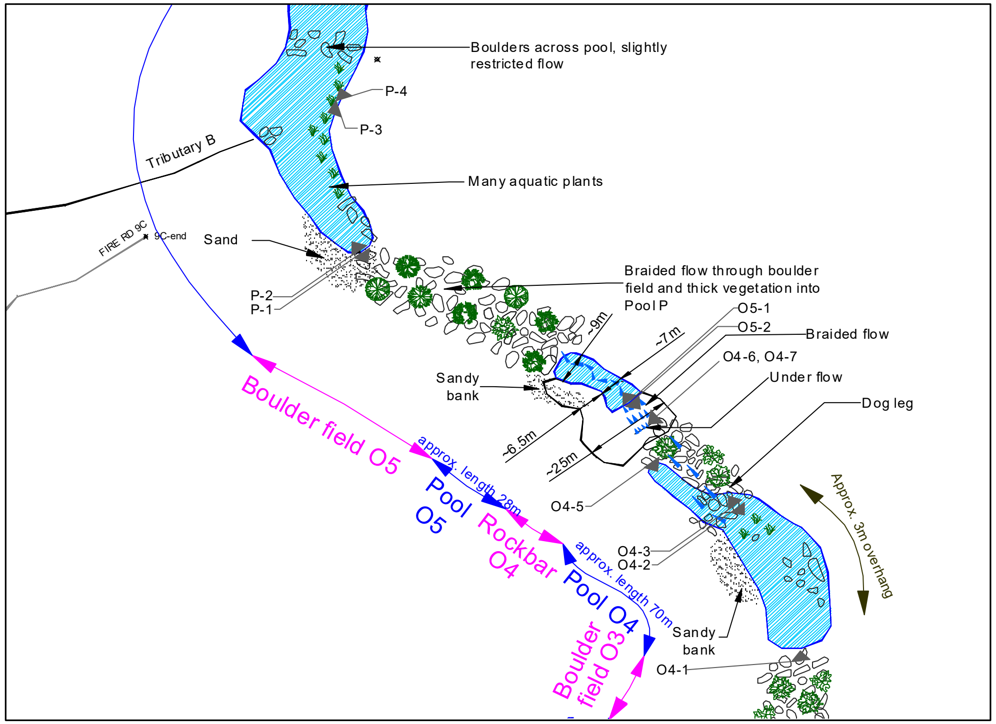
O4-7 Flow emerging and alluvial deposit at upstream end of Rockbar O4

Photo Details

Photo ID	Easting	Northing	Bearing
O4-1	310465	6215013	355
O4-2	310447	6215058	145
O4-3	310447	6215058	325
O4-5	310424	6215070	145
O4-6	310421	6215080	230
O4-7	310421	6215080	230

POOL O5 - STREAM MAPPING SUMMARY

O5-1 Upstream end of Pool O5 looking upstream



O5-2 Upstream end of Pool O5 looking downstream

Pool O5 notes (as at 17 Dec 2008)

- Pool O5 is approximately 28m long and varies in width from approximately 7m to 9m. Water depth varies from approximately 0.2m to 0.7m.
- Pool bed is sandstone with sand deposits and boulders and some aquatic vegetation.
- The pool is formed in the north east haf of Rockbar 04 at the downstream end of the rockbar. The exposed sandstone on the south west side of the pool slopes up from the pool to approximately 0.3m maximum height above the pool.

Photo Details

Photo ID	Easting	Northing	Bearing
O5-1	310417	6215090	140
O5-2	310417	6215090	320

POOL P - STREAM MAPPING SUMMARY

P-1 Upstream end of Pool P looking Upstream

P-3 Looking south west to Tributary B

P-2 Upstream end of Pool P looking Downstream

P-4 Looking downstream to boulders and aquatic vegetation

P-5 Downstream end of Pool P looking Upstream

P-7 Underflow into rockbar

P-6 Downstream end of Pool P looking Downstream

P-8 Looking north west across Rockbar P (WRS6)

Pool P and Rockbar P (WRS6) notes (as at 17 Dec 2008)

- Width varies from approximately 12m to 20m with an average of approximately 15m
- Water depth varies from approximately 2m (u/s end) to 0.2m with an average of approximately 0.6m
- Base of the pool is sandstone with several boulders and large detached blocks. Flow is restricted by boulders just downstream of Tributary B as shown in the sketch (Photo P-4).
- Minor alluvial deposits, mainly along the sides of the pool. Many aquatic plants near the u/s end on the eastern side of the pool.
- Water flows below the Rockbar P. Entry point is approximatelly 9m from the d/s end of Pool P at a 1.1m step up in the rockbar. Flow below the rockbar is audible .

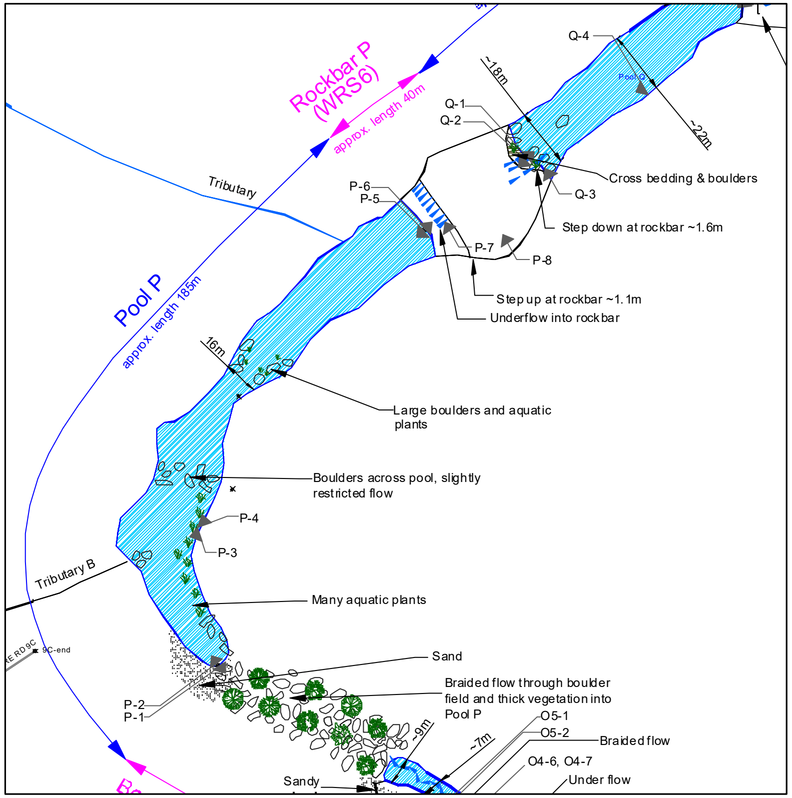


Photo Details

Photo ID	Easting	Northing	Bearing
P-1	310343	6215133	145
P-2	310343	6215133	325
P-3	310337	6215175	250
P-4	310339	6215179	340
P-5	310410	6215274	230
P-6	310410	6215274	50
P-7	310417	6215274	330
P-8	310437	6215269	330

POOL Q and Q1 - STREAM MAPPING SUMMARY

Q-1 Upstream end of Pool Q looking Downstream

Q-3 West bank at u/s end of Pool Q

Q-2 Upstream end of Pool Q looking Upstream

Q-4 Looking upstream at ~40m from the upstream end of Pool Q

Q-5 Downstream end of Pool Q looking Upstream

Q-6 Downstream end of Pool Q looking Downstream

Pool Q and Rockbar Q notes (as at 17 Dec 2008)

- Width varies from approximately 18m to 22m. Water depth varies from approximately 1m to 2m.
- Base of Pool Q is sandstone with some detached blocks.
- North west side of the rockbar is approximately 0.4m higher than the water level at the location of the flow between Pool Q and Q1.
- Rockbar Q is approximately 34m across at the widest point.

Pool Q1 notes (as at 17 Dec 2008)

- Water enters Pool Q1 via a small 0.4m waterfall.
- Pool Q1 is located within Rockbar Q.
- Width varies from approximately 9m to 21m. Length is approximately 30m. Water depth varies from approximately 0.3m to 1.1m.
- Base of the pool is sandstone with pot holes and some detached blocks.
- Elevation drops approximately 1m from Pool Q1 to Pool R.

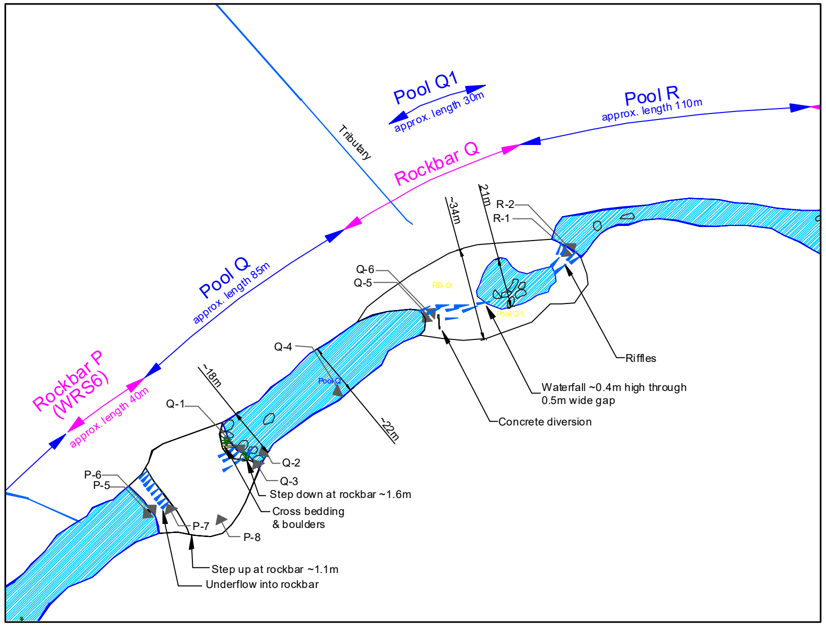


Photo Details

Photo ID	Easting	Northing	Bearing
Q-1	310443	6215297	50
Q-2	310453	6215297	230
Q-3	310451	6215291	330
Q-4	310481	6215320	240
Q-5	310514	6215349	230
Q-6	310514	6215349	50

POOL R - STREAM MAPPING SUMMARY

R-1 Upstream end of Pool R looking Upstream

R-2 Upstream end of Pool R looking Downstream

Pool R and Rockbar R (WRS7) notes (as at 17 Dec 2008)

- Width varies from approximately 12m (u/s end) to 22m (d/s end). Water depth varies from approximately 0.3m to 0.6m. Pool length is approximately 110m.
- Base of the pool is sandstone with detached blocks, and sediment. Boulders present up to approximately 5m size.
- Rockbar R width varies from approximately 18m to 27m. Rockbar R length is approximately 135m.
- Water flows over most of the width of the rockbar as shallow flow and riffles.
- Most of the rockbar surface has a shallow downstream slope with the last 20m becoming steeper.
- Vertical drop in height from Pool R to Pool S is approximately 7m.
- Four waterfalls located at d/s end of the rockbar from 0.4m to 1.2m height.

R-3 Downstream end of Pool R looking Upstream

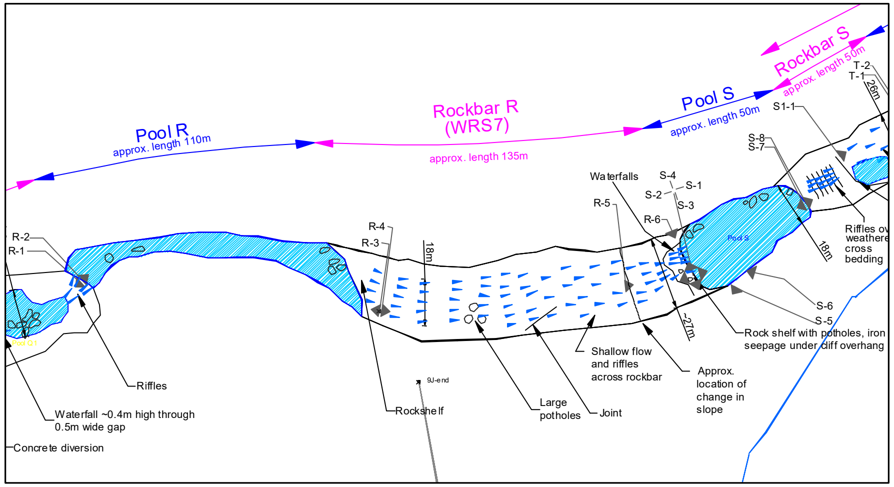


Photo Details

Photo ID	Easting	Northing	Bearing
R-1	310566	6215374	225
R-2	310566	6215374	45
R-3	310681	6215362	280
R-4	310681	6215362	100
R-5	310776	6215372	80
R-6	310794	6215394	160

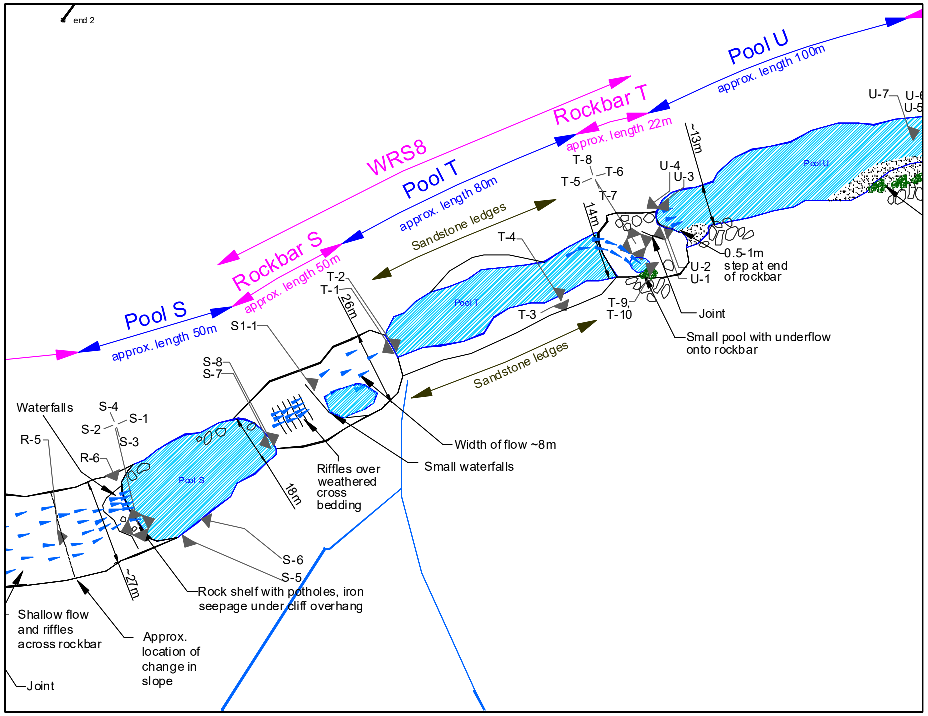
R-4 Downstream end of Pool R looking Downstream

R-5 Rockbar R change of slope looking Downstream

R-6 Downstream end of Rockbar R looking at south east bank

POOL S1 - STREAM MAPPING SUMMARY

S1-1 Pool S1 looking downstream and at south east bank



Pool S1 notes (as at 17 Dec 2008)

- Pool S1 is located at the approximate midpoint of Rockbar S.
- Pool S1 is approximately 14m long and 9m wide. Water depth is approximately 1.8m.
- Flow enters the pool by small waterfalls approximately 0.2m to 0.4m high.
- Base of the pool is sandstone.

Photo Details

Photo ID	Easting	Northing	Bearing
S1-1	310858	6215423	65

POOL S - STREAM MAPPING SUMMARY

S-1 Upstream end of Pool S looking Downstream

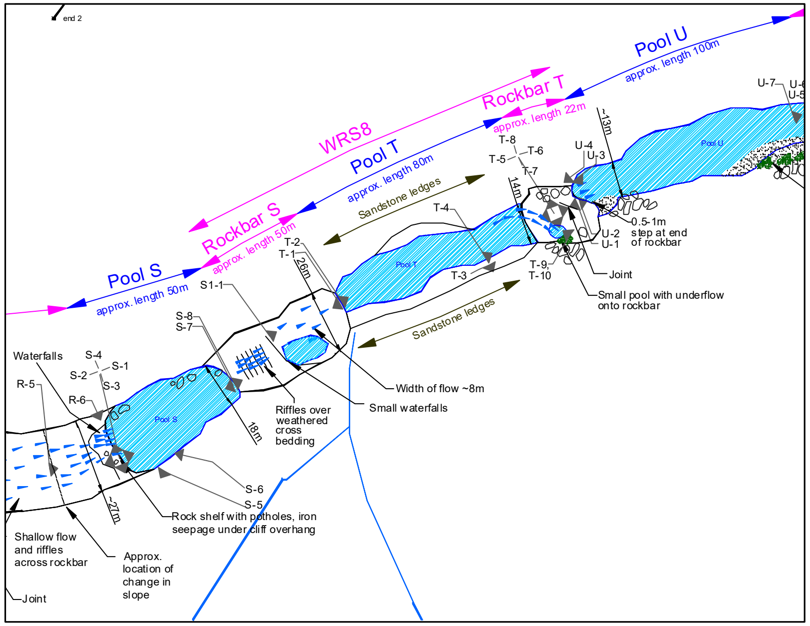
S-3 South east bank and u/s end of Pool S

Pool S and Rockbar S (WRS8) notes (as at 17 Dec 2008)

- Width is approximately 18m. Water depth at the upstream end of Pool S is 4.7m. Averge depth appears to be approximately 1.5m. Length of Pool S is approximately 50m.
- Base of the pool is sandstone.
- Estimated total height of waterfalls at upstream end of Pool S is approximately 1.9m.
- Some boulders along north side to about 3m size.
- Rockbar S is approximately 50m long and 26m wide.
- Weathered cross bedding present in the upstream end of the rockbar.
- Water flows over most of the width of the rockbar with a small pool located at the approximate middle of the rockbar (See separate sheet for Pool S1).

S-2 Upstream end of Pool S looking Upstream

S-4 North west bank and u/s end of Pool S



S-7 Downstream end of Pool S looking Upstream

S-5 Iron staining at seepage

S-8 Downstream end of Pool S looking Downstream

S-6 Looking upstream to waterfalls from south east bank

Photo Details

Photo ID	Easting	Northing	Bearing
S-1	310802	6215376	70
S-2	310802	6215376	250
S-3	310802	6215376	160
S-4	310802	6215376	340
S-5	310818	6215371	210
S-6	310825	6215377	290
S-7	310845	6215404	245
S-8	310845	6215404	65

POOL T - STREAM MAPPING SUMMARY

T-1 Upstream end of Pool T looking Upstream

T-3 Iron stain at seepage, south east bank

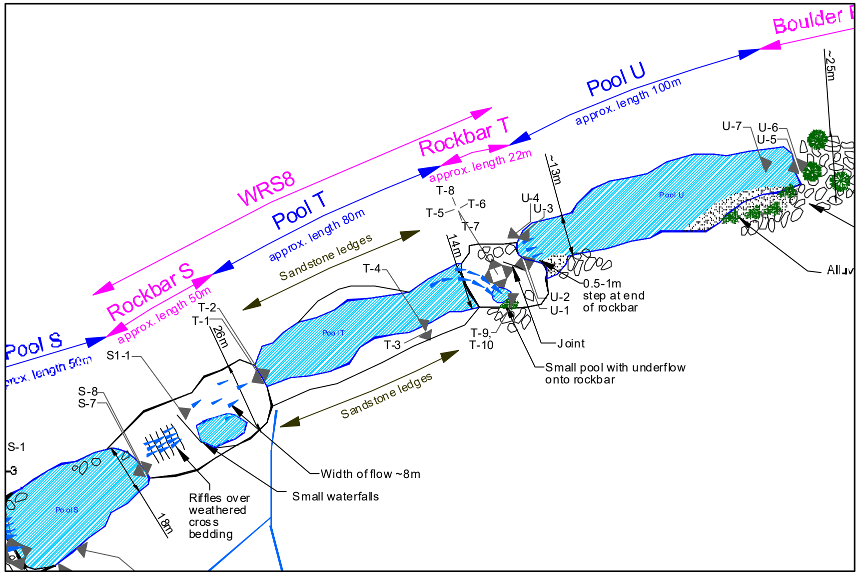
T-4 Minor seepage at south east bank

<u>Pool T and Rockbar T (WRS8) notes (as at 24 Dec 2008)</u>

- Average width is approximately 14m. Depth varies from approximately 0.1m to 0.5m with an average of approximately 0.3m. The length of Pool T is approximately 80m.
- Base of the pool is sandstone with pot holes at about the middle of the pool and sediment at the upstream end.
- Sandstone ledges with cross bedding present both sides of the pool. Distance between ledges is approximately 30m.
- Minor seepage and iron staining observed at cross bedding in sandstone ledges.
- Rockbar T is approximately 22m long and 27m wide and has pot holes.
- Water from Pool T flows over the surface of Rockbar T to a small pool which is approximately 5m in diameter. Flow from the small pool enters the rockbar as underflow and emerges at Pool U.

T-2 Upstream end of Pool T looking Downstream

T-7 South east bank and downstream end of Pool T



T-5 Downstream end of Pool T looking Upstream

T-8 North west bank at downstream end of Pool T

T-6 Downstream end of Pool T looking Downstream

T-9 Small pool and underflow into rockbar

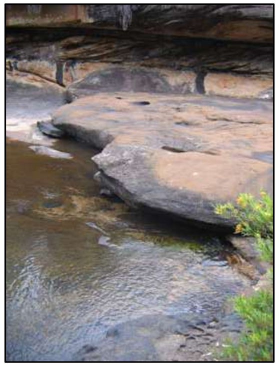
T-10 Small pool on rockbar T

Photo Details

Photo ID	Easting	Northing	Bearing
T-1	310885	6215436	240
T-2	310885	6215436	60
T-3	310935	6215464	150
T-4	310935	6215464	70
T-5	310965	6215471	250
T-6	310965	6215471	70
T-7	310965	6215471	160
T-8	310965	6215471	340
T-9	310971	6215462	330
T-10	310971	6215462	300

POOL U - STREAM MAPPING SUMMARY

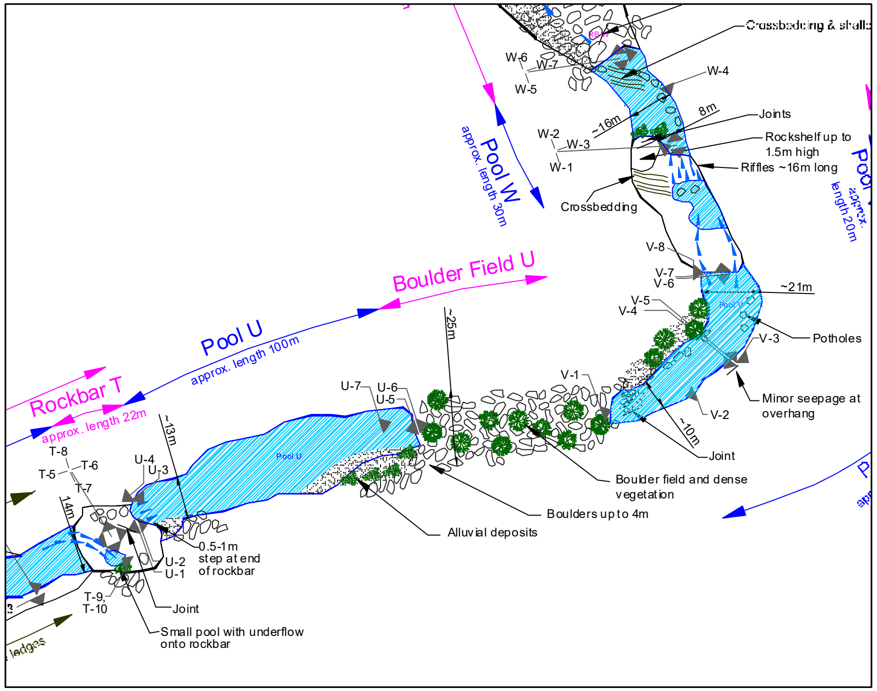
U-1 Upstream end of Pool U looking Upstream



U-3 Potholes and flow emerging

<u>Pool U notes (as at 24 Dec 2008)</u>

- Average width is approximately 13m. Water depth varies from approximately 0.3m to 1.3m. Pool length is approximately 100m.
- Base of the pool is sandstone with boulders and large detached blocks up to 4m size, and alluvial deposits mainly on the south east bank. Flow is restricted by boulders at about the middle of the pool.
- Aquatic vegetation observed at the upstream end and at the alluvial deposits.
- Pool U ends at a boulder field with boulders up to approximately 5m in size and vegetation. The width of the boulder field at the downstream end of the pool is approximately 25m.
- The vertical drop in height from Pool T to Pool U is approximately 4m.



U-2 Upstream end of Pool U looking Downstream

U-5 Downstream end of Pool U looking Upstream

U-4 Potholes and flow emerging

U-6 Downstream end of Pool U looking Downstream

U-7 ~10m from Downstream end of Pool U looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
U-1	310974	6215474	250
U-2	310974	6215474	70
U-3	310974	6215484	140
U-4	310971	6215485	230
U-5	311067	6215507	250
U-6	311067	6215507	70
U-7	311055	6215508	70

POOL V - STREAM MAPPING SUMMARY

V-1 Upstream end of Pool V looking Downstream

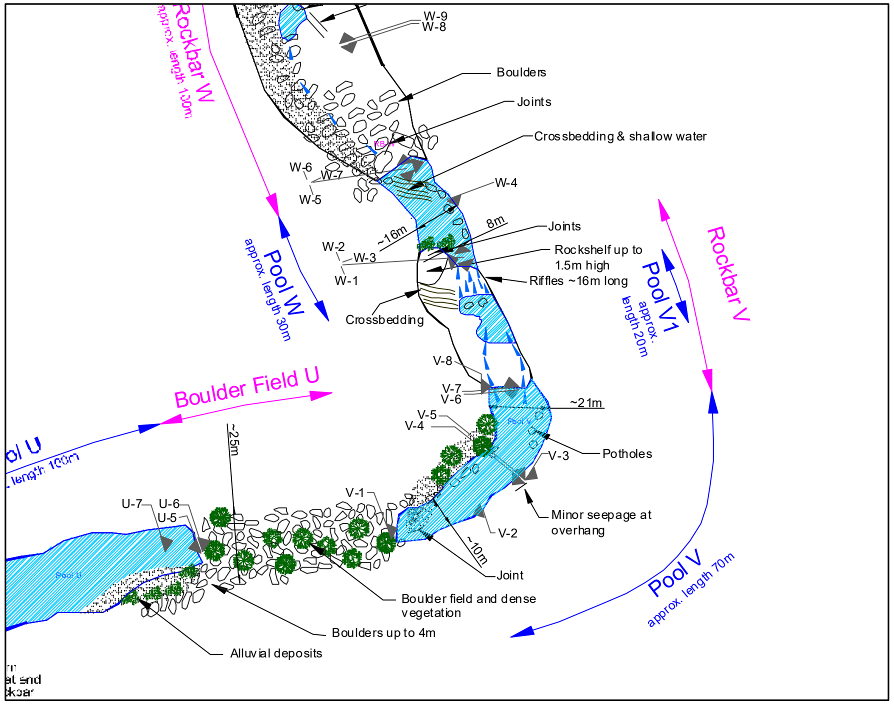
V-3 Overhang at east bank

Pool V and Rockbar V notes (as at 24 Dec 2008)

- Width varies from approximately 10m to 21m. Water depth varies from approximately 0.1m (u/s end) to 1.2m (d/s end)
- Base of the pool is sandstone with scattered boulders, minor alluvial deposits at the upstream end and aquatic vegetation at the upstream end.
- Minor seepage observed from sandstone ledges on south east side.
- Rockbar V varies from approximately 13m to 21m width and is approximately 55m long.
- Cross bedding is present at the downstream end.
- Pool V1 is located on the east side of Rockbar V. Pool V1 is approximately 11m wide, 20m long and 1m deep.
- Water flows from Pool V1 to Pool W via riffles over an approximate 1m vertical drop in elevation. A rock shelf that rises approximately 1.5m above Pool W is located on the west side of the riffles.

V-2 Upstream end of Pool V looking Upstream

V-4 Mid pool looking Upstream from east bank



V-6 Downstream end of Pool V looking Upstream

V-5 Mid pool looking Downstream from east bank

V-7 Downstream end of Pool V looking Downstream

V-8 Looking at east bank at Downstream end of Pool V

Photo Details

Photo ID	Easting	Northing	Bearing
V-1	311127	6215511	70
V-2	311159	6215519	250
V-3	311174	6215531	120
V-4	311170	6215529	220
V-5	311170	6215529	40
V-6	311167	6215558	175
V-7	311167	6215558	355
V-8	311158	6215558	90

POOL W - STREAM MAPPING SUMMARY

W-1 Upstream end of Pool W looking Upstream

W-3 East bank at Upstream end of Pool W

W-2 Upstream end of Pool W looking Downstream

W-4 Mid pool looking Upstream from east bank

W-5 Downstream end of Pool W looking Upstream

W-7 Looking at east bank at Downstream end of Pool W

W-6 Downstream end of Pool W looking Downstream

<u>Pool W notes (as at 24 Dec 2008)</u>

- Width varies from approximately 8m to 16m. Water depth varies from approximately 0.2m to 1.7m.
- Base of the pool is sandstone with boulders up to 5m size, alluvial deposit and aquatic vegetation.
- Cross bedding present in the pool base.
- Rockbar W is described on separate sheet.

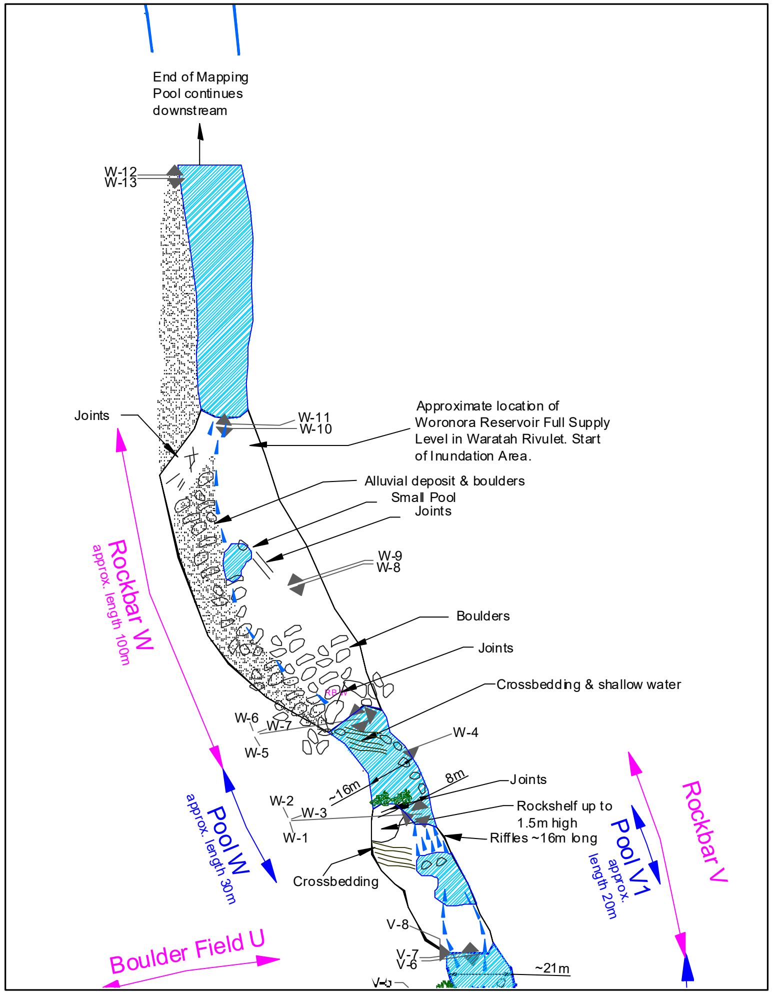


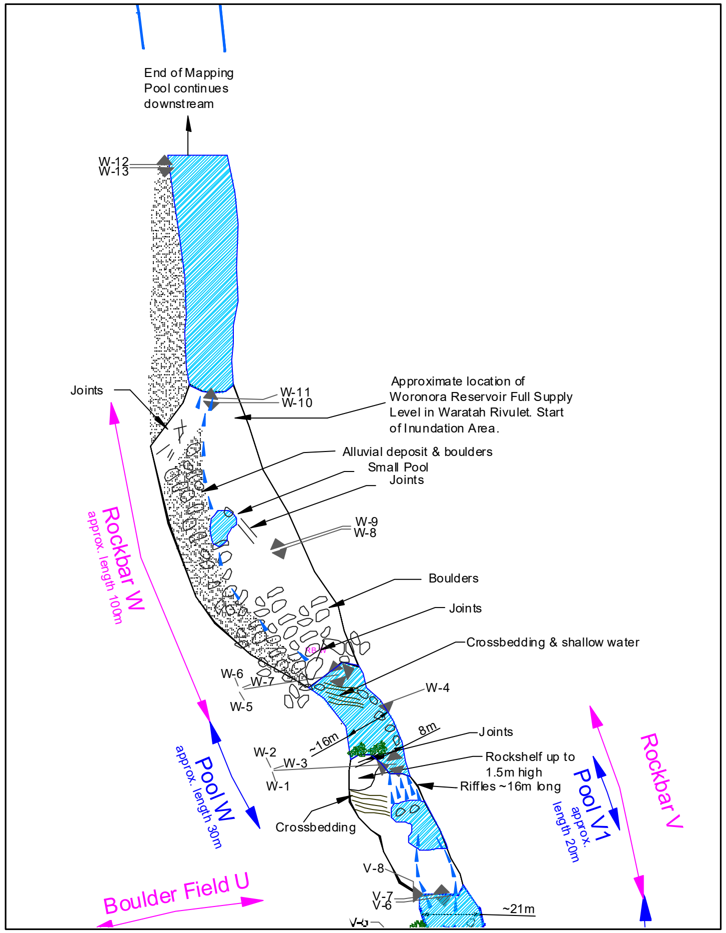
Photo Details

Photo ID	Easting	Northing	Bearing
W-1	311153	6215601	170
W-2	311153	6215601	350
W-3	311153	6215601	70
W-4	311150	6215621	160
W-5	311134	6215630	170
W-6	311134	6215630	350
W-7	311134	6215630	70

ROCKBAR W - STREAM MAPPING SUMMARY

W-8 Midway along Rockbar W looking Upstream

W-12 End of mapping (Pool X) looking Downstream



W-9 Midway along Rockbar W looking Downstream

Rockbar W notes (as at 24 Dec 2008)

- Rockbar W width varies from approximately 15m to 34m and length is approximately 100m.
- There are numerous boulders at the upstream end of the rockbar varying up to approximately 5m maximum size covering most of the rockbar.
- There are large deposits of alluvial material and boulders along the western side.
- Water flows along a shallow channel between the exposed sandstone and the alluvial deposits. There is a small pool about midway along the rockbar measuring approximately 6m wide by 10m long and 0.3m depth.
- The surface water flows into Pool X at about the estimated location of the full supply level of Woronora Reservoir.

W-10 Downstream end of Rockbar W looking Upstream

W-11 Downstream end of Rockbar W looking Downstream (Pool X)

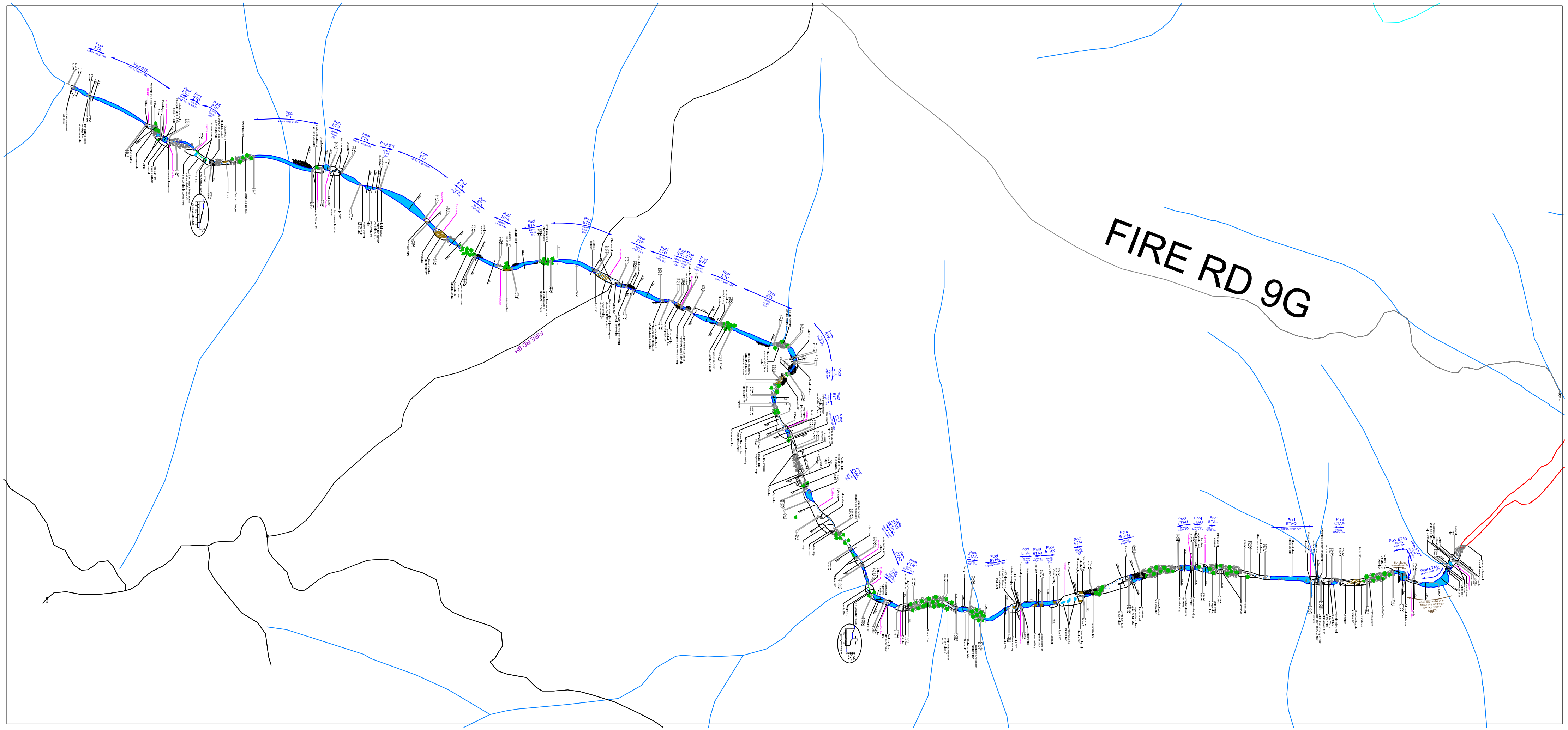
W-13 End of mapping (Pool X) looking Upstream

Photo Details

Photo ID	Easting	Northing	Bearing
W-8	311115	6215671	165
W-9	311115	6215671	340
W-10	311092	6215720	180
W-11	311092	6215720	0
W-12	311078	6215796	0
W-13	311078	6215796	180

APPENDIX 2

EASTERN TRIBUTARY STREAM MAPPING AND PHOTOGRAPHIC RECORD


FIRE RD 9G
FIRE RD 9H

POOL ETA STREAM MAPPING SUMMARY

ETA-1 Upstream end of Pool ETA looking Upstream

ETA-2 Upstream end of Pool ETA looking Downstream

ETA-3 Rockbar Upstream of Pool ETA looking Upstream

ETA-4 Rockbar Upstream of Pool ETA looking Downstream

ETA-5 Downstream end of Pool ETA looking Upstream

ETA-6 Downstream end of Pool ETA looking Downstream

Pool ETA notes (as at 29 Dec 2008)

- Width varies from approximately 2m to 6m
- Water depth varies from approximately 0.1m over approximately 12m length at the upstream end of the pool to approximately 0.3m
- Base of the pool is sandstone with several boulders up to approximately 1m size.
- Iron staining/deposits present over base of pool
- Rockbar upstream of the pool is approximately 3m wide and mostly covered with vegetation debris
- Rockbar downstream of the pool is approximately 3m wide and 6m long.
- Water flows along the eastern side of the rockbar and iron staining and cross bedding are present.

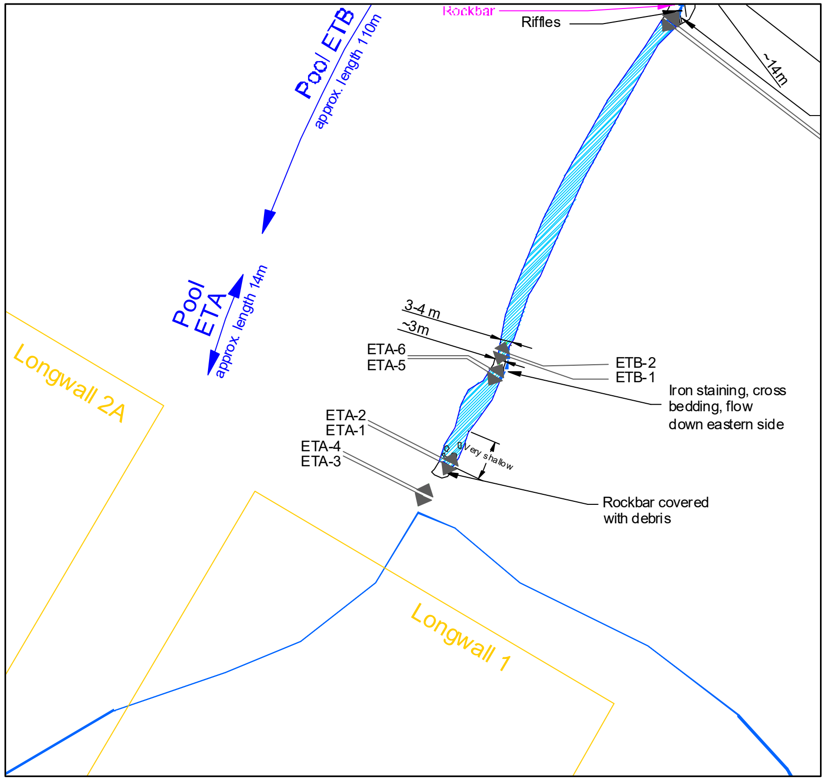


Photo Details

Photo ID	Easting	Northing	Bearing
ETA-1	311285	6213180	206
ETA-2	311285	6213180	26
ETA-3	311277	6213171	206
ETA-4	311277	6213171	26
ETA-5	311298	6213207	211
ETA-6	311298	6213207	31

POOL ETB STREAM MAPPING SUMMARY

ETB- 1 Upstream end of Pool ETB looking Upstream

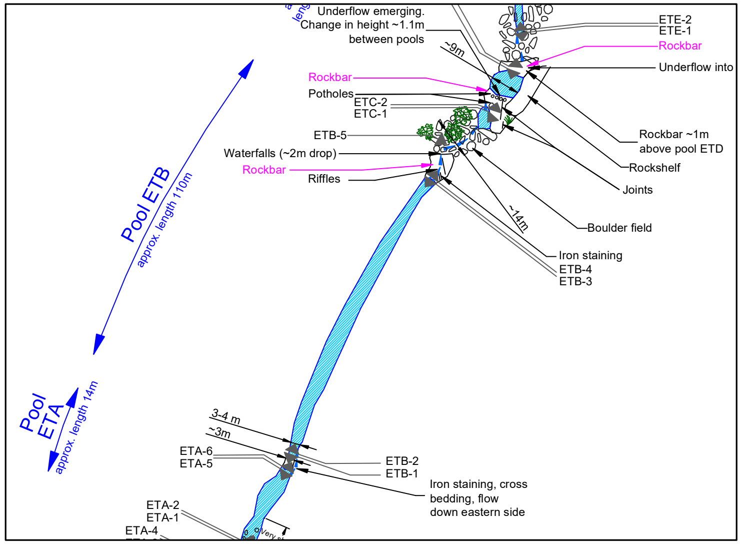
ETB- 2 Upstream end of Pool ETB looking Downstream

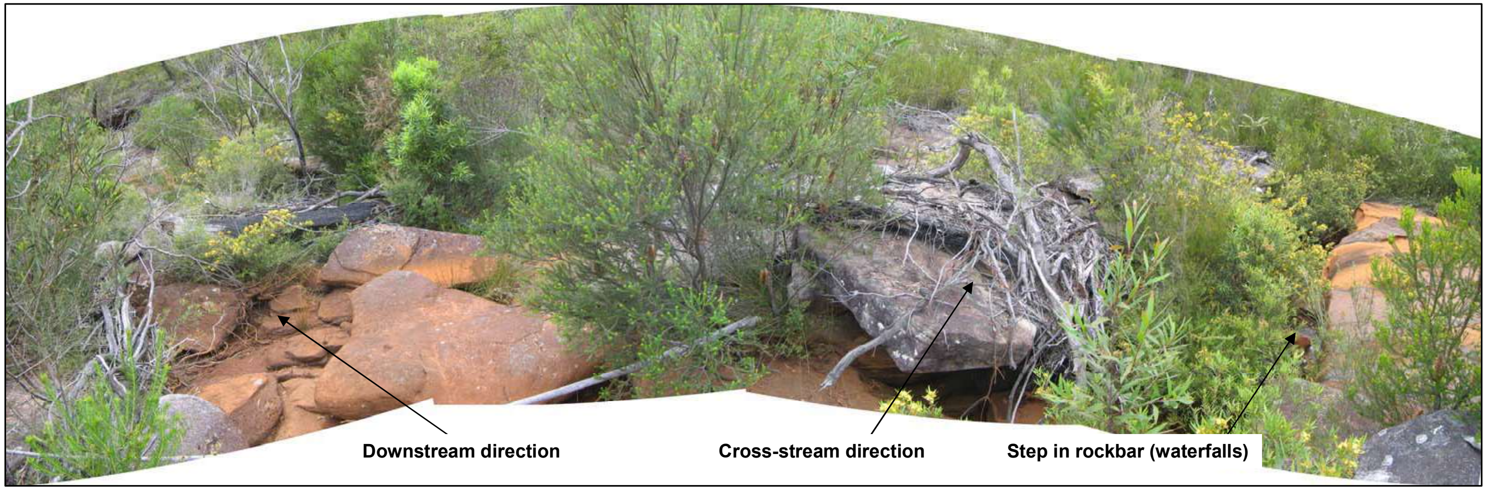
ETB-3 Downstream end of Pool ETB looking Upstream

Pool ETB notes (as at 29 Dec 2008)

- Width varies from approximately 3m to 5m
- Water depth varies from approximately 0.7m at the downstream end to 1.5m at the upstream end.
- Base of the pool could not be seen in many locations but confirmed as sandstone at some locations
- Rockbar at the downstream end of Pool ETB has an approximate 2m waterfall. Water then flows into a boulder field.

ETB-4 Downstream end of Pool ETB looking Downstream





ETB-5 From Western bank- composite from step in rockbar to Downstream direction

Photo Details

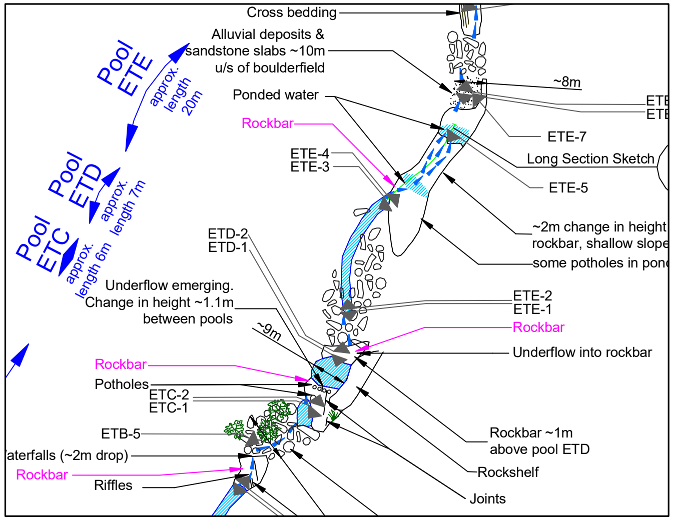
Photo ID	Easting	Northing	Bearing
ETB-1	311300	6213213	199
ETB-2	311300	6213213	19
ETB-3	311350	6213311	208
ETB-4	311350	6213311	38
ETB-5	311354	6213325	120

POOL ETC STREAM MAPPING SUMMARY

ETC-1 Downstream end of Pool ETC looking Upstream

<u>Pool ETC notes (as at 29 Dec 2008)</u>

- Width is approximately 4m and length is approximately 6m.
- Average water depth is approximately 0.4m.
- Base of the pool is sandstone.
- Rockbar at downstream end of the pool is approximately 13m wide.



ETC-2 Downstream end of Pool ETC looking Downstream

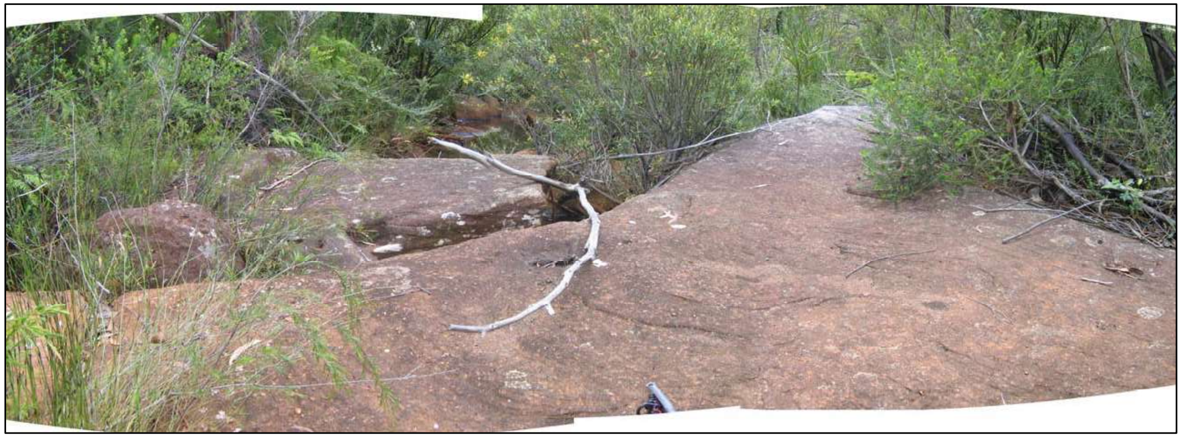
Photo Details

Photo ID	Easting	Northing	Bearing
ETC-1	311373	6213335	221
ETC-2	311373	6213335	19

POOL ETD STREAM MAPPING SUMMARY

ETD-1 Downstream end of Pool ETD looking Upstream

ETC-2 (cropped) Downstream end of Pool ETC looking Downstream showing pool ETD in the background



ETD-2 Downstream end of Pool ETD looking Downstream

Pool ETD notes (as at 29 Dec 2008)

- Pool width is approximately 9m and length is approximately 7m.
- Average water depth is 0.4m. Maximum depth is approximately 0.8m.
- Base of the pool is sandstone with alluvial deposits and scattered boulders up to approximately 1m size.
- Iron staining present on exposed sandstone.

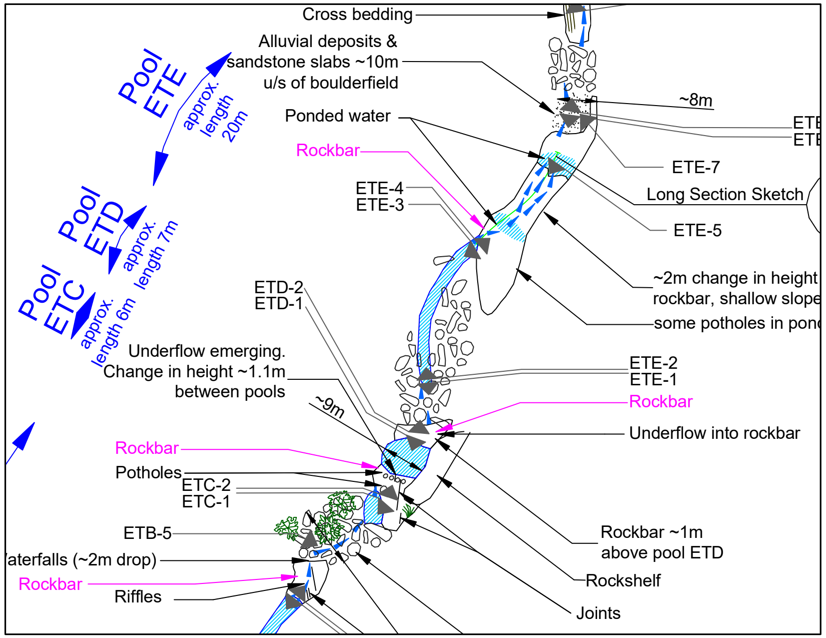


Photo Details

Photo ID	Easting	Northing	Bearing
ETC-2	311373	6213335	19
ETD-1	311380	6213351	200
ETD-2	311380	6213351	6

POOL ETE STREAM MAPPING SUMMARY

ETE-1 Upstream end of Pool ETE looking Upstream

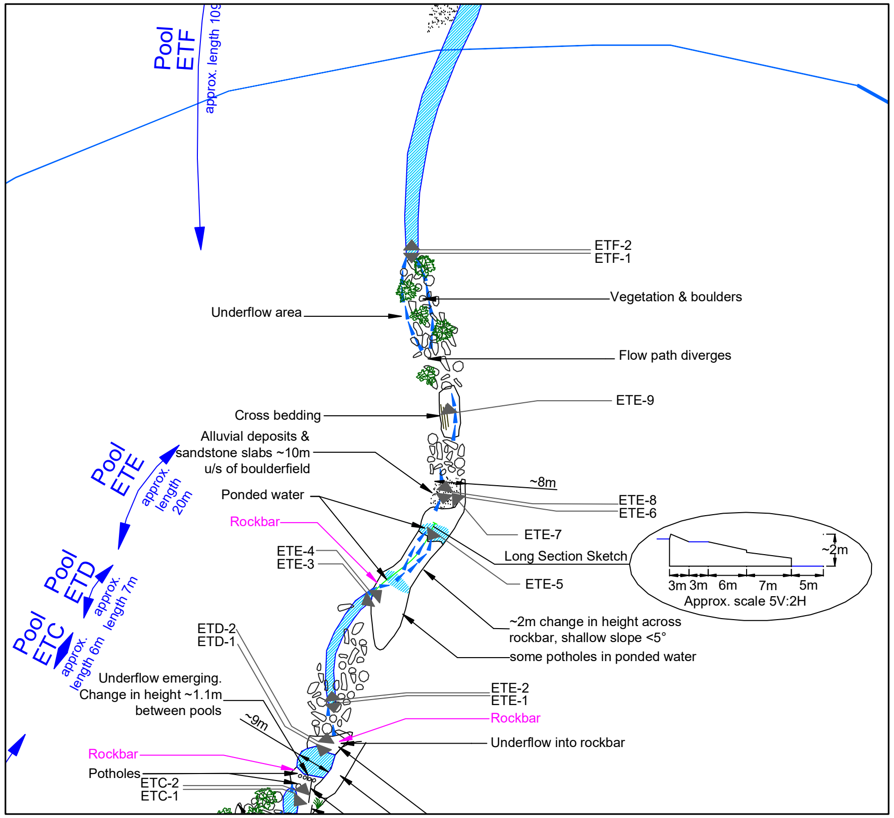
ETE-2 Upstream end of Pool ETE looking Downstream

Pool ETE notes (as at 29 Dec 2008)

- Width varies from approximately 2m to 5m
- Average water depth is approximately 0.4m. Maximum depth is approximately 0.5m.
- Base of the pool is sandstone with alluvial deposits and several boulders up to approximately 2m size.
- Thick vegetation encroaches at sides of the pool.
- Boulder field present on most of the east side of the pool.

(Notes continued on second sheet)

ETE-3 Downstream end of Pool ETE looking Upstream



ETE-4 Downstream end of Pool ETE looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETE-1	311382	6213364	174
ETE-2	311382	6213364	354
ETE-3	311395	6213396	241
ETE-4	311395	6213396	50

POOL ETE DOWNSTREAM MAPPING SUMMARY

ETE-5 On Rockbar Downstream end of Pool ETE looking Upstream

ETE-7 Sandstone slabs between Rockbar and Boulder Field

ETE-9 Exposed Sandstone within Boulder Field

Pool ETE Downstream notes (as at 29 Dec 2008)

- Water flows as shallow flow and riffles from Pool ETE over a large rockbar which has potholes and cross bedding.
- Some ponded water present on the rockbar.
- Rockbar drops approximately 2m in height as shown in sketch below.
- Sandstone is broken up into slab shaped pieces, up to approximately 150mm thickness at the downstream end of the rockbar.
- Flow continues mostly through boulder field with a small section of exposed cross bedded sandstone (Photo ETE-9).

ETE-6 Between Rockbar and Boulder Field looking Upstream

ETE-8 Between Rockbar and Boulder Field looking Downstream

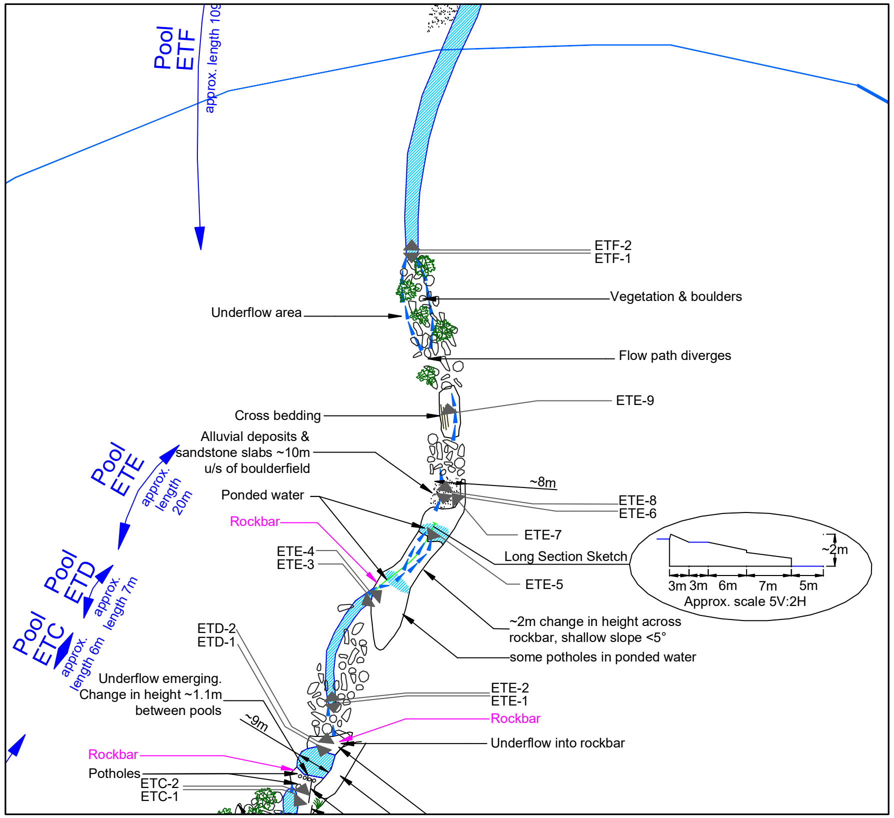


Photo Details

Photo ID	Easting	Northing	Bearing
ETE-5	311413	6213416	215
ETE-6	311418	6213429	188
ETE-7	311418	6213429	320
ETE-8	311418	6213429	8
ETE-9	311418	6213454	351

POOL ETF STREAM MAPPING SUMMARY

ETF-1 Upstream end of Pool ETF looking Upstream

ETF-2 Upstream of Pool ETF looking Downstream

ETF-3 Downstream end of Pool ETF looking Upstream

ETF-4 Downstream end of Pool ETF looking Downstream

Pool ETF notes (as at 29 Dec 2008)

- Width varies from approximately 1m at the upstream end to 5m at the downstream end, with an average of approximately 5m.
- Water depth varies from approximately 0.1m to an estimated 1 to 1.5m maximum depth with an average of approximately 0.6m.
- Alluvial deposits, scattered boulders (up to ~ 0.5m size) and vegetation debris present at the upstream end of the pool.
- Large alluvial deposit approximately 10m wide on the western bank at the downstream end of the pool.
- Base of the pool is sandstone with alluvial deposits mainly on the western side.
- Rockbar downstream of the pool is approximately 14m wide and has vegetation debris and scattered boulders on the surface.
- Pool ETG is approximately 0.6m below Pool ETF.

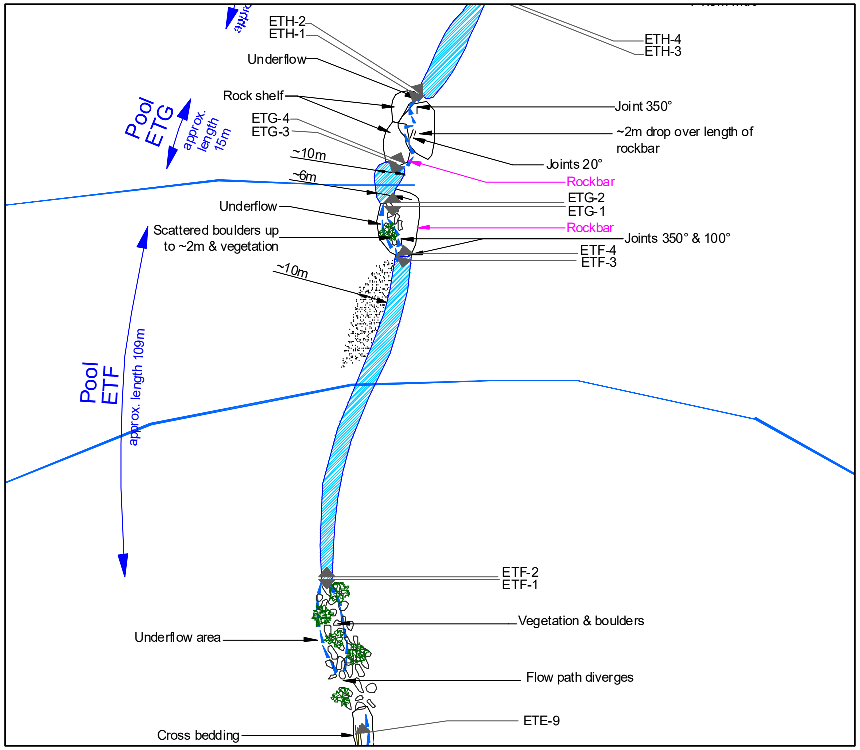


Photo Details

Photo ID	Easting	Northing	Bearing
ETF-1	311407	6213505	180
ETF-2	311407	6213505	0
ETF-3	311433	6213609	192
ETF-4	311433	6213609	350

POOL ETG STREAM MAPPING SUMMARY

ETG-1 Upstream end of Pool ETG looking Upstream

ETG-2 Upstream end of Pool ETG looking Downstream

ETG-3 Downstream end of Pool ETG looking Upstream

ETG-4 Downstream end of Pool ETG looking Downstream

Pool ETG notes (as at 29 Dec 2008)

- Width varies from approximately 6m to 10m. Length is approximately 15m.
- Base of the pool is sandstone with alluvial deposits.
- Water flows into a narrow channel at the downstream end of the pool. The channel has a maximum depth of approximately 1m.
- Cross bedding present in the rockbar downstream of the pool.
- Pool ETH is approximately 2m below Pool ETG.

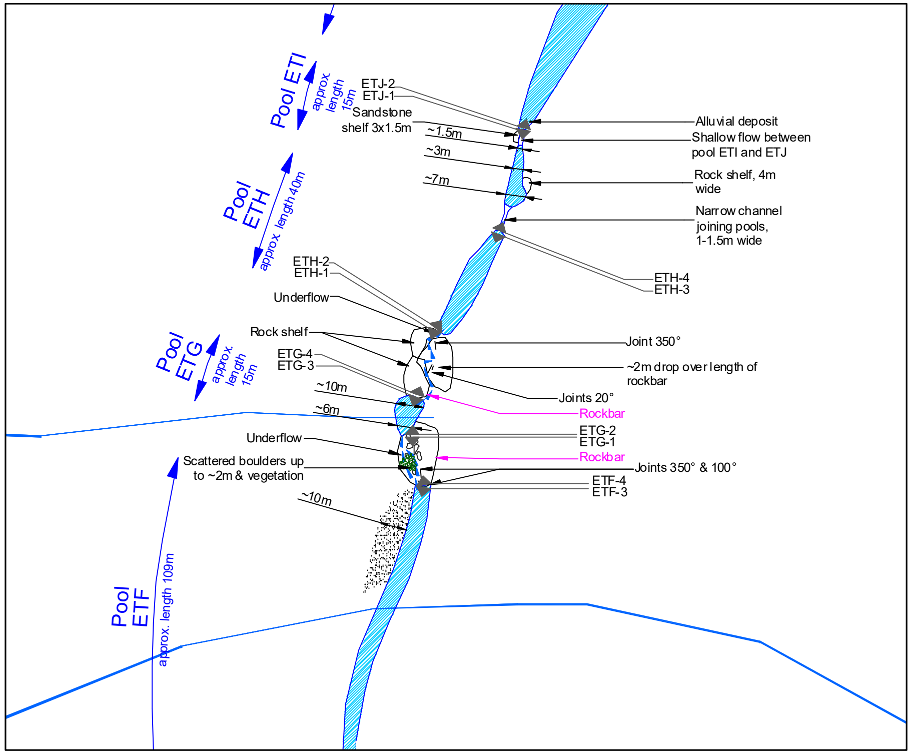


Photo Details

Photo ID	Easting	Northing	Bearing
ETG-1	311429	6213626	180
ETG-2	311429	6213626	0
ETG-3	311436	6213636	202
ETG-4	311436	6213636	22

POOLS ETH & ETI STREAM MAPPING SUMMARY

ETH-1 Upstream end of Pool ETH looking Upstream

ETH-2 Upstream end of Pool ETH looking Downstream

ETH-3 Downstream end of Pool ETH looking Upstream

ETH-4 Downstream end of Pool ETH looking Downstream

Pools ETH and ETI notes (as at 29 Dec 2008)

- Width varies from approximately 1m to 6m with an average of approximately 5m.
- Average water depth is approximately 1.5m.
- Base appears to be mainly sandstone and alluvial deposits however much of the base was not visible.
- Water flows into a narrow channel approximately 1m to 1.5m wide and 0.5m deep at the downstream end of the pool.
- The channel is approximately 15m to 20m long and joins into Pool ETI.
- Pool ETI width varies from approximately 1.5m to 7m with an average of approximately 3m.
- Base of Pool ETI is sanstone and alluvial deposits.

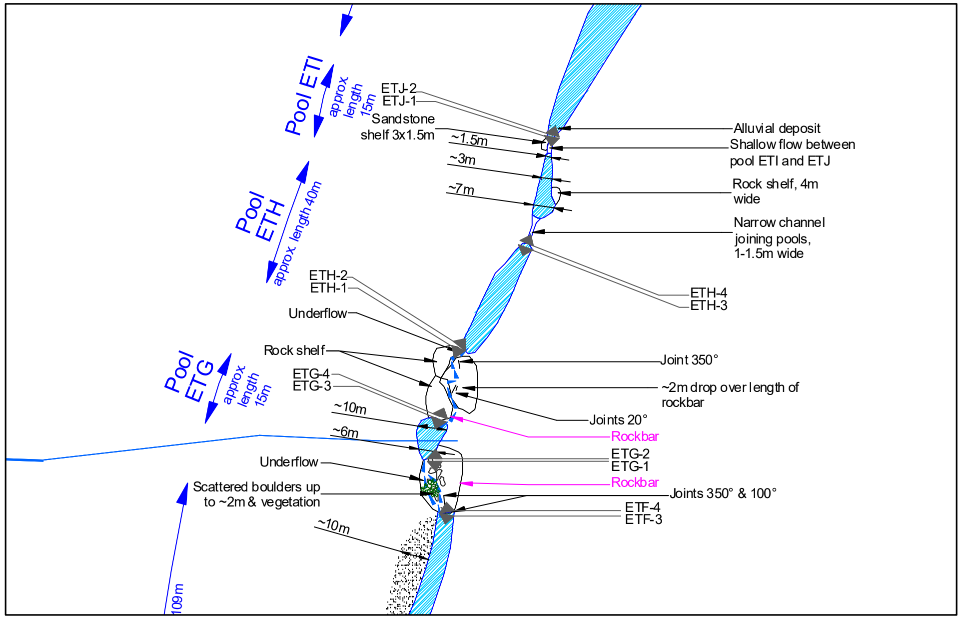


Photo Details

Photo ID	Easting	Northing	Bearing
ETH-1	311436	6213663	200
ETH-2	311436	6213663	38
ETH-3	311458	6213695	201
ETH-4	311458	6213695	21

POOL ETJ STREAM MAPPING SUMMARY

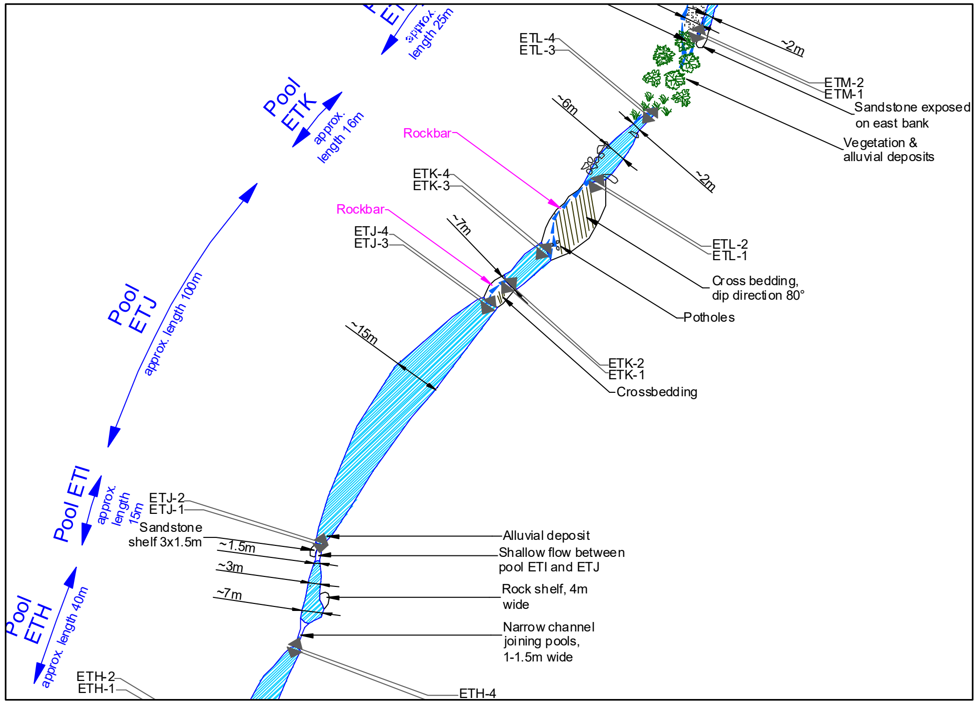
ETJ-1 Upstream end of Pool ETJ looking Upstream

ETJ-2 Upstream end of Pool ETJ looking Downstream

Pool ETJ notes (as at 29 Dec 2008)

- Width varies from approximately 1.5m to 15m with an average of approximately 7m.
- Water depth varies from approximately 1m to approximately 1.5m
- Base of the pool is sandstone with alluvial deposits and boulders up to approximately 0.5m size.
- Rockbar downstream of the pool is approximately 7m wide and 9m long.

ETJ-3 Downstream end of Pool ETJ looking Upstream



ETJ-4 Downstream end of Pool ETJ looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETJ-1	311466	6213731	189
ETJ-2	311466	6213731	17
ETJ-3	311520	6213810	217
ETJ-4	311520	6213810	37

POOL ETK STREAM MAPPING SUMMARY

ETK-1 Upstream end of Pool ETK looking Upstream

ETK-2 Upstream end of Pool ETK looking Downstream

ETK-3 Downstream end of Pool ETK looking Upstream

ETK-4 Downstream of Pool ETK looking Downstream

Pool ETK notes (as at 29 Dec 2008)

- Width varies from approximately 7m to 9m. Length is approximately 16m.
- Average water depth is approximately 0.7m.
- Base of the pool is sandstone and alluvial deposits.
- Rockbar downstream of the pool has potholes and weathered cross bedding.
- Water flows along the western side of the rockbar.
- Pool ETL is approximately 1.6m below Pool ETK.

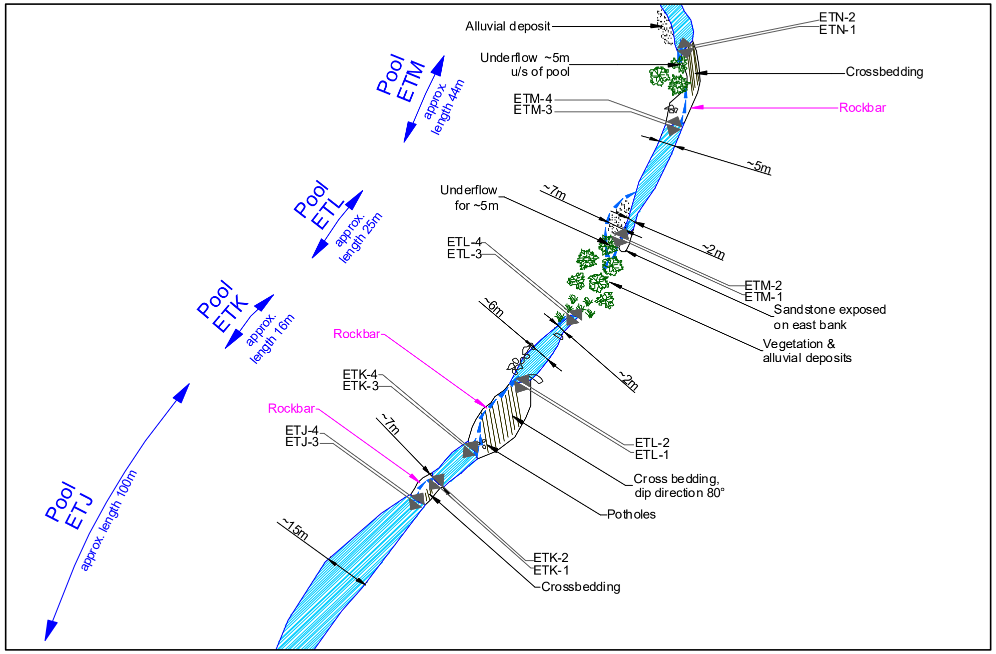


Photo Details

Photo ID	Easting	Northing	Bearing
ETK-1	311526	6213817	217
ETK-2	311526	6213817	37
ETK-3	311538	6213829	217
ETK-4	311538	6213829	37

POOL ETL STREAM MAPPING SUMMARY

ETL-1 Upstream end of Pool ETL looking Upstream

ETL-2 Upstream end of Pool ETL looking Downstream

ETL-3 Downstream end of Pool ETL looking Upstream

ETL-4 Downstream of Pool ETL looking Downstream

Pool ETL notes (as at 29 Dec 2008)

- Width varies from approximately 2m to 6m.
- Average water depth is approximately 0.5m.
- Base of the pool is sandstone with alluvial deposits and boulders up to approximately 1m size.
- Pool flows into vegetated area with alluvial deposits (difficult access in this area to confirm flow path).
- Flow diverges approximately halfway between Pools ETL and ETM.

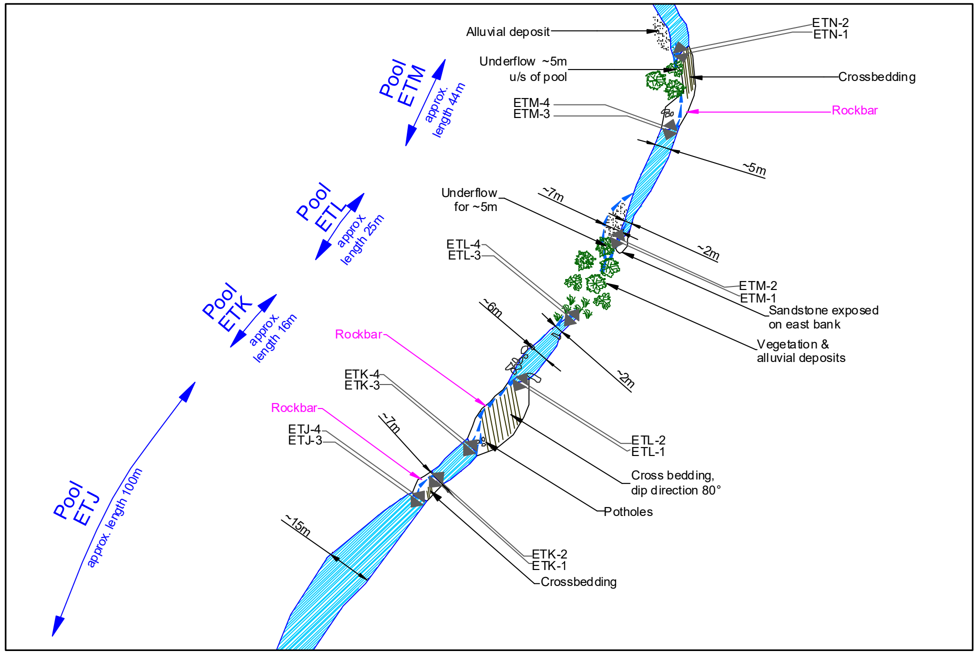


Photo Details

Photo ID	Easting	Northing	Bearing
ETL-1	311555	6213852	213
ETL-2	311555	6213852	33
ETL-3	311572	6213875	220
ETL-4	311572	6213875	40

POOL ETM STREAM MAPPING SUMMARY

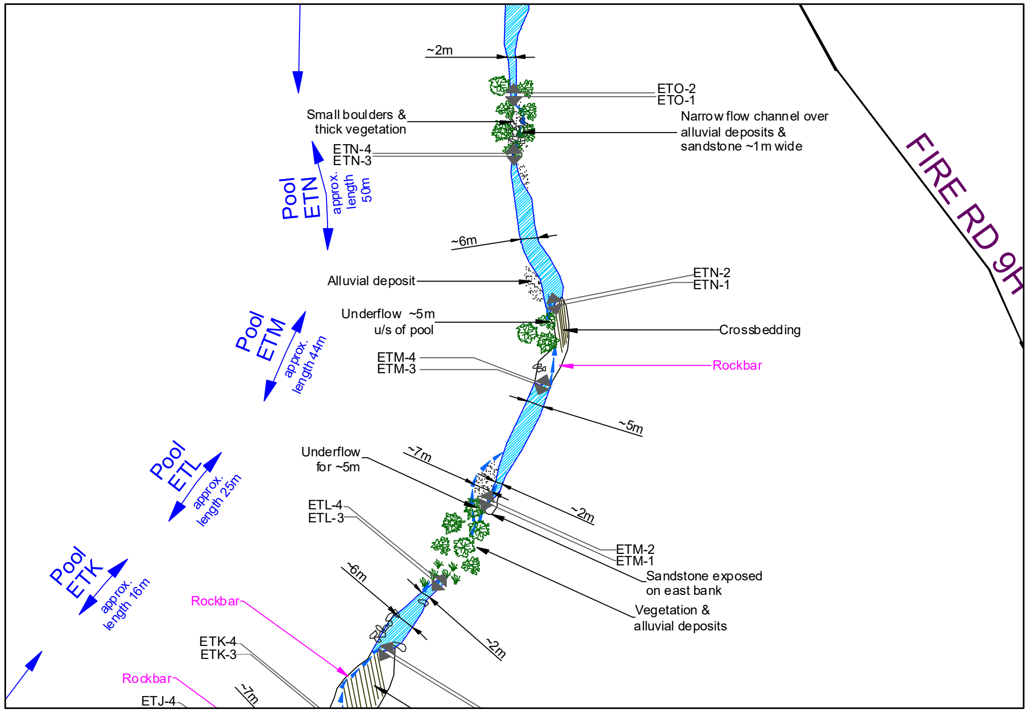
ETM-1 Upstream end of Pool ETM looking Upstream

ETM-2 Upstream end of Pool ETM looking Downstream

Pool ETM notes (as at 29 Dec 2008)

- Width varies from approximately 2m to 5m.
- Base of the pool is sandstone with several boulders up to approximately 1m size.
- Rockbar downstream of the pool is approximately 9m wide.
- Cross bedding present in the rockbar.
- Some underflow at the downstream end of the rockbar.

ETM-3 Downstream end of Pool ETM looking Upstream



ETM-4 Downstream of Pool ETM looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETM-1	311587	6213902	205
ETM-2	311587	6213902	25
ETM-3	311605	6213941	201
ETM-4	311605	6213941	21

POOL ETN STREAM MAPPING SUMMARY

ETN-1 Upstream end of Pool ETN looking Upstream

ETN-2 Upstream end of Pool ETN looking Downstream

ETN-3 Downstream end of Pool ETN looking Upstream

ETN-4 Downstream end of Pool ETN looking Downstream

<u>Pool ETN notes (as at 29 Dec 2008)</u>

- Width varies from approximately 3m to 6m
- Average water depth is approximately 0.3m. Maximum depth is approximately 1m.
- Base of the pool is sandstone with alluvial deposits and cross bedding.
- Rockbar at upstream end of the pool is approximately 1m above Pool ETN on the eastern side and approximately 0.3m above the pool on the western side.

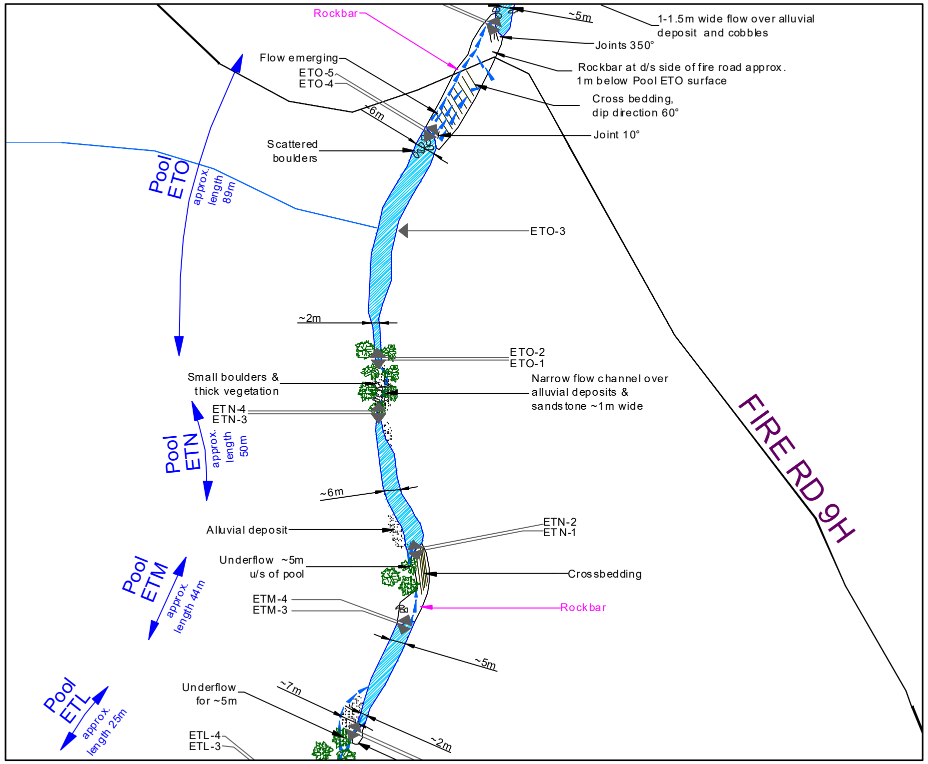


Photo Details

Photo ID	Easting	Northing	Bearing
ETN-1	311608	6213968	168
ETN-2	311608	6213968	348
ETN-3	311595	6214018	180
ETN-4	311595	6214018	0

POOL ETO STREAM MAPPING SUMMARY

ETO-1 Upstream end of Pool ETO looking Upstream

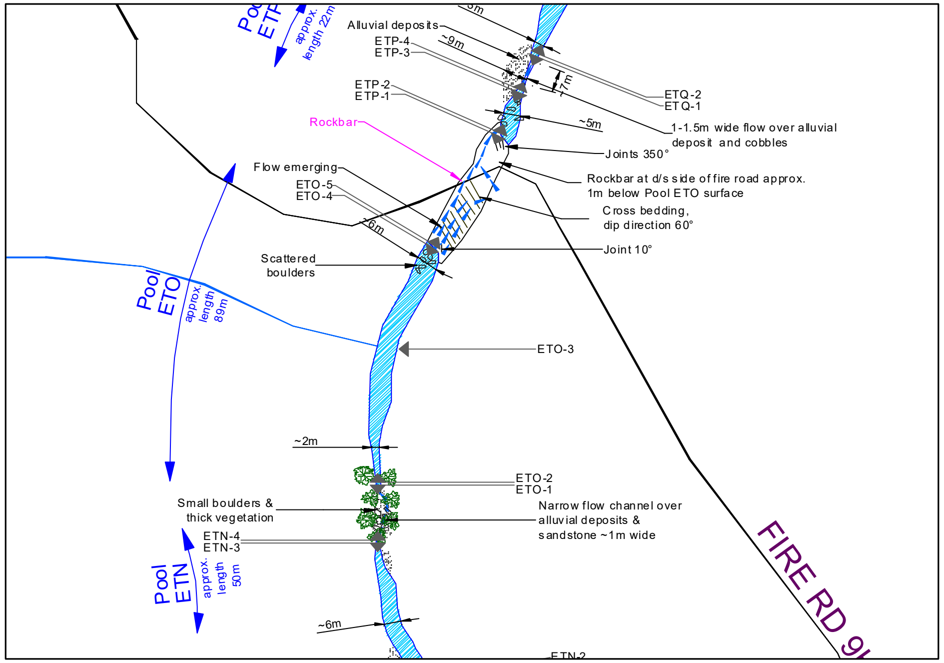
ETO- 2 Upstream end of Pool ETO looking Downstream

ETO-3 Tributary approximately midway along Pool ETO

Pool ETO notes (as at 29 Dec 2008)

- Width varies from approximately 2m to 6m.
- Maximum water depth is approximately 1m at the downstream end of the pool.
- Base of the pool is sandstone with minor alluvial deposits and scattered boulders up to approximately 1m size at the downstream end.
- Rockbar downstream of the pool is approximately 5m wide.
- Water flows over most of the rockbar width at the upstream end and along the western side at the downstream end. Cross bedding is present.

ETO-4 Downstream end of Pool ETO looking Upstream



ETO-5 Downstream end of Pool ETO looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETO-1	311596	6214037	180
ETO-2	311596	6214037	0
ETO-3	311603	6214084	270
ETO-4	311613	6214119	212
ETO-5	311613	6214119	32

POOL ETP STREAM MAPPING SUMMARY

ETP-1 Upstream end of Pool ETP looking Upstream

ETP-2 Upstream end of Pool ETP looking Downstream

ETP-3 Downstream end of Pool ETP looking Upstream

ETP-4 Downstream end of Pool ETP looking Downstream

Pool ETP notes (as at 29 Dec 2008)

- Width varies from approximately 3m to 5m
- Average water depth is approximately 0.3m.
- Base of the pool is sandstone with alluvial deposits and boulders up to approximately 0.5m size.
- Cross bedding is present in the base of the pool.

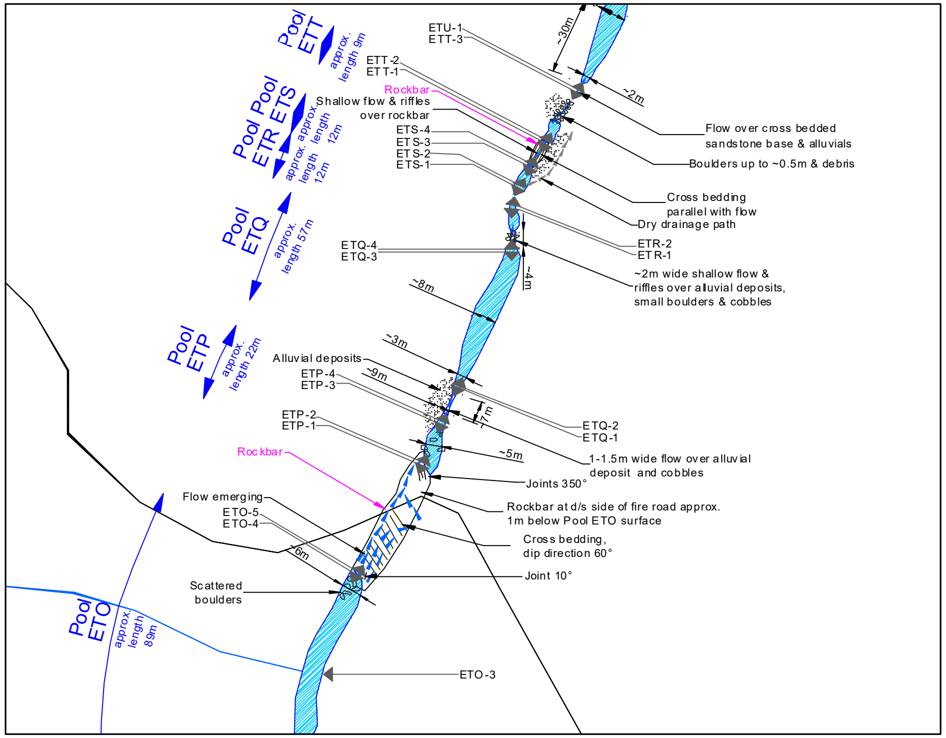


Photo Details

Photo ID	Easting	Northing	Bearing
ETP-1	311634	6214158	205
ETP-2	311634	6214158	25
ETP-3	311641	6214173	205
ETP-4	311641	6214173	25

POOL ETQ STREAM MAPPING SUMMARY

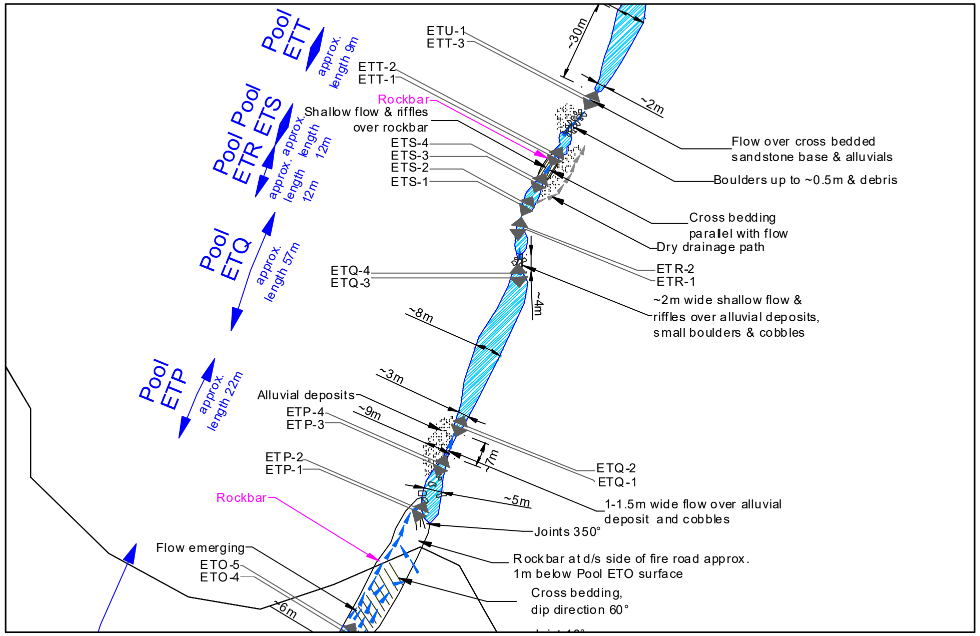
ETQ-1 Upstream end of Pool ETQ looking Upstream

ETQ-2 Upstream end of Pool ETQ looking Downstream

Pool ETQ notes (as at 29 Dec 2008)

- Width varies from approximately 3m to 8m
- Water depth varies from approximately 0.2m to approximately 1m. Average water depth is approximately 0.6m.
- Base of the pool is sandstone with alluvial deposits. Several sandstone cobbles at the upstream end of the pool.
- Water flows from Pool ETQ over alluvial deposits, small boulders and cobbles.

ETQ-3 Downstream end of Pool ETQ looking Upstream



ETQ-4 Downstream end of Pool ETQ looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETQ-1	311648	6214186	205
ETQ-2	311648	6214186	25
ETQ-3	311666	6214234	180
ETQ-4	311666	6214234	0

POOL ETR STREAM MAPPING SUMMARY

ETR-1 Downstream end of Pool ETR looking Upstream

ETR-2 Downstream end of Pool ETR looking Downstream

<u>Pool ETR notes (as at 29 Dec 2008)</u>

- Width varies from approximately 2m to 4m
- Average water depth is approximately 0.6m.
- Base of the pool is sandstone but is mostly covered with alluvial deposits, boulders and cobbles.
- Flow continues over exposed sandstone to Pool ETS.

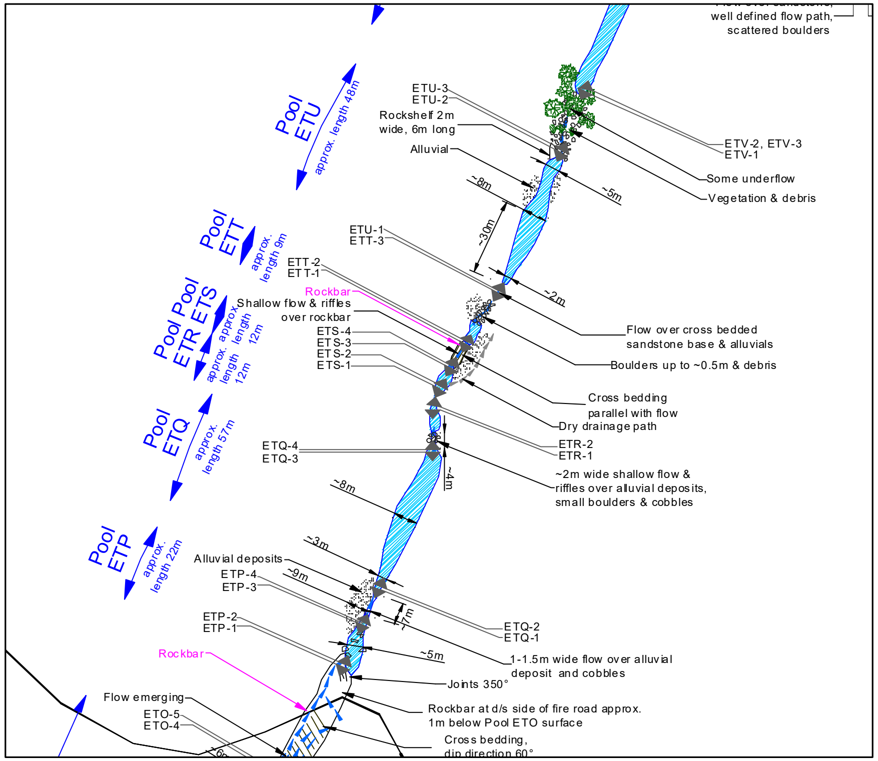


Photo Details

Photo ID	Easting	Northing	Bearing
ETR-1	311666	6214249	180
ETR-2	311666	6214249	10

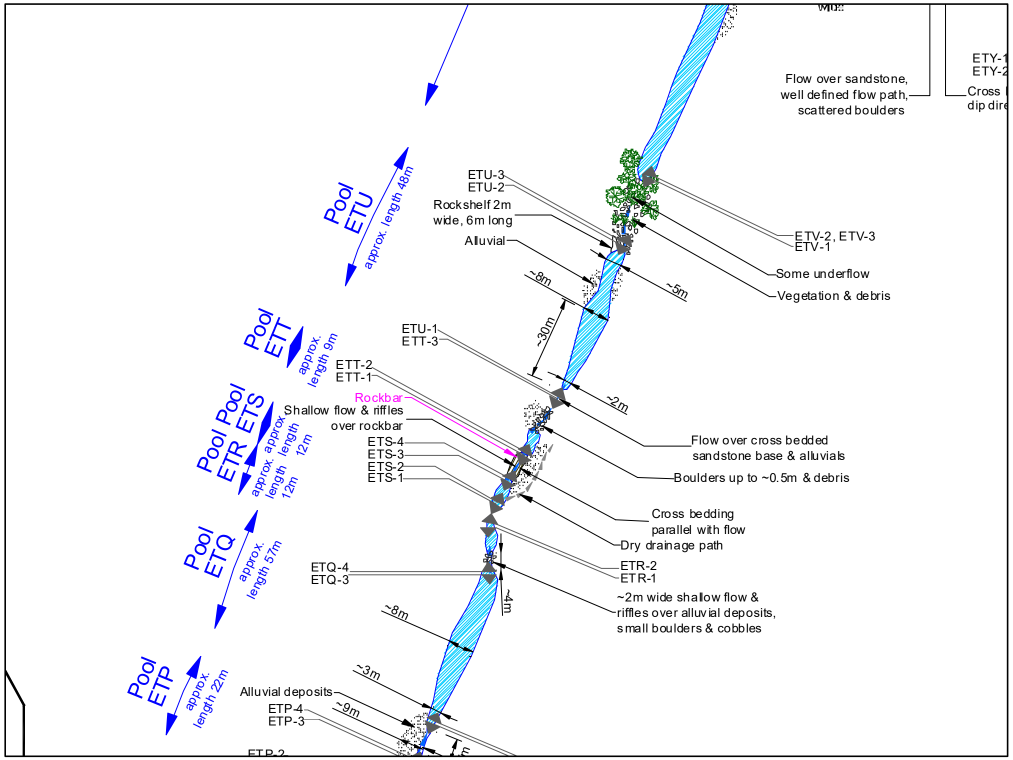
POOL ETS STREAM MAPPING SUMMARY

ETS-1 Upstream end of Pool ETS looking Upstream

ETS-2 Upstream end of Pool ETS looking Downstream

Pool ETS notes (as at 29 Dec 2008)
- Width varies from approximately 2m to 4m
- Water depth varies from approximately 0.2m to 0.6m. Average water depth is approximately 0.3m
- Large alluvial deposit on eastern side of the pool. A dry drainage path is present through the alluvial deposits.
- Pool base is sandstone with alluvial deposits, cobbles and boulders.
- Water flows from the pool as riffles over crossbedded sandstone rockbar.

ETS-3 Downstream end of Pool ETS looking Upstream



ETS-4 Downstream end of Pool ETS looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETS-1	311668	6214256	209
ETS-2	311668	6214256	29
ETS-3	311672	6214264	209
ETS-4	311672	6214264	29

POOL ETT STREAM MAPPING SUMMARY

ETT-1 Upstream end of Pool ETT looking Upstream

ETT-2 Upstream end of Pool ETT looking Downstream

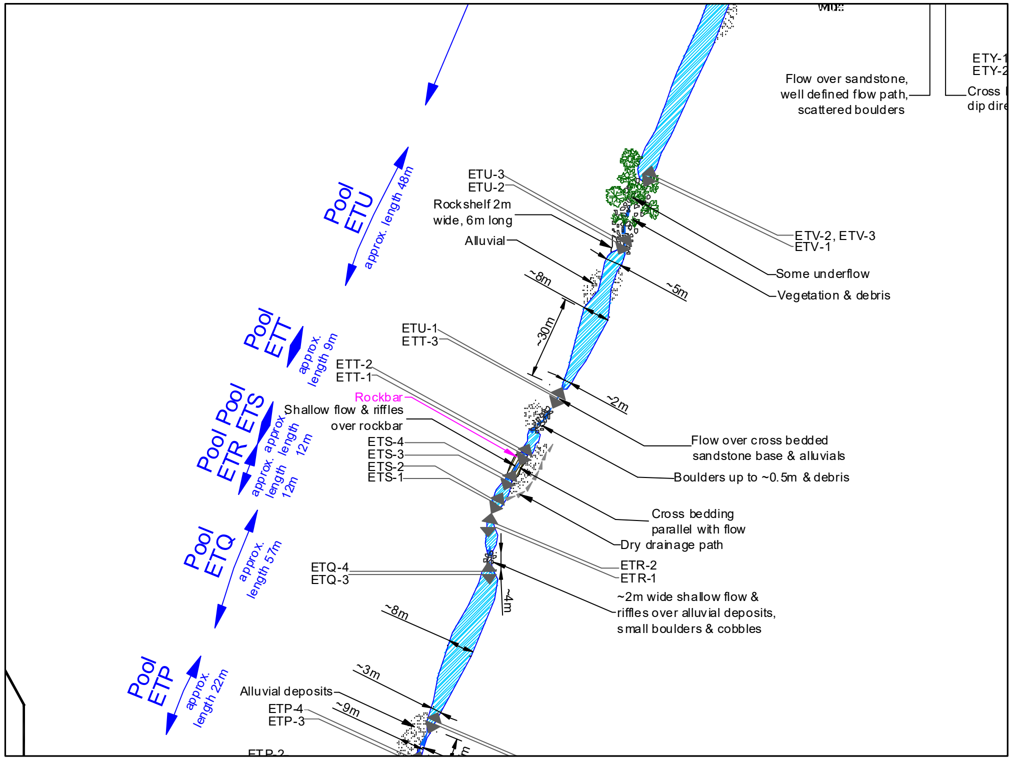
<u>Pool ETT notes (as at 29 Dec 2008)</u>

- Width varies from approximately 2m to 4m
- Water depth varies from approximately 0.2m to 0.6m with an average of approximately 0.3m.
- Base of the pool is sandstone with allluvial deposits, boulders and cobbles.
- Large alluvial deposit on eastern side of the pool. A dry drainage path is present through the alluvial deposits.
- Cross bedding present.
- Downstream of the pool, water flows over cross bedded sandstone and alluvial deposits.
- Boulders up to about 0.5m size and debris are present at the downstream end of the pool.

Photo Details

Photo ID	Easting	Northing	Bearing
ETT-1	311614	6214277	209
ETT-2	311614	6214277	29
ETT-3	311689	6214291	209

ETT-3 Upstream end of Pool ETU looking Upstream



POOL ETU STREAM MAPPING SUMMARY

ETT-3 Upstream end of Pool ETU looking Upstream

ETU- 1 Upstream end of Pool ETU looking Downstream

ETU-2 Downstream end of Pool ETU looking Upstream

ETU-3 Downstream end of Pool ETU looking Downstream

<u>Pool ETU notes (as at 29 Dec 2008)</u>

- Width varies from approximately 2m to 8m.
- Water depth varies up to a maximum of approximately 1.5m to 2m.
- Base of the pool is sandstone with alluvial deposits and boulders.
- Thick vegetation and debris present downstream of the pool.
- Some underflow between Pools ETU and ETV.

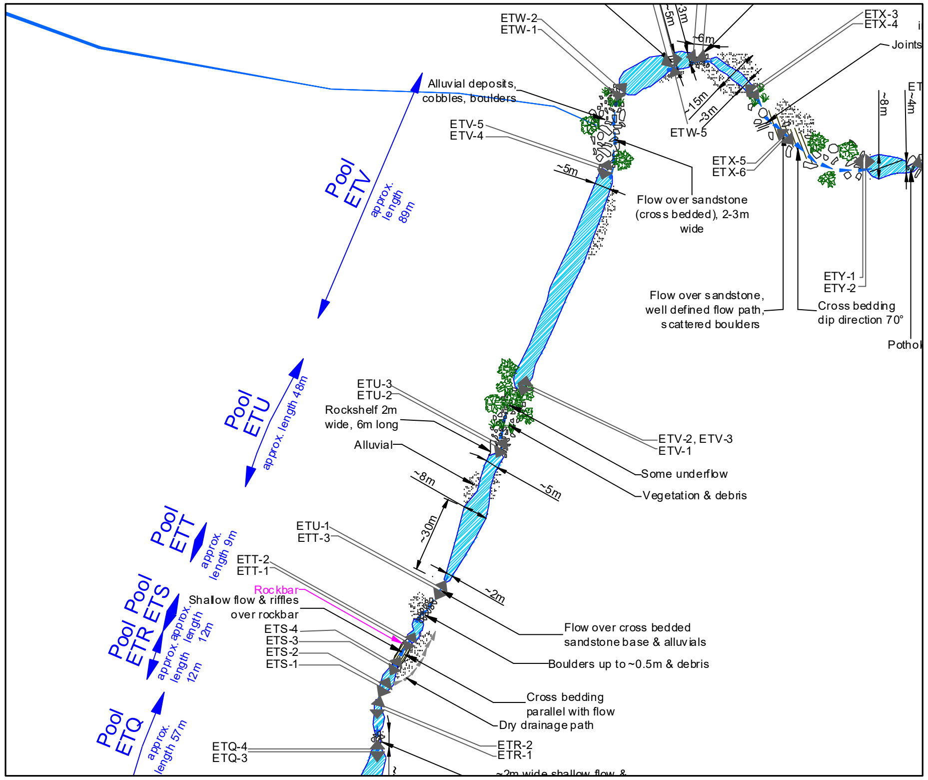


Photo Details

Photo ID	Easting	Northing	Bearing
ETT-3	311689	6214291	209
ETU-1	311689	6214291	29
ETU-2	311709	6214340	209
ETU-3	311709	6214340	29

POOL ETV STREAM MAPPING SUMMARY

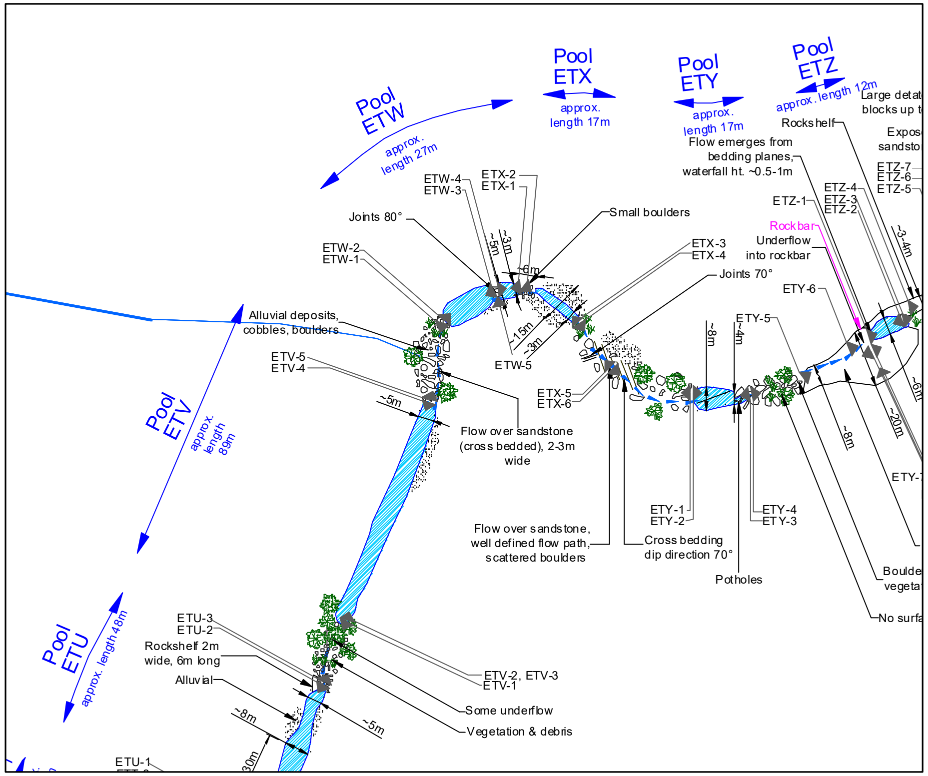
ETV-1 Upstream end of Pool ETV looking Upstream

ETV-2 and ETV-3 Upstream end of Pool ETV looking Downstream

Pool ETV notes (as at 29 Dec 2008)

- Average width is approximately 5m.
- Water depth varies from approximately 0.3m to 1m. Average water depth is approximately 0.6m over most of the pool. A length of approximately 20m at the downstream end of the pool has an average depth of approximately 0.3m.
- Base of the pool is sandstone with alluvial deposits and boulders up to approximately 1.5m size.
- Flow out of the pool is over cross bedded sandstone.
- Most of the surface between Pools ETV and ETW comprises alluvial deposits, cobbles and boulders.

ETV-4 Downstream end of Pool ETV looking Upstream



ETV-5 Downstream end of Pool ETV looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETV-1	311717	6214361	206
ETV-2	311717	6214361	14
ETV-3	311717	6214361	14
ETV-4	311745	6214437	199
ETV-5	311745	6214437	19

POOL ETW STREAM MAPPING SUMMARY

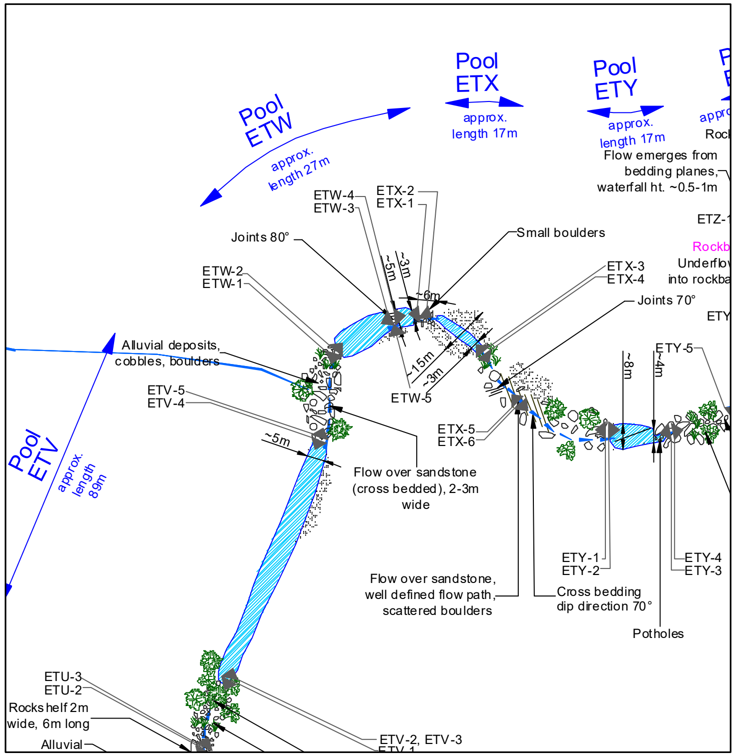
ETW-1 Upstream end of Pool ETW looking Upstream

ETW-2 Upstream end of Pool ETW looking Downstream

Pool ETW notes (as at 29 Dec 2008)

- Width varies from approximately 3m to 5m.
- Water depth varies up to a maximum of approximately 1.5m to 2m.
- Base of the pool is sandstone with alluvial deposits and several boulders up to approximately 1m size.
- A small rockbar almost separates a smaller section of the pool downstream. The rockbar is approximately 5m wide and 1m to 3m long. Water flows over the rockbar across eroded joints.
- The smaller section of pool downstream of the rockbar is approximately 0.1m to 0.6m deep with an average of approximately 0.4m.

ETW-3 Approximately 8m from Downstream end of Pool ETW looking Upstream



ETW-4 Approximately 8m from Downstream end of Pool ETW looking Downstream

ETW-5 Small Rock bar at downstream end of Pool ETW

Photo Details

Photo ID	Easting	Northing	Bearing
ETW-1	311750	6214465	196
ETW-2	311750	6214465	41
ETW-3	311769	6214476	263
ETW-4	311769	6214476	83
ETW-5	311769	6214476	310

POOL ETX STREAM MAPPING SUMMARY

ETX-1 Upstream end of Pool ETX looking Upstream to Pool ETW

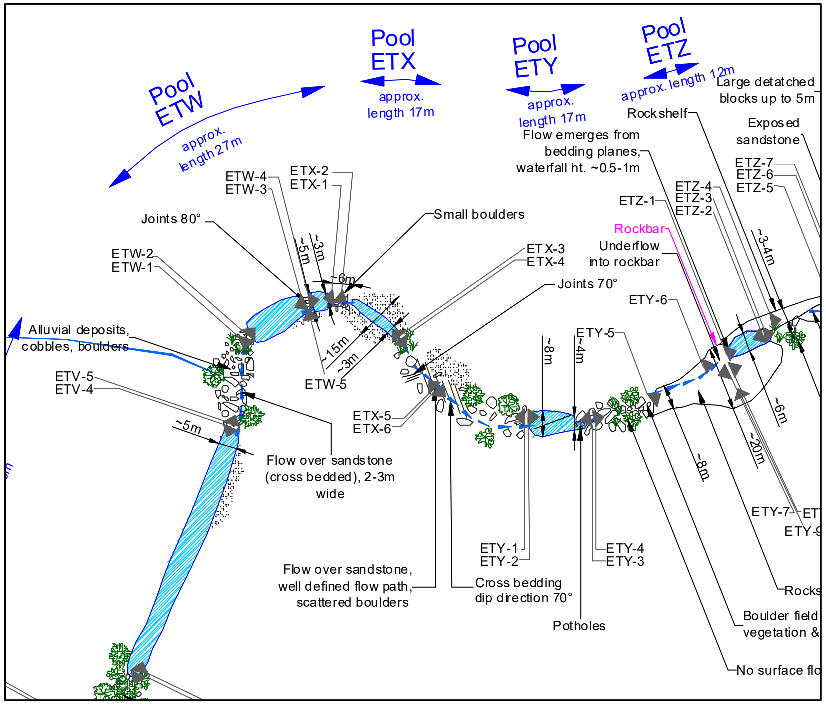
ETX-2 Upstream end of Pool ETX looking Downstream

ETX-3 Downstream end of Pool ETX looking Upstream

ETX-4 Downstream end of Pool ETX looking Downstream

Pool ETX notes (as at 29 Dec 2008)

- Width is an average of approximately 3m.
- The pool is located between alluvial deposits with a total width of approximately 15m.
- Water depth varies from approximately 0.1m to 0.5m with an average of approximately 0.3m.
- Base of the pool is sandstone with alluvial deposits, cobbles and boulders.



ETX-5 In Boulder Field looking Upstream

ETX-6 In Boulder Field looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETX-1	311776	6214477	264
ETX-2	311776	6214477	125
ETX-3	311797	6214464	316
ETX-4	311797	6214464	145
ETX-5	311808	6214449	315
ETX-6	311808	6214449	135

POOL ETY STREAM MAPPING SUMMARY

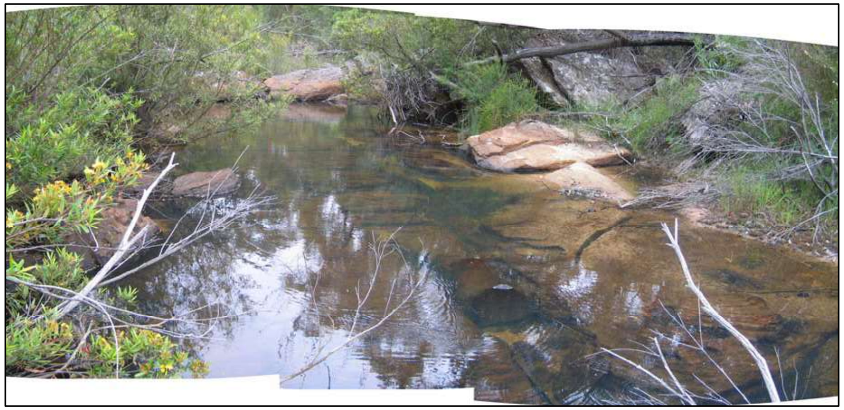
ETY-3 Downstream of Pool ETY looking Upstream

<u>Pool ETY notes (as at 29 Dec 2008)</u>

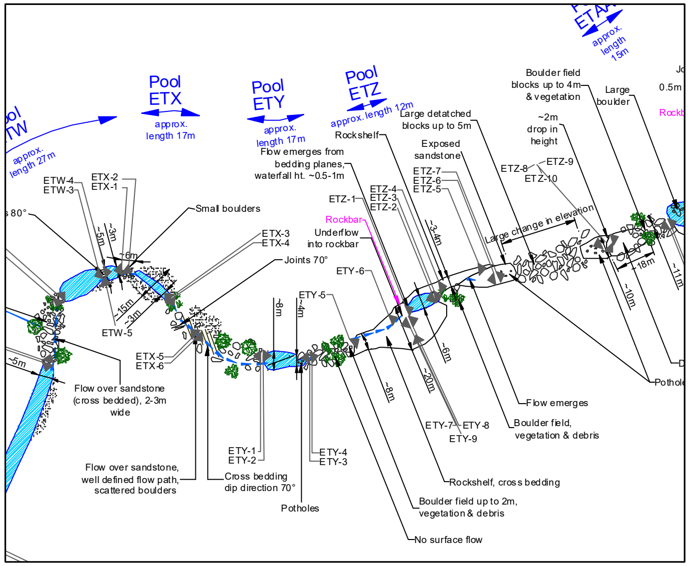
- Width varies from approximately 4m to 8m.
- Water depth varies from approximately 0.1m to 0.5m with an average of approximately 0.3m.
- Base of the pool is cross bedded sandstone with alluvial deposits, some potholes and boulders.

(notes for downstream section continued on following sheet)

ETY-1 Upstream end of Pool ETY looking Upstream



ETY-2 Upstream end of Pool ETY looking Downstream



ETY-4 Downstream of Pool ETY looking Downstream

ETY-5 Rockbar Downstream of Pool ETY looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETY-1	311836	6214440	270
ETY-2	311836	6214440	90
ETY-3	311856	6214440	259
ETY-4	311856	6214440	79

POOL ETY DOWNSTREAM MAPPING SUMMARY

ETY-5 On Rockbar Downstream of Pool ETY looking Downstream

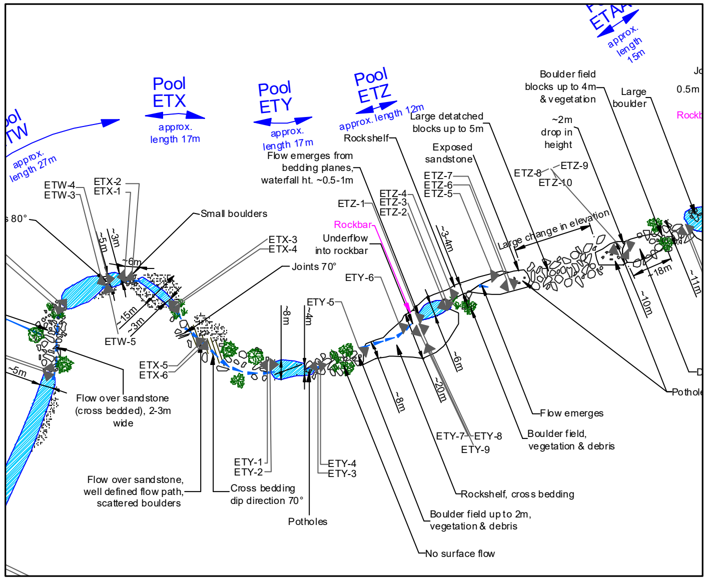
ETY-7 Midpoint on Rockbar Downstream of Pool ETY looking Upstream

<u>Pool ETY Downstream notes (as at 29 Dec 2008)</u>

- Water from Pool ETY enters a boulder field with boulders up to approximately 2m size, vegetation and debris.
- No surface flow was observed in the boulder field.
- Flow emerges onto a rock shelf approximately 8m to 20m wide. Cross bedding present.
- Flow emerges from bedding planes and enters Pool ETZ via a waterfall 0.5m to 1m high.
- Pool ETZ estimated to be approximately 4m below Pool ETY.

ETY-6 Underflow on Rockbar Downstream of Pool ETY

ETY-8 Midpoint on Rockbar Downstream of Pool ETY looking Downstream



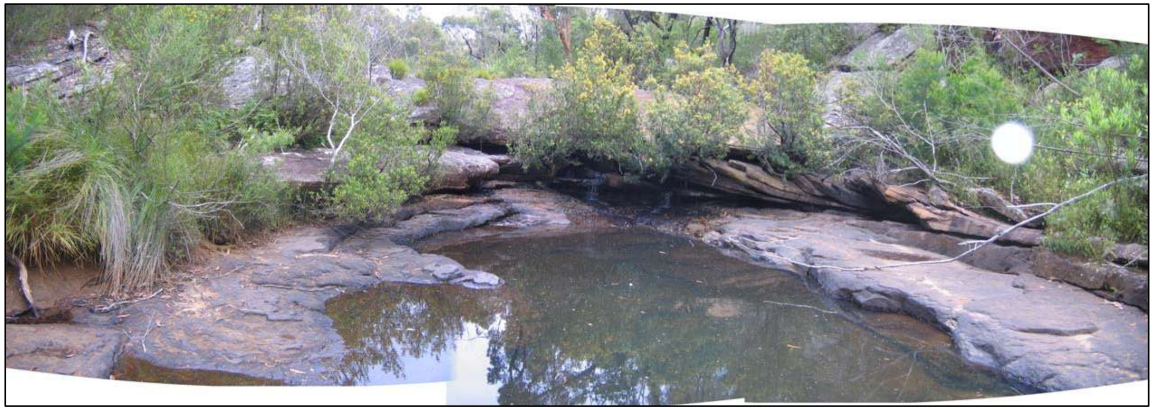
ETY-9 Midpoint on Rockbar Downstream of Pool ETY looking toward the West bank

Photo Details

Photo ID	Easting	Northing	Bearing
ETY-5	311874	6214446	54
ETY-6	311890	6214455	69
ETY-7	311898	6214454	245
ETY-8	311898	6214454	65
ETY-9	311902	6214446	335

POOL ETZ STREAM MAPPING SUMMARY

ETZ-1 Upstream end of Pool ETZ looking Downstream

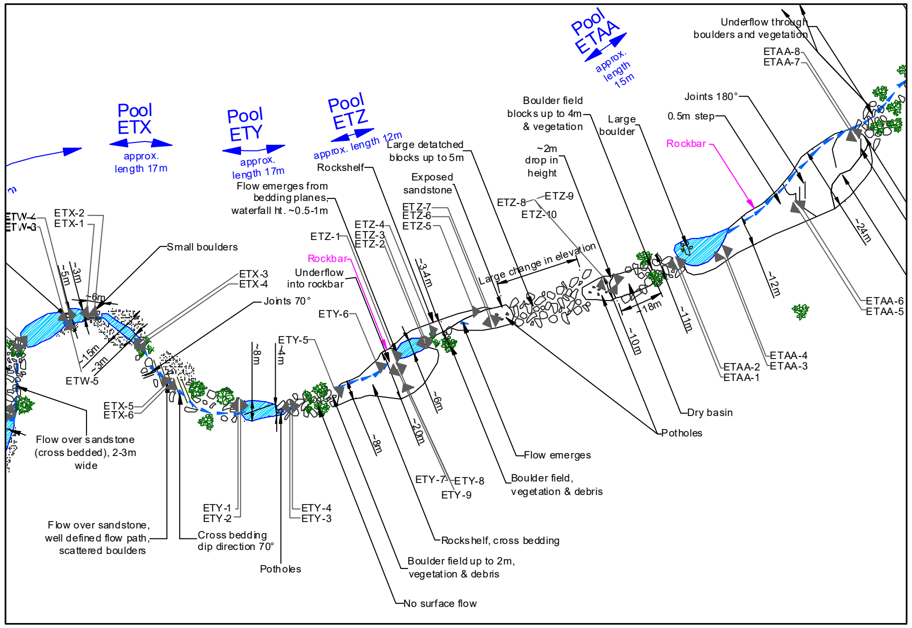


ETZ-2 Downstream end of Pool ETZ looking Upstream

Pool ETZ notes (as at 29 Dec 2008)

- Width varies from approximately 4m to 6m.
- Maximum water depth is approximately 0.6m.
- Base of the pool is sandstone with minor alluvial deposits.

(Notes continued on second sheet)



ETZ-3 Downstream end of Pool ETZ looking Downstream

ETZ-4 Exposed sandstone at Downstream end of Pool ETZ looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETZ-1	311896	6214459	69
ETZ-2	311910	6214468	248
ETZ-3	311909	6214465	79
ETZ-4	311911	6214470	79

POOL ETZ DOWNSTREAM MAPPING SUMMARY

ETZ-5 Exposed sandstone Downstream end of Pool ETZ looking Downstream

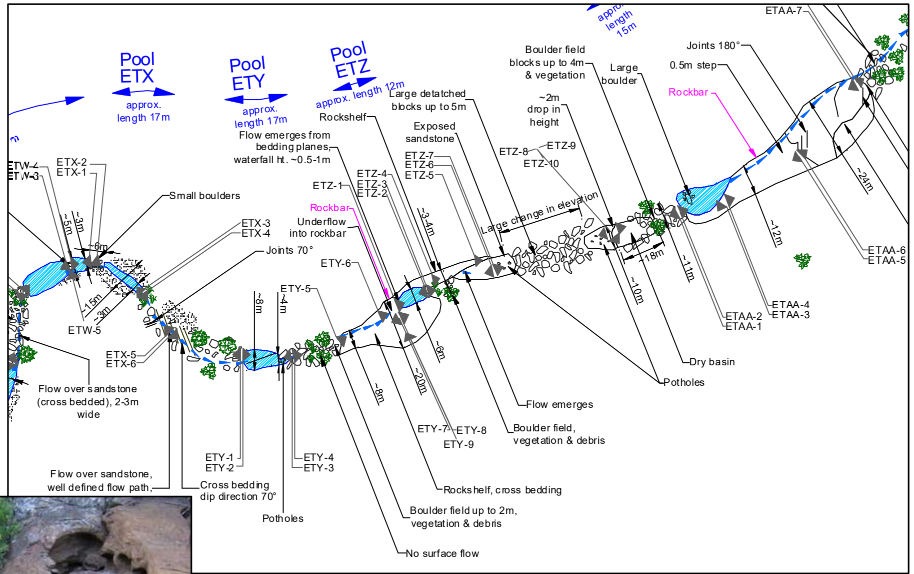
ETZ-6 Flow emerging Downstream end of Pool ETZ

ETZ-7 Exposed sandstone Downstream end of Pool ETZ looking Downstream

Pool ETZ downstream notes (as at 29 Dec 2008)

- Rockbar downstream of Pool ETZ is approximately 3m to 4m wide.
- Boulder field located on the south eastern side of the rockbar.
- Water emerges approximately 15m downstream of Pool ETZ
- There is a large change in vertical height over the boulder field located between exposed sandstone (could not be measured on site).
- Several potholes observed in exposed sandstone.
- A possible dry pool is located close to the upstream end of Pool ETAA.
- Boulder fields have sandstone blocks up to approximately 4m to 5m size.

ETZ-8 Exposed sandstone with potholes looking upstream to boulder field



ETZ-9 Possible dry pool looking Downstream

ETZ-10 Cracking at step down in sandstone

Photo Details

Photo ID	Easting	Northing	Bearing
ETZ-5	311927	6214477	80
ETZ-6	311935	6214473	259
ETZ-7	311935	6214473	68
ETZ-8	311981	6214488	250
ETZ-9	311981	6214488	70
ETZ-10	311981	6214488	140

POOL ETAA STREAM MAPPING SUMMARY

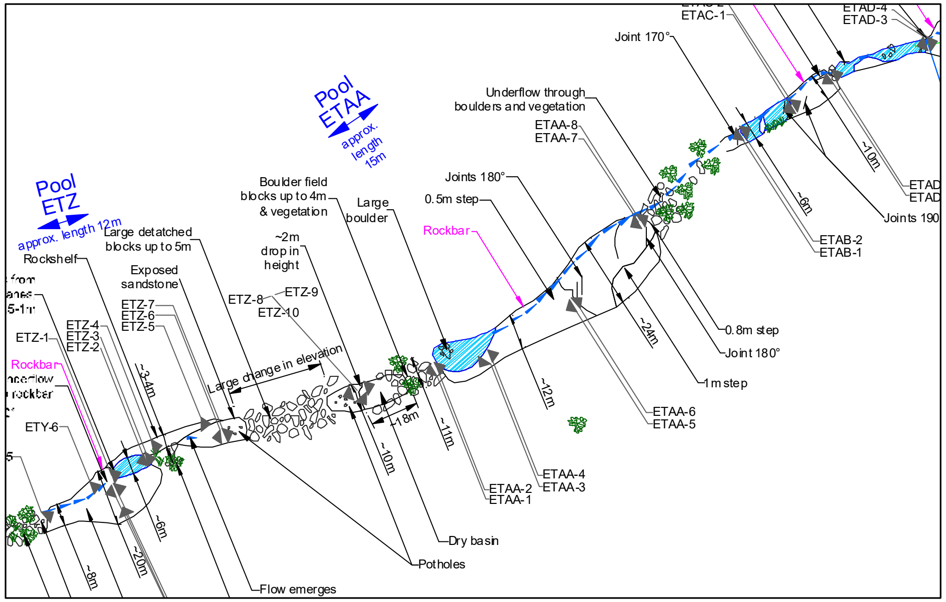
ETAA-1 Upstream end of Pool ETAA looking Upstream

ETAA-2 Upstream end of Pool ETAA looking Downstream

Pool ETAA notes (as at 19 Dec 2008)

- Width varies from approximately 4m to 9m
- Water depth varies from approximately 0.1m to 1m with an average of approximately 0.5m.
- Base of the pool is sandstone with minor alluvial deposits and boulders.
- Rock ledges present on south east side (~0.5m high) and north west side (~1m).
- Rockbar downstream of the pool is approximately 12m wide and approximately 24m wide further downstream.

(Notes continued on second sheet)



ETAA-3 Downstream end of Pool ETAA looking Upstream along south east bank.

ETAA-4 Downstream end of Pool ETAA looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETAA-1	312007	6214496	242
ETAA-2	312007	6214496	68
ETAA-3	312025	6214500	213
ETAA-4	312025	6214500	68

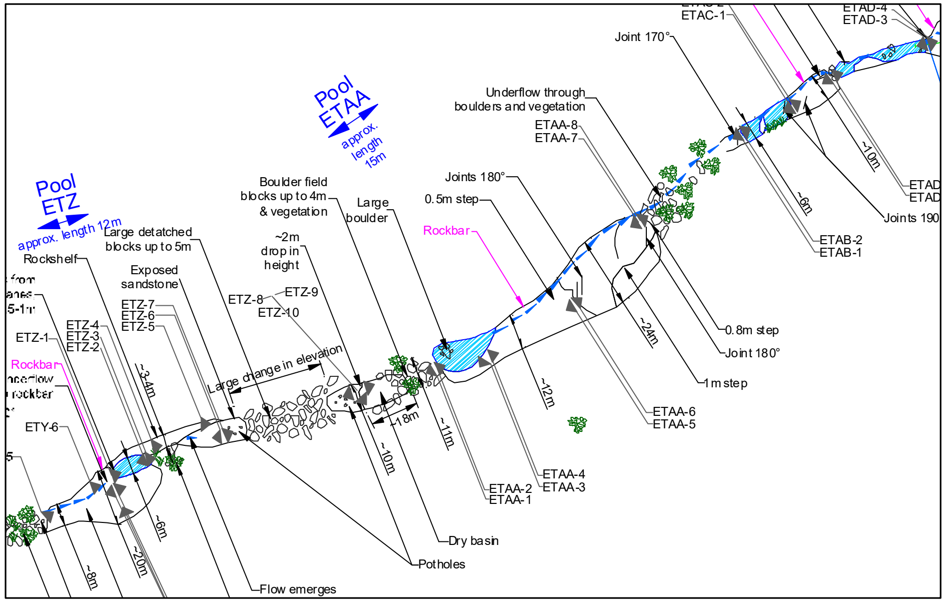
POOL ETAA DOWNSTREAM MAPPING SUMMARY

ETAA-5 On rockbar Downstream of Pool ETAA looking Upstream

Pool ETAA Downstream notes (as at 19 Dec 2008)

- Flow continues along the north western edge of the rockbar.
- There is an approximate 0.5m step approximately midway along the rockbar where the flow forms a small waterfall.
- A small area of ponded water is located on the south eastern side of the rockbar below an approximate 1m step in the rockbar (Photo ETAA-7).
- Water flow continues into a boulder field downstream of the rockbar.

ETAA-6 On rockbar Downstream of Pool ETAA looking Downstream



ETAA-7 Downstream end of rockbar Downstream of Pool ETAA looking Upstream

ETAA-8 Downstream end of rockbar Downstream of Pool ETAA looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETAA-5	312054	6214518	237
ETAA-6	312054	6214518	46
ETAA-7	312077	6214546	237
ETAA-8	312077	6214546	57

POOLS ETAB & ETAC STREAM MAPPING SUMMARY

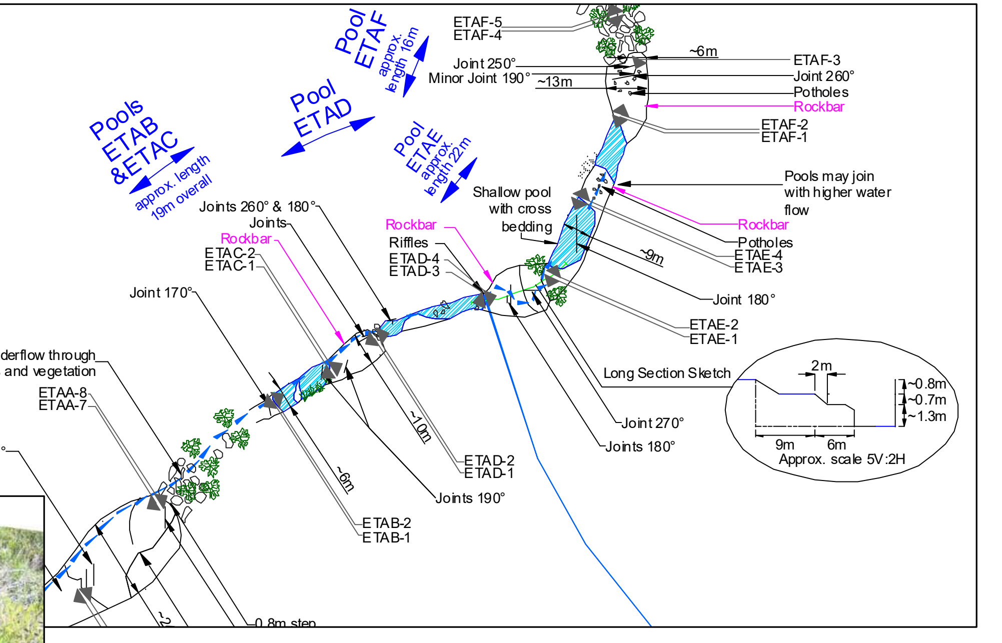
ETAB-1 Upstream end of Pool ETAB looking Upstream

ETAB-2 Upstream end of Pool ETAB looking Downstream

<u>Pools ETAB and ETAC notes (as at 19 Dec 2008)</u>

- Pools ETAB and ETAC are separated by a small rockbar. Water flows around the rockbar and the two pool levels are almost the same.
- Pool ETAB is approximately 6m wide and 10m long.
- Pool ETAC is approximately 6m wide and 9m long.
- Water depth is generally very shallow to a maximum of approximately 0.5m.
- Bases of the pools are sandstone with minor alluvial deposits.

ETAC-1 Downstream end of Pool ETAC looking Upstream



ETAC-2 Downstream end of Pool ETAC looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETAB-1	312112	6214577	237
ETAB-2	312112	6214577	57
ETAC-1	312129	6214586	237
ETAC-2	312129	6214586	57

POOL ETAD STREAM MAPPING SUMMARY

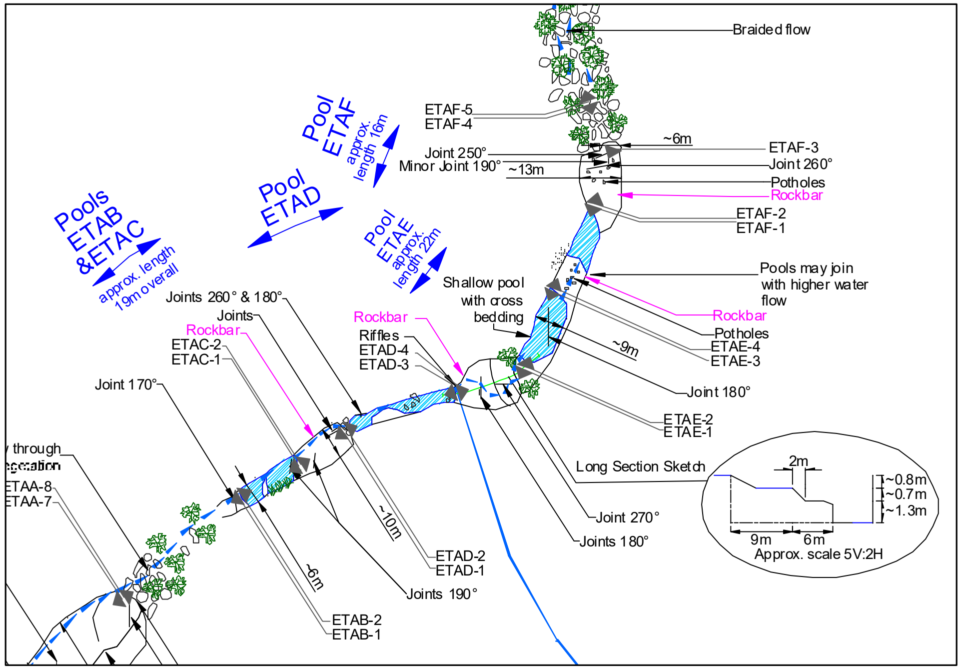
ETAD-1 Upstream end of Pool ETAD looking Upstream

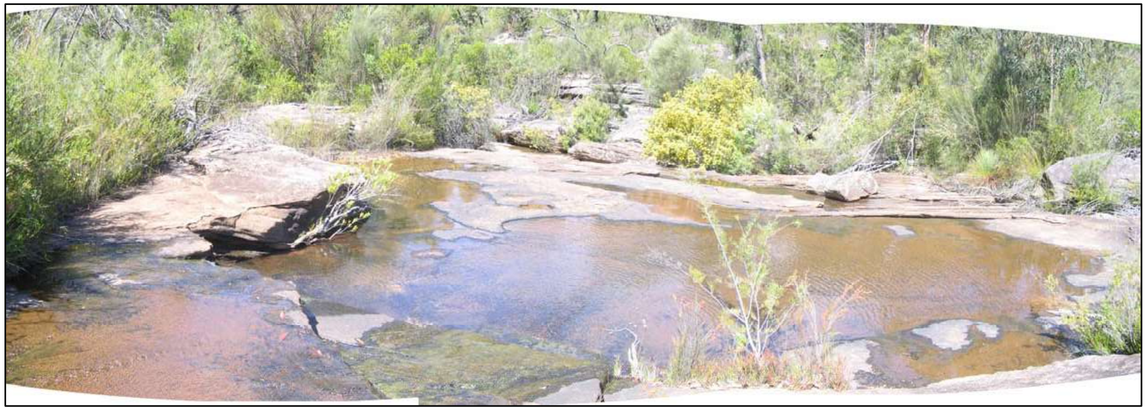
ETAD-2 Upstream end of Pool ETAD looking Downstream

Pool ETAD notes (as at 19 Dec 2008)

- Width varies from approximately 1m to 5m.
- Water depth varies from approximately 0.1m to 0.5m.
- Base of the pool is sandstone with minor alluvial deposits and some scattered cobbles and boulders up to approximately 2m size.
- Rockbar downstream of the pool is wide and near level. Some cross bedding is present.
- Pool ETAE is approximately 2.8m below Pool ETAD (see sketch below).

ETAD-3 Downstream end of Pool ETAD looking Upstream





ETAD-4 Downstream end of Pool ETAD looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETAD-1	312130	6214594	237
ETAD-2	312143	6214596	70
ETAD-3	312175	6214607	254
ETAD-4	312175	6214607	74

POOL ETAE STREAM MAPPING SUMMARY

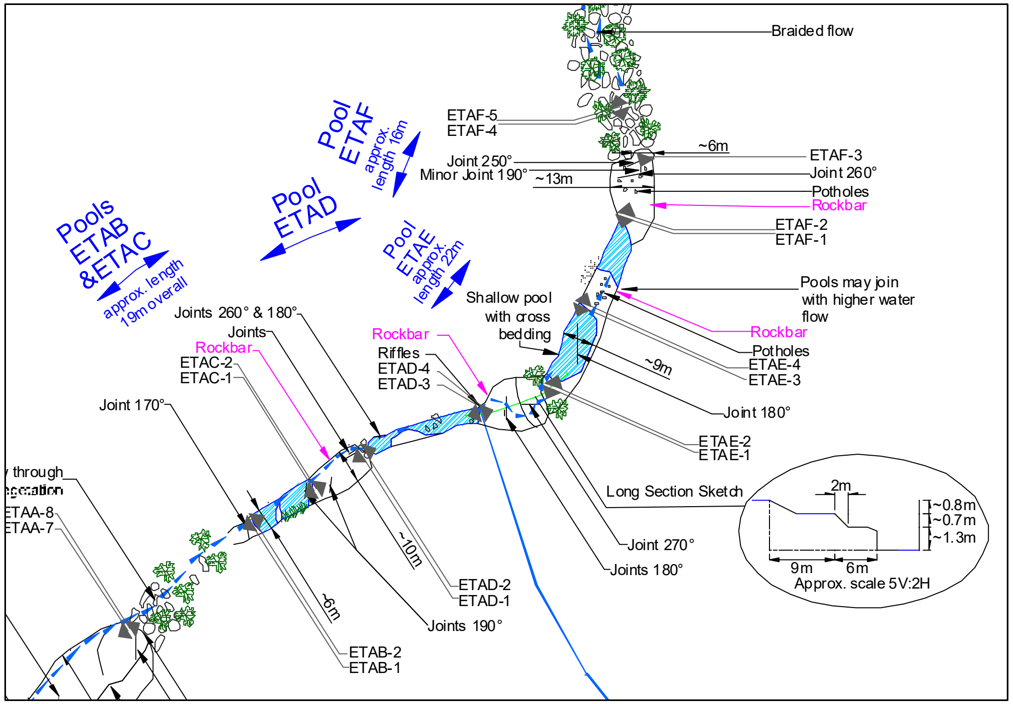
ETAE-1 Upstream end of Pool ETAE looking Upstream

ETAE-2 Upstream end of Pool ETAE looking Downstream

Pool ETAE notes (as at 19 Dec 2008)

- Width varies from approximately 2m to 9m.
- Water depth varies up to approximately 0.5m.
- Base of the pool is sandstone with minor alluvial deposits.
- Cross bedding present in the base of the pool.
- Rockbar downstream of the pool has cross bedding and potholes.
- Water flows over the middle of the rockbar as shallow flow and riffles. Pools ETAE and ETAF may become one large pool with higher water levels.

ETAE-3 Downstream end of Pool ETAE looking Upstream



ETAE-4 Downstream end of Pool ETAE looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETAE-1	312195	6214614	204
ETAE-2	312195	6214614	24
ETAE-3	312204	6214638	204
ETAE-4	312204	6214638	24

POOL ETAF STREAM MAPPING SUMMARY

ETAF-1 Downstream end of Pool ETAF looking Upstream

ETAF-2 Downstream end of Pool ETAF looking Downstream

ETAF-3 Downstream end of Pool ETAF (Downstream end of rockbar) looking Upstream

Pool ETAF notes (as at 19 Dec 2008)

- Width varies from approximately 2m to 7m.
- Water depth varies from approximately 0.1m to 0.5m.
- Base of the pool is sandstone with minor alluvial deposits.
- Cross bedding and potholes are present in the base of the pool.
- Water flows to a small pool/ponded area on the east side of the rockbar (Photo ETAF-3) but no other surface flow observed over rockbar downstream of the pool.
- Rockbar downstream of the pool is approximately 13m wide
- Joints and potholes present in the rockbar.

(Notes continued on second sheet)

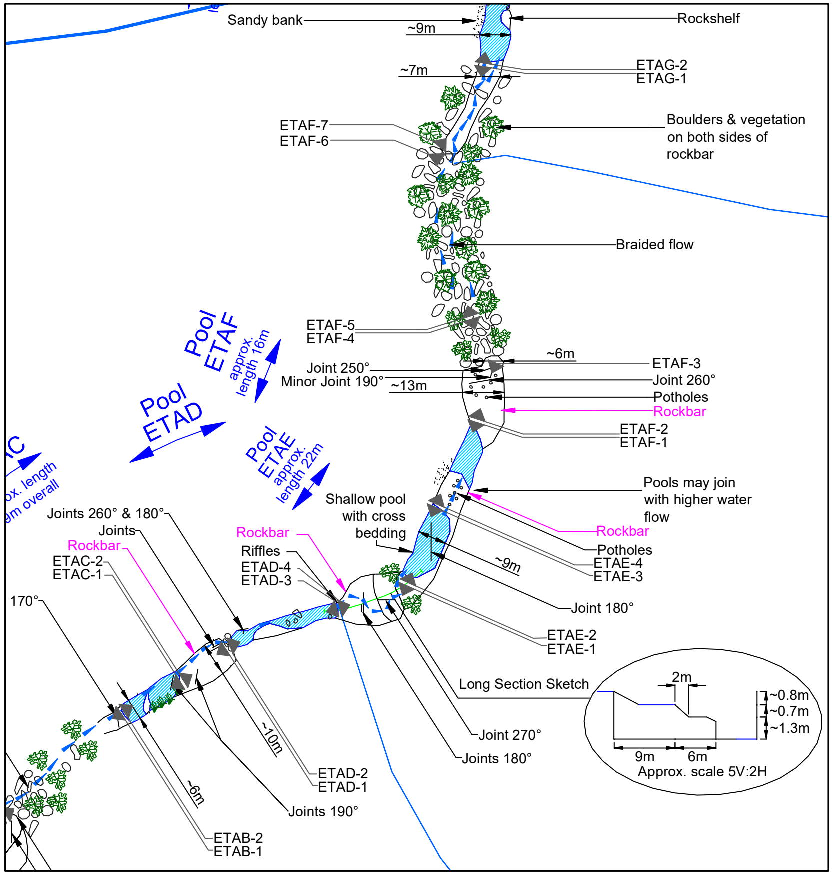


Photo Details

Photo ID	Easting	Northing	Bearing
ETAF-1	312216	6214663	204
ETAF-2	312216	6214663	24
ETAF-3	312211	6214680	203

POOL ETAF DOWNSTREAM MAPPING SUMMARY

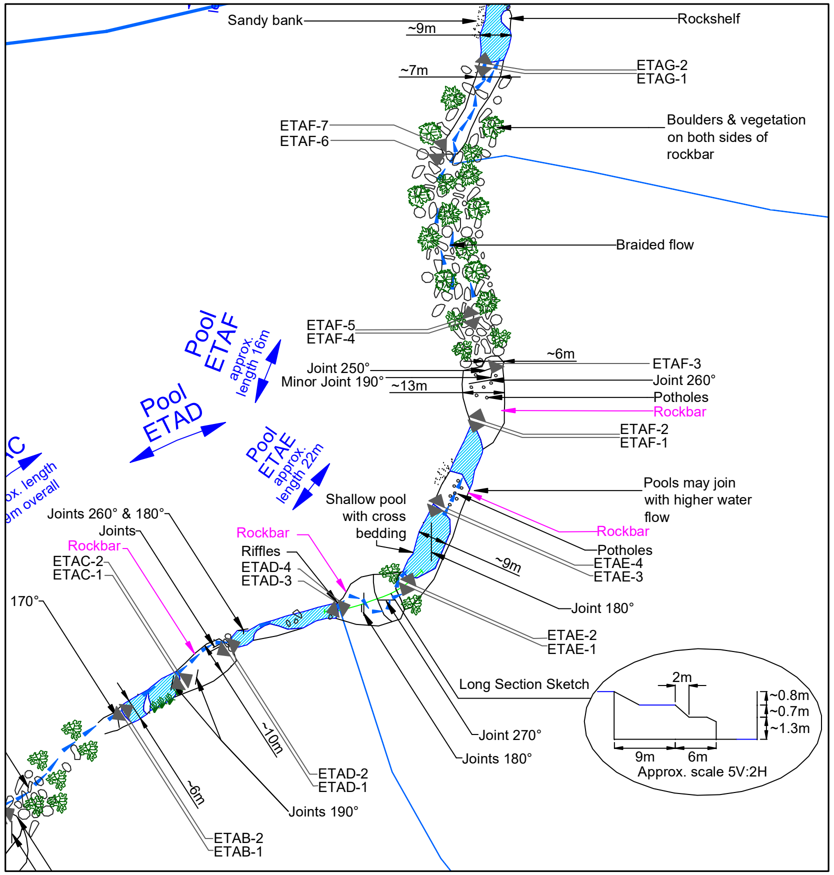
ETAF-4 In boulder field Downstream of Pool ETAF looking Upstream

ETAF-5 In boulder field Downstream of Pool ETAF looking Downstream

<u>Pool ETAF Downstream notes (as at 19 Dec 2008)</u>

- Further downstream of the rockbar below Pool ETAF, water flows through a boulder field with boulders up to approximately 3m size.
- Water flows onto exposed sandstone downstream of the boulder field, before entering Pool ETAG.

ETAF-6 Downstream end of boulder field Downstream of Pool ETAF looking Upstream



ETAF-7 Downstream end of boulder field Downstream of Pool ETAF looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETAF-4	312214	6214693	162
ETAF-5	312214	6214693	342
ETAF-6	312204	6214742	180
ETAF-7	312204	6214742	40

POOL ETAG STREAM MAPPING SUMMARY

ETAG-1 Upstream end of Pool ETAG looking Upstream

ETAG-2 Upstream end of Pool ETAG looking Downstream

ETAG-3 Downstream end of Pool ETAG looking Upstream

ETAG-4 Downstream end of Pool ETAG looking Downstream

<u>Pool ETAG notes (as at 19 Dec 2008)</u>

- Width varies from approximately 3m to 9m.
- Water depth varies from approximately 0.1m to 1m.
- Base of the pool is sandstone with alluvial deposits, mainly on the western side.
- Boulders up to approximately 0.5m are present at the downstream eastern end of the pool.
- Algae deposits present.
- Water flows into a boulder field downstream of the pool. Boulders up to approximately 3m size.

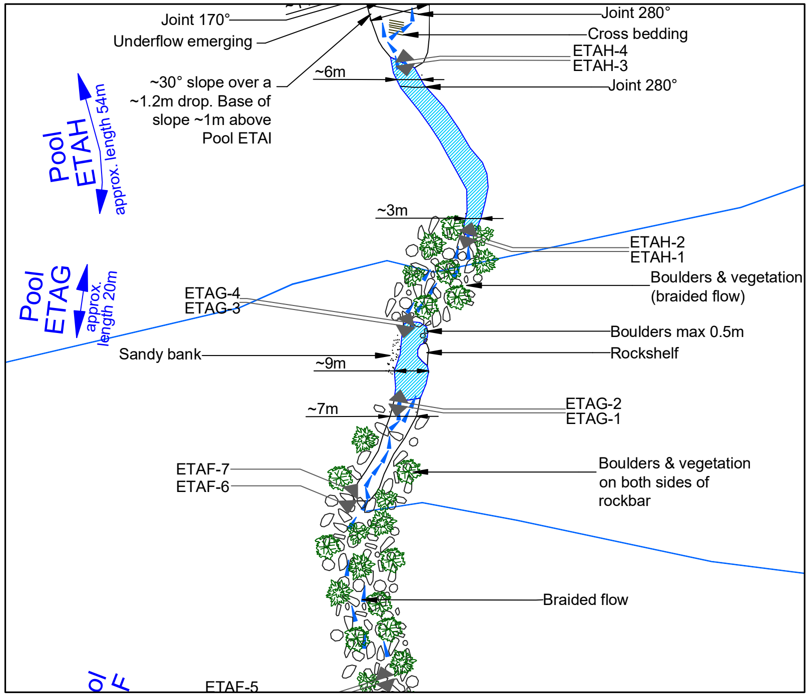


Photo Details

Photo ID	Easting	Northing	Bearing
ETAG-1	312217	6214767	189
ETAG-2	312217	6214767	9
ETAG-3	312219	6214788	188
ETAG-4	312219	6214788	26

POOL ETAH STREAM MAPPING SUMMARY

ETAH-1 Upstream end of Pool ETAH looking Upstream

ETAH-2 Upstream end of Pool ETAH looking Downstream

ETAH-3 Downstream end of Pool ETAH looking Upstream

ETAH-4 Downstream end of Pool ETAH looking Downstream

Pool ETAH notes (as at 19 Dec 2008)

- Width varies from approximately 3m to 6m.
- Water depth varies from approximately 0.3m to 1.5m.
- Base of the pool is sandstone with alluvial deposits.
- Water depth is very shallow with some sandstone exposed over approximately 8m at the downstream end of the pool.
- Rockbar downstream of the pool is cross bedded.
- Water flows over most of the rockbar surface with some ponded areas and some underflow.
- Pool ETAI is more than 2m below Pool ETAH.

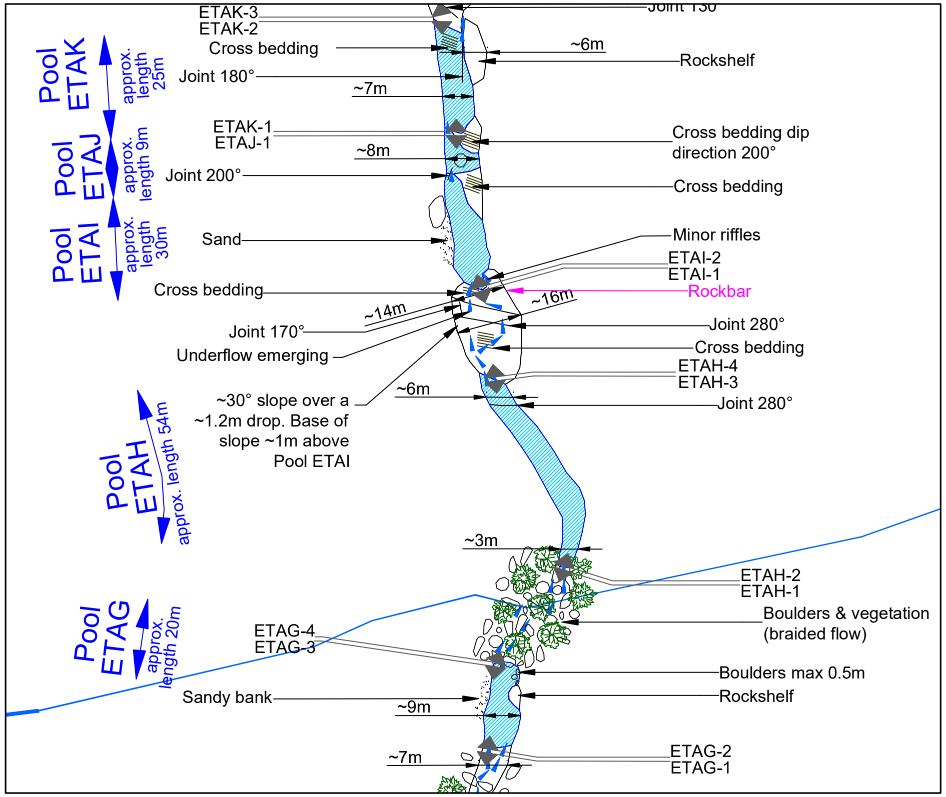


Photo Details

Photo ID	Easting	Northing	Bearing
ETAH-1	312236	6214812	197
ETAH-2	312236	6214812	17
ETAH-3	312220	6214859	172
ETAH-4	312220	6214859	352

POOLS ETAI & ETAJ STREAM MAPPING SUMMARY

ETAI-1 Upstream end of Pool ETAI looking Upstream

ETAI-2 Upstream end of Pool ETAI looking Downstream

ETAJ-1 Downstream end Pool ETAJ looking Upstream

<u>Pools ETAI and ETAJ notes (as at 19 Dec 2008)</u>

- Width varies from approximately 2m to 8m.
- Water depth varies from approximately 0.2m to 1m.
- Base of the pool is sandstone with alluvial deposits and scattered boulders.
- Large sand bank present on the western side of the pool.
- Sandstone is cross bedded.
- Only small rockbars separate Pools ETAI, AJ and AK. Pools may join to become one large pool with higher water levels.

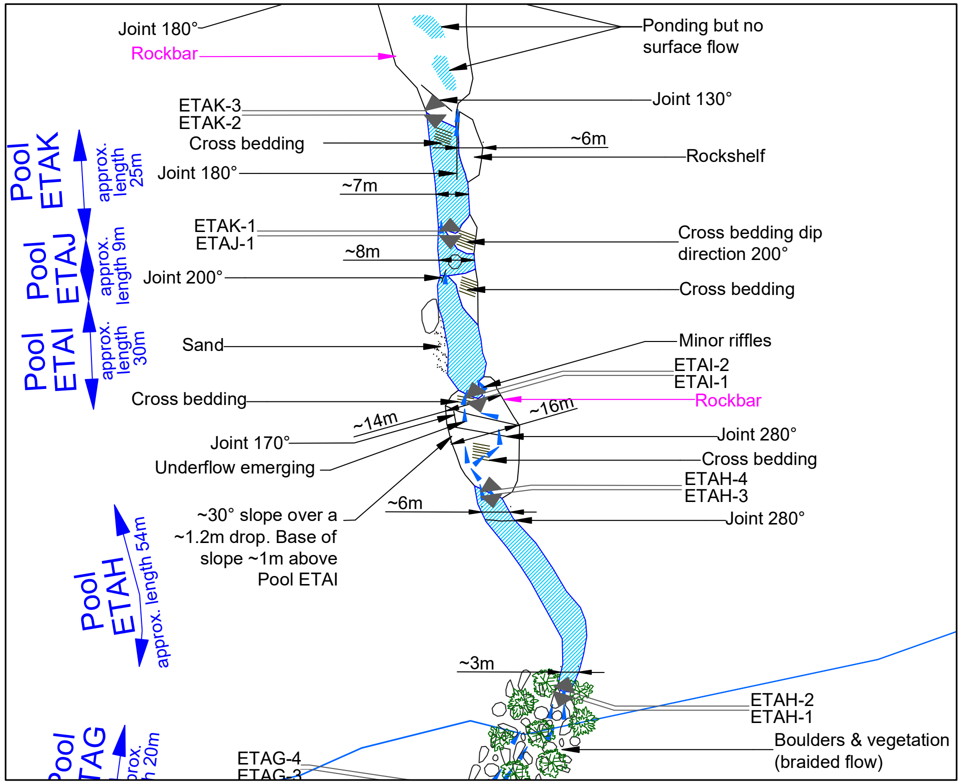


Photo Details

Photo ID	Easting	Northing	Bearing
ETAI-1	312216	621481	164
ETAI-2	312216	621481	344
ETAJ-1	312210	6214919	180

POOL ETAK STREAM MAPPING SUMMARY

ETAK-1 Upstream end of Pool ETAK looking Downstream

ETAK-2 Downstream end of Pool ETAK looking Upstream

ETAK-3 Downstream end Pool ETAK looking Downstream

Pool ETAK notes (as at 19 Dec 2008)

- Width varies from approximately 4m to 7m.
- Water depth varies from approximately 0.2m to 0.5m.
- Base of the pool is sandstone with minor alluvial deposits.
- Sandstone is cross bedded and weathered.
- Rockbar downstream of Pool ETAK has several small pools/ponded areas but no surface flow observed.
- Maximum width of rockbar is approximately 21m.

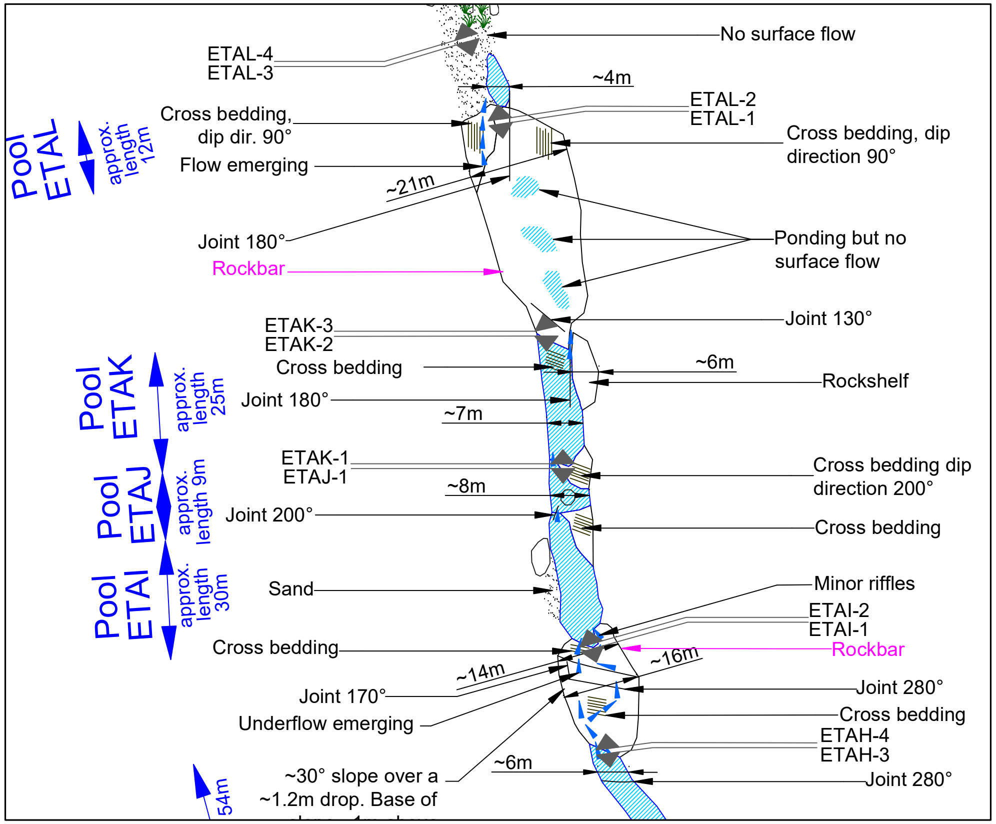
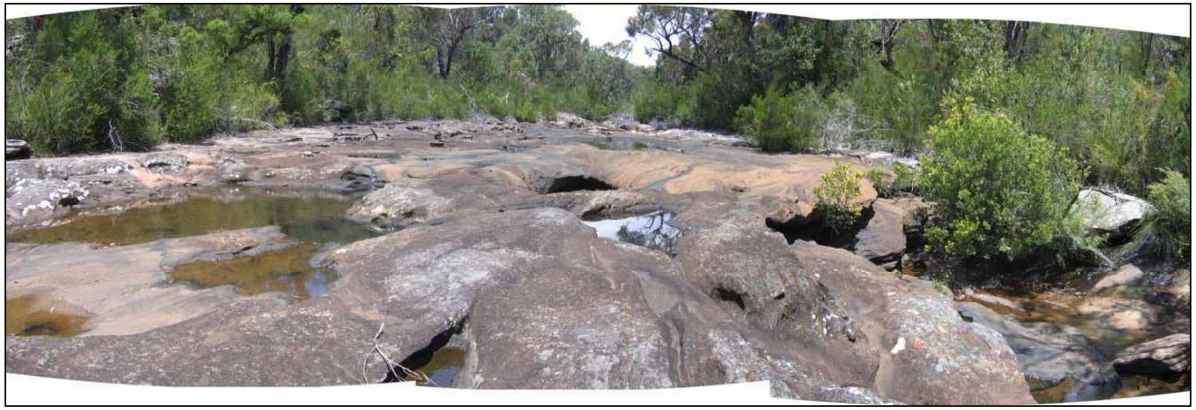


Photo Details

Photo ID	Easting	Northing	Bearing
ETAK-1	312210	6214919	0
ETAK-2	312207	6214948	180
ETAK-3	312207	6214948	347

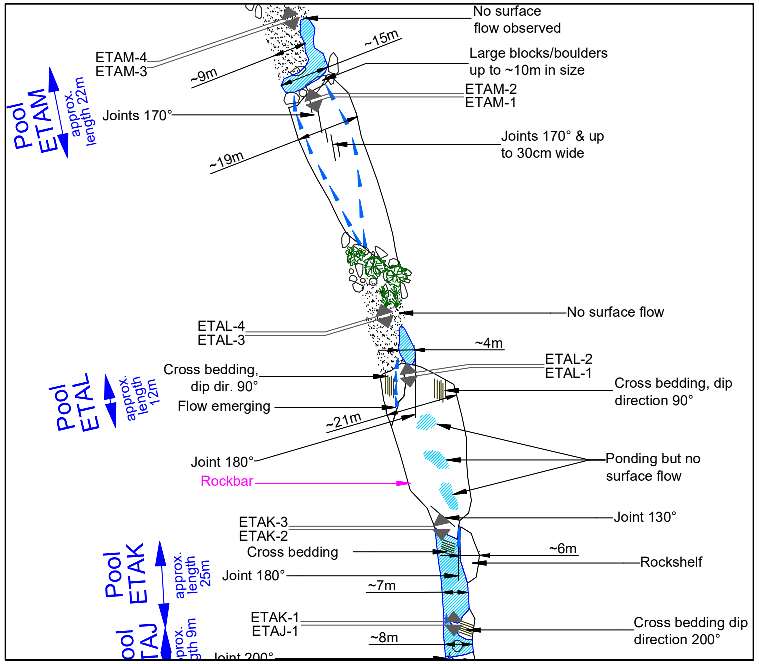
POOL ETAL STREAM MAPPING SUMMARY



ETAL-1 Upstream end of Pool ETAL looking Upstream

Pool ETAL notes (as at 19 Dec 2008)

- Pool ETAL is approximately 1.5m below the upstream rockbar.
- Width varies from approximately 2m to 4m. Length is approximately 12m.
- Water depth varies from approximately 0.1m to 0.8m.
- Base of the pool is sandstone with alluvial deposits.
- Large alluvial deposits on the western and downstream sides of the pool.
- Algae present in the pool.
- No surface flow observed downstream of the pool.
- Flow emerges approximately 30m downstream of the pool from a small boulder field onto exposed sandstone.



ETAL-2 Upstream end of Pool ETAL looking Downstream

ETAL-3 Downstream end of Pool ETAL looking Upstream

ETAL-4 Downstream end of Pool ETAL looking Downstream

Photo Details

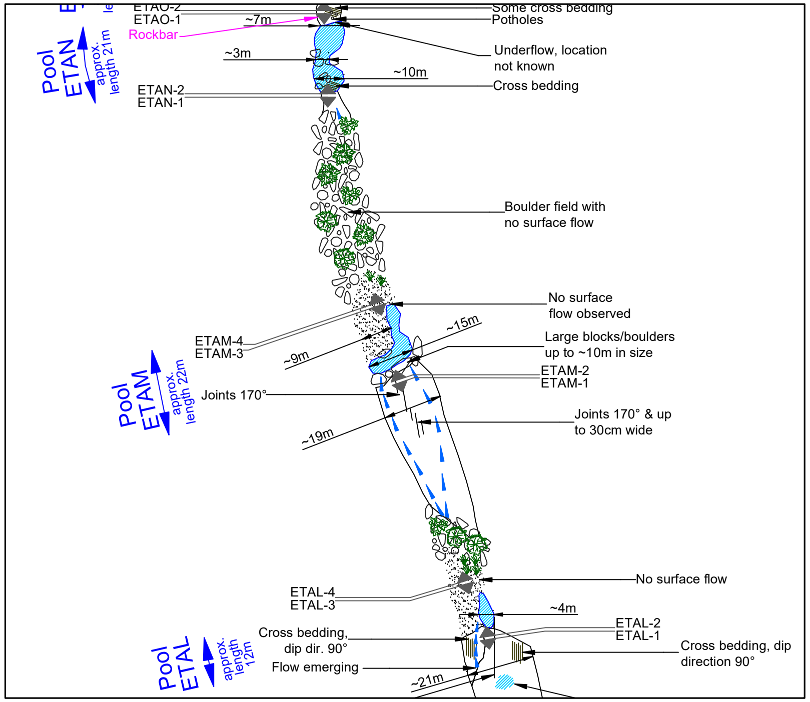
Photo ID	Easting	Northing	Bearing
ETAL-1	312197	6214992	171
ETAL-2	312197	6214992	351
ETAL-3	312190	6215010	163
ETAL-4	312190	6215010	343

POOL ETAM STREAM MAPPING SUMMARY

ETAM-1 Upstream end of Pool ETAM looking Upstream

Pool ETAM notes (as at 19 Dec 2008)

- Pool ETAM is approximately 3m below the upstream rockbar.
- Width varies from approximately 15m at the upstream end to 2m at the downstream end.
- Water depth varies up to approximately 0.8m
- Base of the pool is alluvial deposit.
- There is a large alluvial deposit on the west bank approximately 9m wide and 25m long.
- Cross bedding present in exposed sandstone.
- Large detached blocks/boulders are present at the upstream end of the pool.
- No surface flow observed downstream of the pool.
- Alluvial deposits present on the downstream side of the pool then boulder field.



ETAM-2 Upstream end of Pool ETAM looking Downstream

ETAM-3 Downstream end of Pool ETAM looking Upstream

ETAM-4 Downstream end of Pool ETAM looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETAM-1	312169	6215073	161
ETAM-2	312169	6215073	341
ETAM-3	312162	6215098	161
ETAM-4	312162	6215098	341

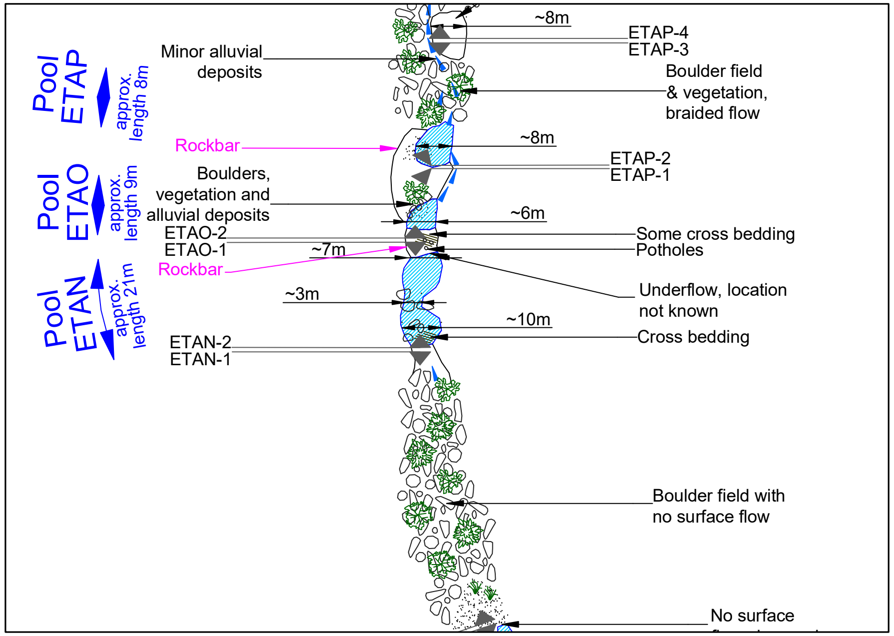
POOLS ETAN & ETAO STREAM MAPPING SUMMARY

ETAN-1 Upstream end of Pool ETAN looking Upstream

ETAN-2 Upstream end of Pool ETAN looking Downstream

<u>Pools ETAN and ETAO notes (as at 19 Dec 2008)</u>

- Widths vary from approximately 3m to 7m.
- Water depth varies up to 0.9m.
- Base of the pool is sandstone with alluvial deposits and scattered boulders up to approximately 4m size.
- Rockbar separating Pool ETAN and ETAO is approximately 7m wide and 7m long. Some cross bedding and potholes are present in the rockbar.
- Water flows around the eastern side of the rockbar downstream of Pool ETAO.



ETAO-1 Upstream end of Pool ETAO looking Upstream

ETAO-2 Upstream end of Pool ETAO looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETAN-1	312146	6215164	180
ETAN-2	312146	6215164	0
ETAO-1	312145	6215190	180
ETAO-2	312145	6215190	0

POOL ETAP STREAM MAPPING SUMMARY

ETAP-1 Upstream end of Pool ETAP looking Upstream

ETAP-3 Braided flow Downstream of Pool ETAP looking Upstream

Pool ETAP notes (as at 19 Dec 2008)

- Pool width is approximately 6m and length is approximately 8m.
- Average water depth is approximately 0.6m.
- Base of the pool is sandstone with alluvial deposits, mainly on the western half of the pool and scattered small boulders.
- Stream becomes braided flow through boulder field downstream of the pool. Some sandstone bedrock is exposed in the boulder field.
- End of the boulder field is approximately 60m downstream of the pool where flow continues along western side of exposed sandstone.

ETAP-2 Upstream end of Pool ETAP looking Downstream

ETAP-4 Sandstone Downstream of Pool ETAP looking Downstream

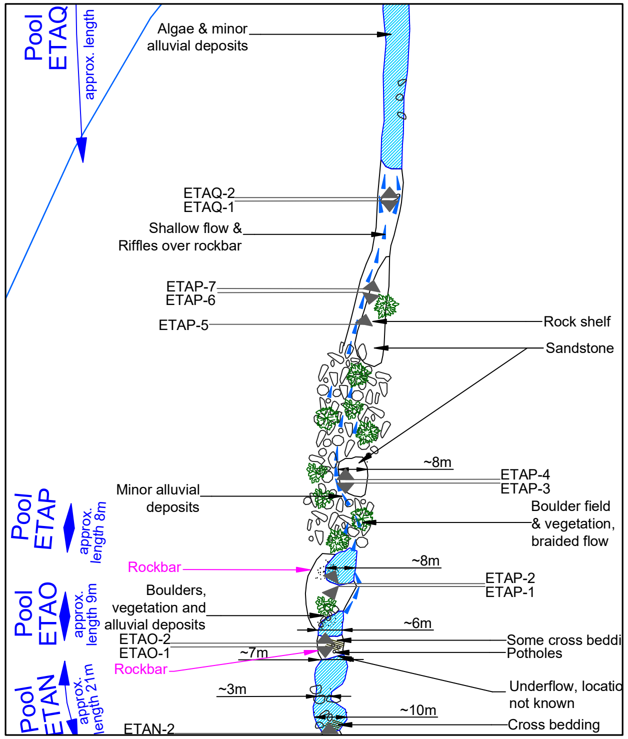


Photo Details

Photo ID	Easting	Northing	Bearing
ETAP-1	312148	6215208	159
ETAP-2	312148	6215208	29
ETAP-3	312151	6215238	180
ETAP-4	312151	6215238	0
ETAP-5	312156	6215283	11
ETAP-6	312158	6215293	191
ETAP-7	312158	6215293	11

ETAP-5 Sandstone Downstream of Pool ETAP looking Downstream

ETAP-6 Sandstone Downstream of Pool ETAP looking Upstream

ETAP-7 Sandstone Downstream of Pool ETAP looking downstream

POOL ETAQ STREAM MAPPING SUMMARY

ETAQ-1 Upstream end of Pool ETAQ looking Upstream

ETAQ-2 Upstream end of Pool ETAQ looking Downstream

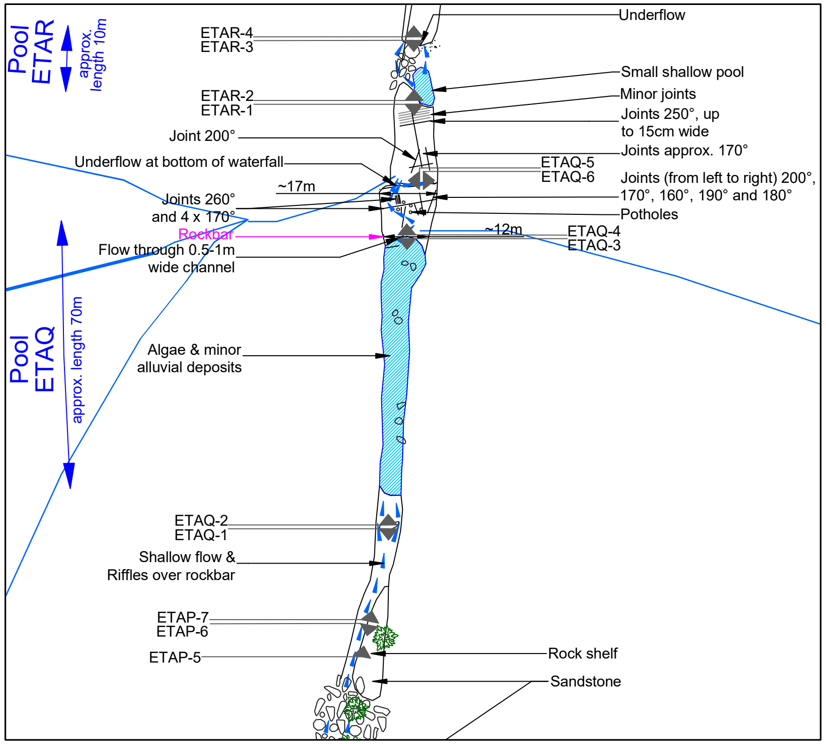
ETAQ-5 Waterfall Downstream of Pool ETAQ

Pool ETAQ notes (as at 19 Dec 2008)

- Width varies from approximately 6m to 12m.
- Water depth varies from approximately 0.1m to 1m.
- Base of the pool is sandstone with alluvial deposits and some boulders up to approximately 2m size.
- Rockbar downstream of the pool varies from approximately 12m to 17m wide. Cross bedding present in the rockbar.
- Water flows from the pool in a channel 0.5m to 1m wide and up to 1m deep. Potholes present around the channel. Water continues as underflow from the channel and emerges near a waterfall.
- The top of the waterfall is approximately 15m downstream of Pool ETAQ and is approximately 1m below the pool level. The waterfall is approximately 3m high.
- Water ponds at the base of the waterfall, then continues as underflow and some minor surface flow.

ETAQ-3 Downstream end of Pool ETAQ looking Upstream

ETAQ-6 Underflow toward Eastern bank at Waterfall



ETAQ-4 Downstream end of Pool ETAQ looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETAQ-1	312164	6215320	180
ETAQ-2	312164	6215320	0
ETAQ-3	312169	6215401	180
ETAQ-4	312169	6215401	0
ETAQ-5	312173	6215418	270
ETAQ-6	312173	6215418	90

POOL ETAR STREAM MAPPING SUMMARY

ETAR-1 Upstream end of Pool ETAR looking Upstream

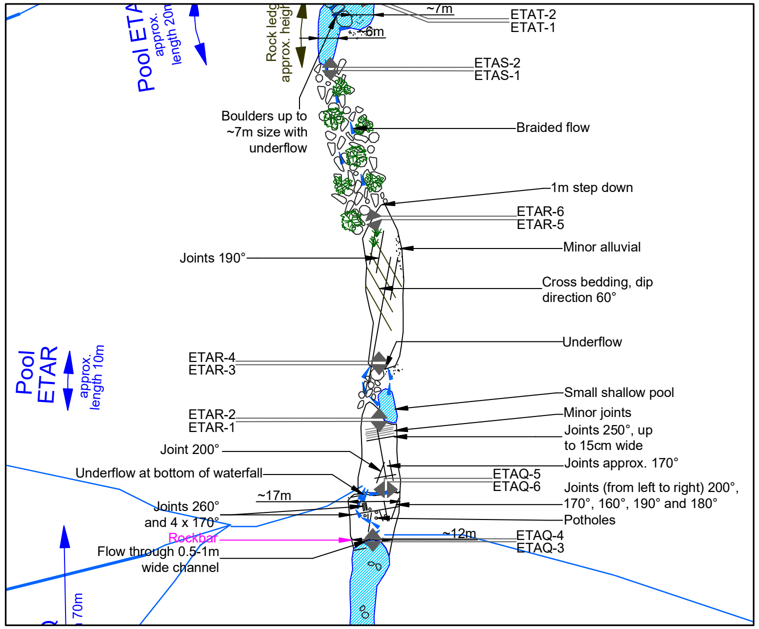
ETAR-4 Downstream of Pool ETAR looking Downstream

Pool ETAR notes (as at 19 Dec 2008)

- Width is approximately 5m.
- Water depth varies up to approximately 0.4m.
- Base of the pool is sandstone with minor alluvial deposits and cobbles and boulders up to approximately 5m size.
- Rockbar downstream of the pool has cross bedding and joints.
- No surface flow observed over the rockbar.
- Water flow continues through boulder field which starts approximately midway between Pools ETAR and ETAS.

ETAR-2 Upstream end of Pool ETAR looking Downstream

ETAR-6 Downstream end of rockbar looking Downstream



ETAR-3 Downstream end of Pool ETAR looking Upstream

ETAR-5 Downstream end of rockbar Downstream of Pool ETAR looking Upstream (camera error)

Photo Details

Photo ID	Easting	Northing	Bearing
ETAR-1	312171	6215439	180
ETAR-2	312171	6215439	0
ETAR-3	312171	6215457	180
ETAR-4	312171	6215457	0
ETAR-5	312169	6215502	160
ETAR-6	312169	6215502	342

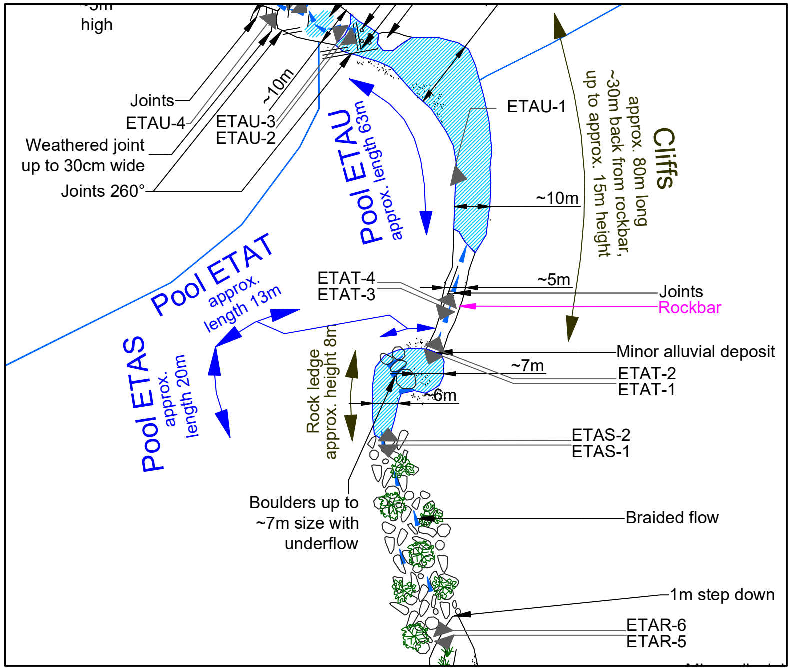
POOLS ETAS & ETAT STREAM MAPPING SUMMARY

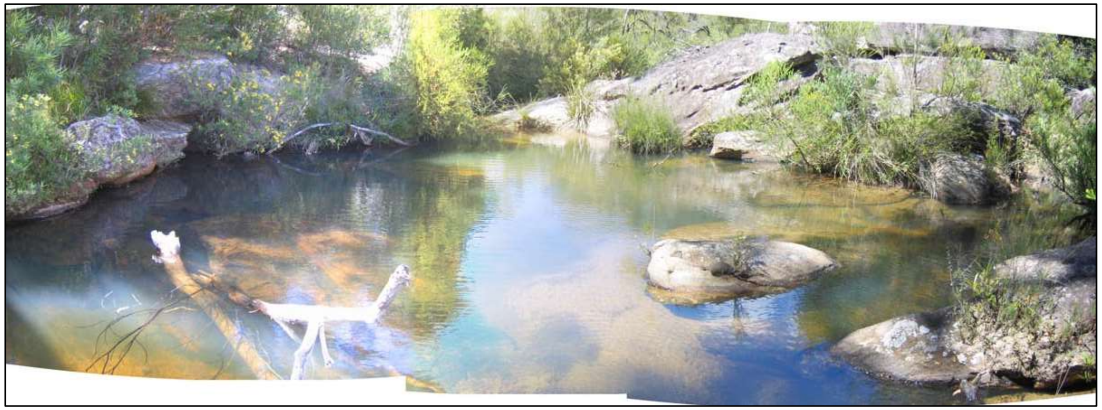
ETAS-1 Upstream end of Pool ETAS looking Upstream

ETAS-2 Upstream end of Pool ETAS looking Downstream

Pools ETAS and ETAT notes (as at 19 Dec 2008)

- Width varies from approximately 2m to 7m.
- Water depth varies from approximately 0.1m to 1.5m.
- Base of the pools is sandstone with alluvial deposits and boulders up to approximately 5m size.
- Separation between Pools ETAS and ETAT appears to be mainly detached block and boulders. Water level in both pools appears to be similar.
- Rockbar downstream of Pool ETAT is cross bedded and mostly covered with water.
- Pool ETAU approximately the same level as Pool ETAT.





ETAT-1 Downstream end of Pool ETAT looking Upstream

ETAT-2 Downstream end of Pool ETAT looking Downstream

ETAT-3 On rockbar Downstream of Pool ETAT looking Upstream

ETAT-4 On rockbar Downstream of Pool ETAT looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
ETAS-1	312156	6215549	180
ETAS-2	312156	6215549	0
ETAT-1	312166	6215572	201
ETAT-2	312166	6215572	21
ETAT-3	312170	6215583	204
ETAT-4	312170	6215583	24

POOL ETAU STREAM MAPPING SUMMARY

ETAU-1 Mid point of Pool ETAU looking toward the Eastern bank

ETAU-2 Downstream end of Pool ETAU looking Upstream

ETAU-3 Downstream end of Pool ETAU looking Downstream

<u>Pool ETAU notes (as at 19 Dec 2008)</u>

- Width varies from approximately 10m to 17m.
- Water depth varies from approximately 0.3m to 1.5m.
- Base of the pool is sandstone with alluvial deposits.
- Cross bedding present.
- Rockbar downstream of the pool has cross bedding and ponded water on surface.
- A waterfall approximately 5m high is located approximately 17m downstream of Pool ETAU.

(Notes continued on second sheet)

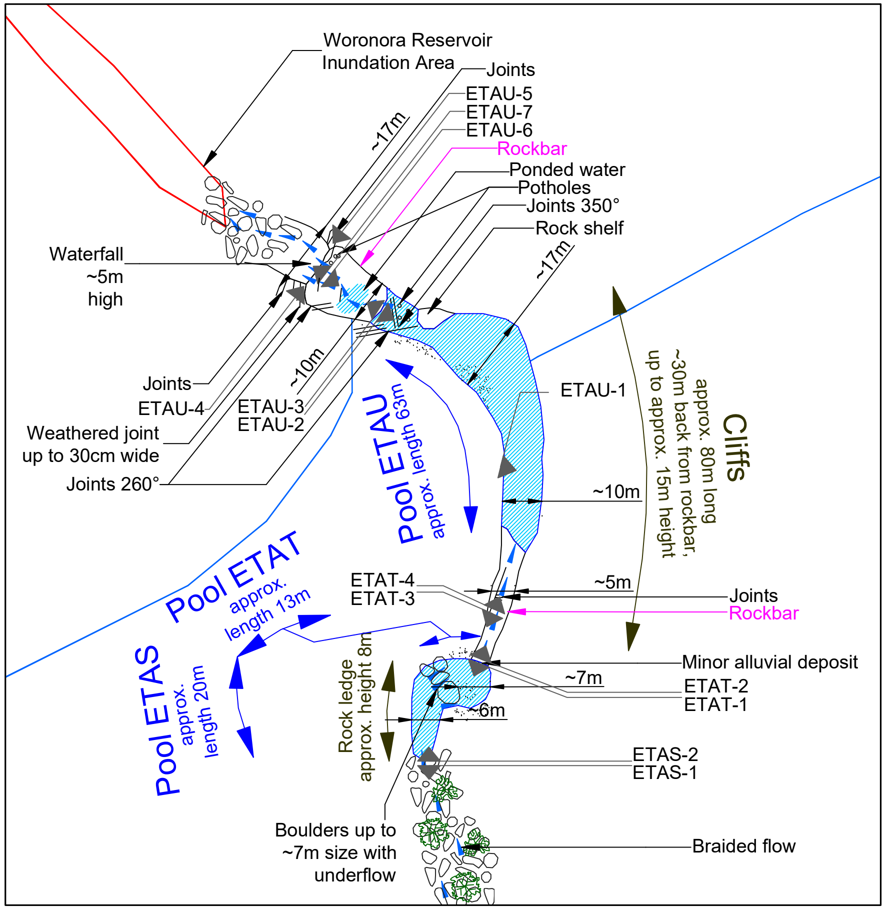


Photo Details

Photo ID	Easting	Northing	Bearing
ETAU-1	312174	6215615	104
ETAU-2	312145	6215650	123
ETAU-3	312145	6215650	303

POOL ETAU DOWNSTREAM MAPPING SUMMARY

ETAU-4 Looking toward Eastern bank at waterfall Downstream of Pool ETAU

ETAU-5 Looking toward Western bank at waterfall Downstream of Pool ETAU

Pool ETAU Downstream notes (as at 19 Dec 2008)

- Waterfall is approximately 5m high.
- Several large detached blocks present on both banks downstream of the waterfall.
- Flow continues along the eastern side from the base of the waterfall into the inundation area of Woronora Reservoir.

ETAU-6 On waterfall Downstream of Pool ETAU looking Upstream

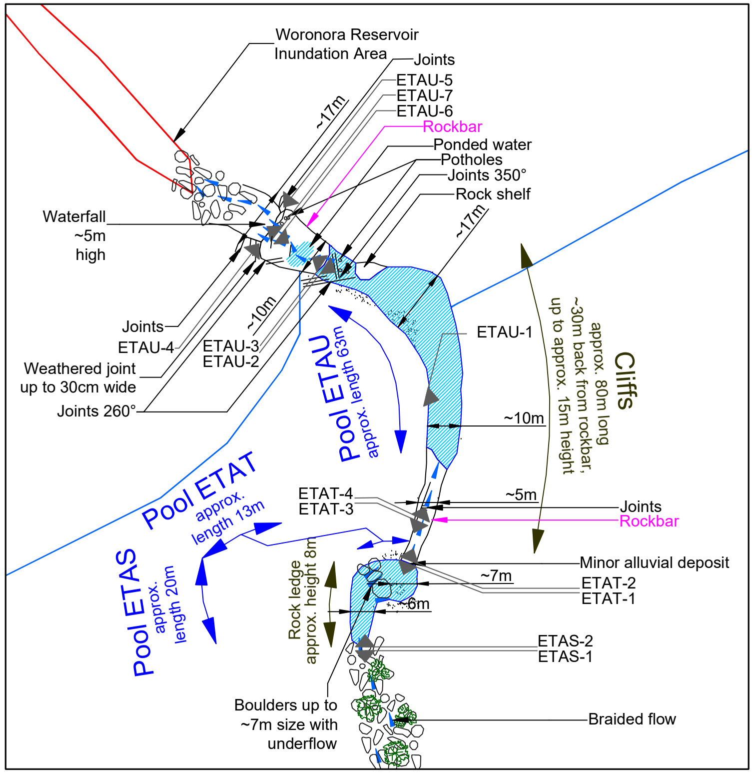


Photo Details

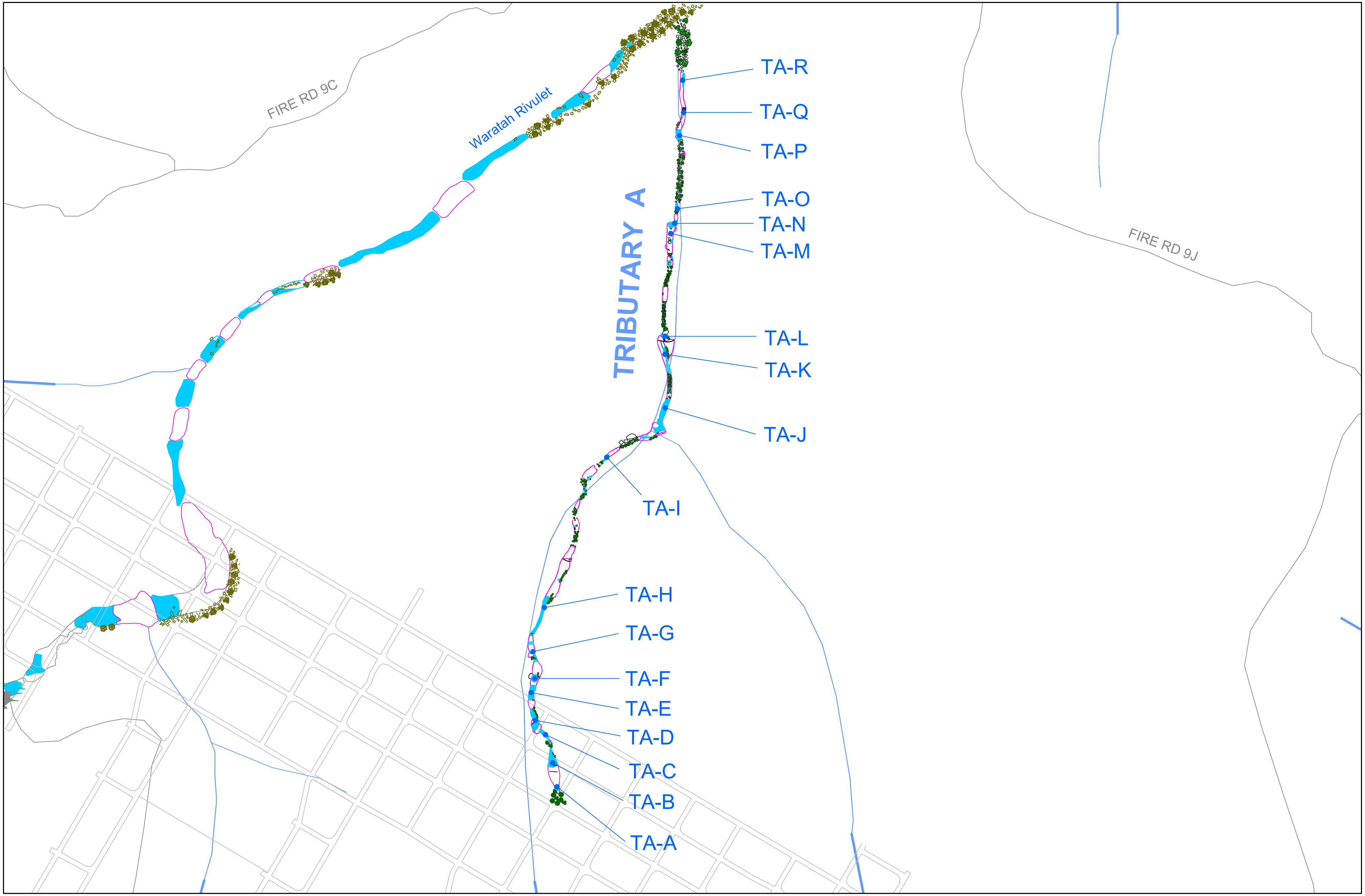
Photo ID	Easting	Northing	Bearing
ETAU-4	312128	6215655	18
ETAU-5	312134	6215665	218
ETAU-6	312133	6215658	127
ETAU-7	312133	6215658	307

ETAU-7 On waterfall Downstream of Pool ETAU looking Downstream

APPENDIX 3

TRIBUTARY A STREAM MAPPING AND PHOTOGRAPHIC RECORD

TRIBUTARY A – GENERAL LAYOUT



TRIBUTARY A STREAM MAPPING SUMMARY

TA01-1 Downstream end of Pool TA-A looking Upstream

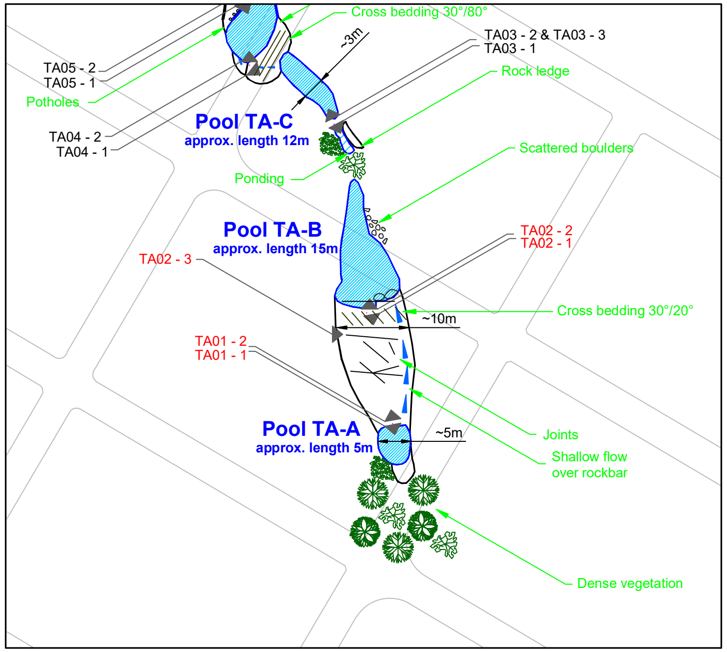
TA01-2 Downstream end of Pool TA-A looking Downstream

Notes (as at 5 January 2010)

- Pool TA-A approximately 5m long, 5m wide and 0.3m deep
- Base of the pool is sandstone
- Rockbar upstream of the pool is approximately 3m wide with scattered vegetation debris
- Rockbar downstream of the pool is approximately 10m wide and 17m long, with many joints and cross bedding at the downstream end
- Flow path along the eastern side of the rockbar toward Pool TA-B

- Pool TA-B approximately 15m long, 8m wide and 0.5m deep
- Base of the pool is sandstone with scattered boulders

TA02-1 Upstream end of Pool TA-B looking Upstream



TA02-2 Upstream end of Pool TA-B looking Downstream

TA02-3 Joint across rockbar between Pools TA-A and TA-B

Photo Details

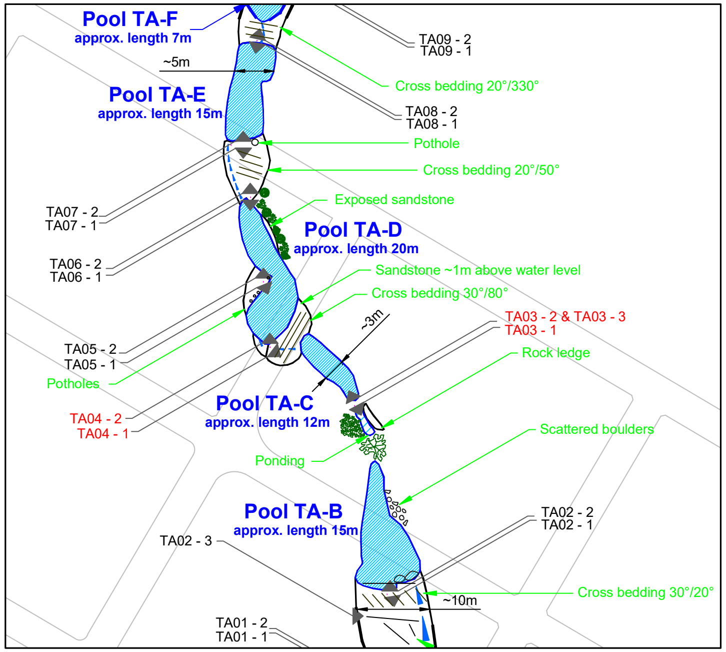
Photo ID	Easting	Northing	Bearing
TA01-1	310238	6214098	170
TA01-2	310238	6214098	350
TA02-1	310234	6214115	170
TA02-2	310234	6214115	0
TA02-3	310234	6214115	90

TRIBUTARY A STREAM MAPPING SUMMARY

TA03-1 Upstream end of Pool TA-C looking Upstream

<u>Notes (as at 5 January 2010)</u>

- Pool TA-C approximately 12m long, 3m wide and 0.2m deep
- Base of the pool is sandstone
- Ponding and vegetation upstream of pool
- Flow path along western side of rockbar toward Pool TA-D



TA03-2 and TA03-3 Upstream end of Pool TA-C looking Downstream

TA04-1 Upstream end of Pool TA-D looking Upstream

TA04-2 Upstream end of Pool TA-D looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA03-1	310229	6214144	155
TA03-2	310229	6214144	335
TA03-3	310229	6214144	335
TA04-1	310216	6214153	130
TA04-2	310216	6214153	0

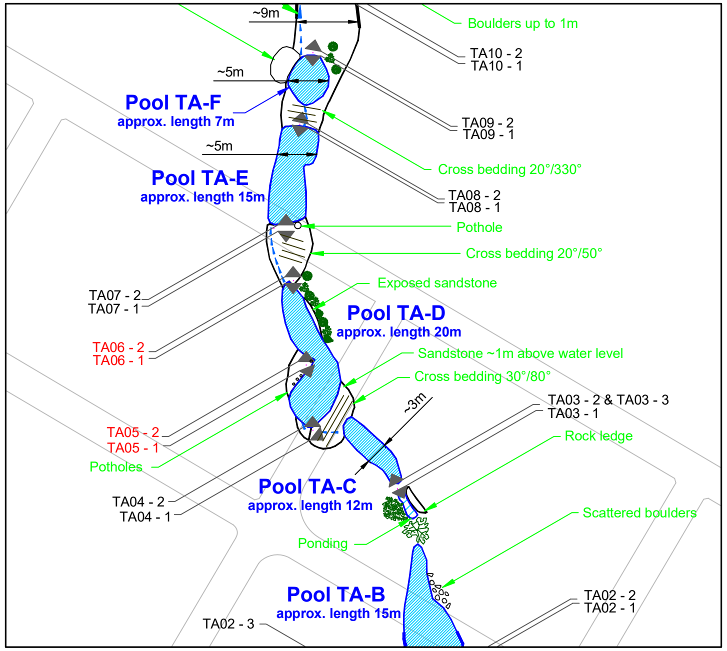
TRIBUTARY A STREAM MAPPING SUMMARY

TA05-1 Midway along Pool TA-D looking Upstream

Notes (as at 5 January 2010)

- Pool TA-D approximately 20m long, up to 9m wide and up to 1m deep at the upstream end
- Base of the pool is sandstone
- Sandstone ledge upstream of pool is approximately 1m above water level

TA05-2 Midway along Pool TA-D looking Downstream



TA06-1 Downstream end of Pool TA-D looking Upstream

TA06-2 Downstream end of Pool TA-D looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA05-1	310215	6214163	160
TA05-2	310215	6214163	0
TA06-1	310213	6214176	180
TA06-2	310213	6214176	0

TRIBUTARY A STREAM MAPPING SUMMARY

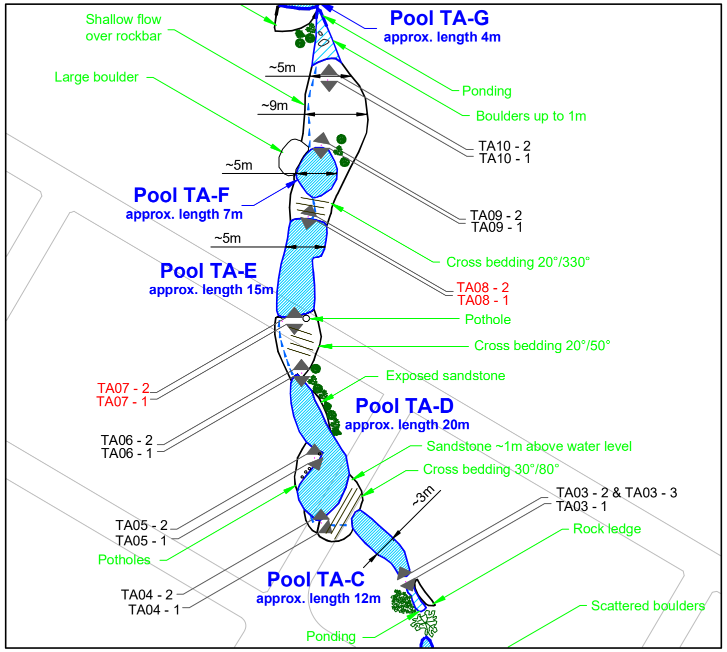
TA07-1 Upstream end of Pool TA-E looking Upstream

TA07-2 Upstream end of Pool TA-E looking Downstream

Notes (as at 5 January 2010)

- Pool TA-E approximately 15m long, 3 to 5m wide and 0.6m deep
- Base of the pool is sandstone
- Rockbar upstream of the pool is approximately 7m wide with cross bedding
- Flow path along western side of rockbar toward Pool TA-E

TA08-1 Downstream end of Pool TA-E looking Upstream



TA08-2 Downstream end of Pool TA-E looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA07-1	310210	6214184	180
TA07-2	310210	6214184	0
TA08-1	310214	6214200	190
TA08-2	310214	6214200	10

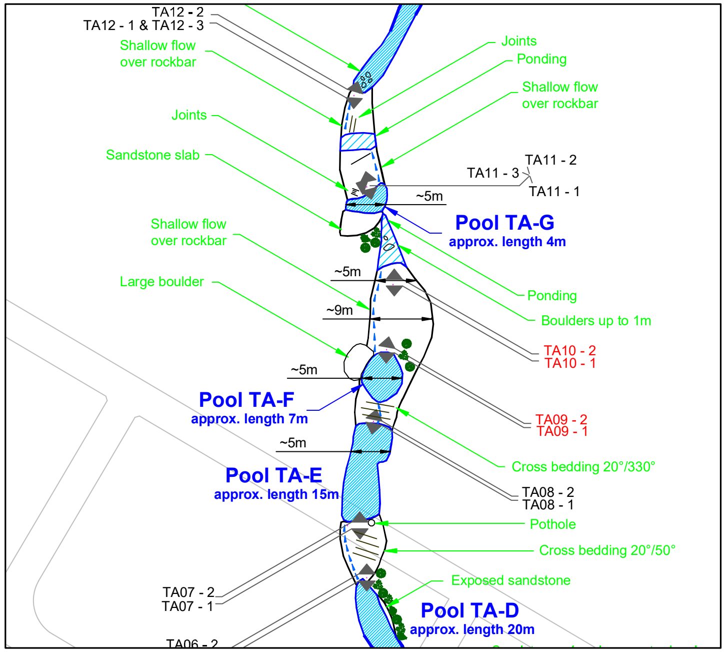
TRIBUTARY A STREAM MAPPING SUMMARY

TA09-1 Downstream end of Pool TA-F looking Upstream

TA09-2 Downstream end of Pool TA-F looking Downstream

Notes (as at 5 January 2010)

- Pool TA-F approximately 7m long, 3 to 5m wide and 0.3m deep
- Base of the pool is sandstone with minor alluvial deposits and algae
- Rockbar upstream of the pool is approximately 5m wide and 3m long with cross bedding
- Rockbar downstream of the pool is approximately 9m wide at the upstream end and 5m wide at the downstream end
- Flow path along western side of rockbar



TA10-1 Rockbar downstream of Pool TA-F looking Upstream

TA10-2 Rockbar downstream of Pool TA-F looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA09-1	310216	6214211	180
TA09-2	310216	6214211	10
TA10-1	310217	6214221	180
TA10-2	310217	6214221	0

TRIBUTARY A STREAM MAPPING SUMMARY

TA11-1 Downstream end of Pool TA-G looking Upstream

TA11-2 Downstream end of Pool TA-G looking Downstream

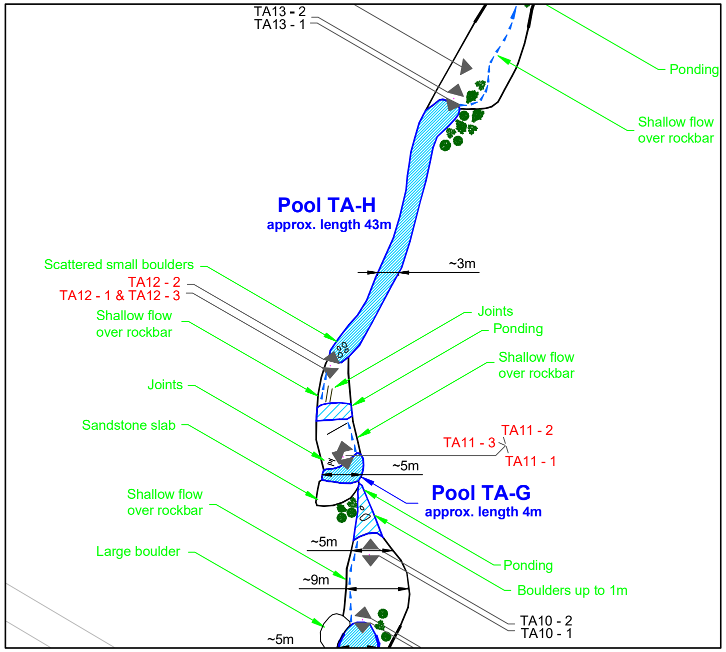
Notes (as at 5 January 2010)

- Pool TA-G approximately 4m long, 5m wide and 0.2m deep
- Base of the pool is sandstone
- Sandstone ledge and ponding upstream of the pool
- Rockbar downstream of the pool is approximately 14m long with ponding in the centre and many joints
- Flow path along eastern side of rockbar toward ponding, then along western side toward Pool TA-H

- Pool TA-H approximately 43m long, 3m wide and up to 1m deep
- Base of the pool is sandstone with alluvial deposits, scattered boulders at the upstream end, and dead trees at the downstream end

TA11-3 Joints

TA12-1 Upstream end of Pool TA-H looking Upstream



TA12-2 Upstream end of Pool TA-H looking Downstream

TA12-3 Joints

Photo Details

Photo ID	Easting	Northing	Bearing
TA11-1	310213	6214236	165
TA11-2	310213	6214236	345
TA11-3	310213	6214236	290
TA12-1	310211	6214250	180
TA12-2	310211	6214250	15
TA12-3	310211	6214250	180

TRIBUTARY A STREAM MAPPING SUMMARY

TA13-1 Downstream end of Pool TA-H looking Upstream

TA13-2 Downstream end of Pool TA-H looking Downstream

TA13-3 East Bank at downstream end of Pool TA-H

TA14-1 Rockbar downstream of Pool TA-H looking Upstream

TA14-2 Overhang looking Downstream (western side)

TA14-3 Overhang looking Downstream (eastern side)

Notes (as at 5 January 2010)

- Rockbar downstream of Pool TA-H is approximately 43m long and up to 9m wide
- Cross bedding is present at the downstream end
- Flow path part way along eastern side of the rockbar
- Flow emerges from bedding at overhang
- Overhang at the downstream end is approximately 1.8m high and 2 to 3m deep

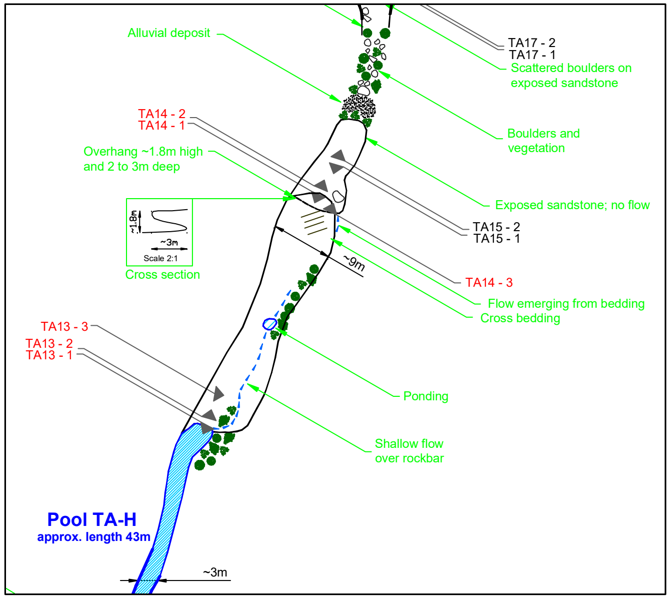


Photo Details

Photo ID	Easting	Northing	Bearing
TA13-1	310230	6214291	210
TA13-2	310230	6214291	15
TA13-3	310230	6214291	100
TA14-1	310249	6214330	25
TA14-2	310249	6214330	205
TA14-3	310249	6214330	25

TRIBUTARY A STREAM MAPPING SUMMARY

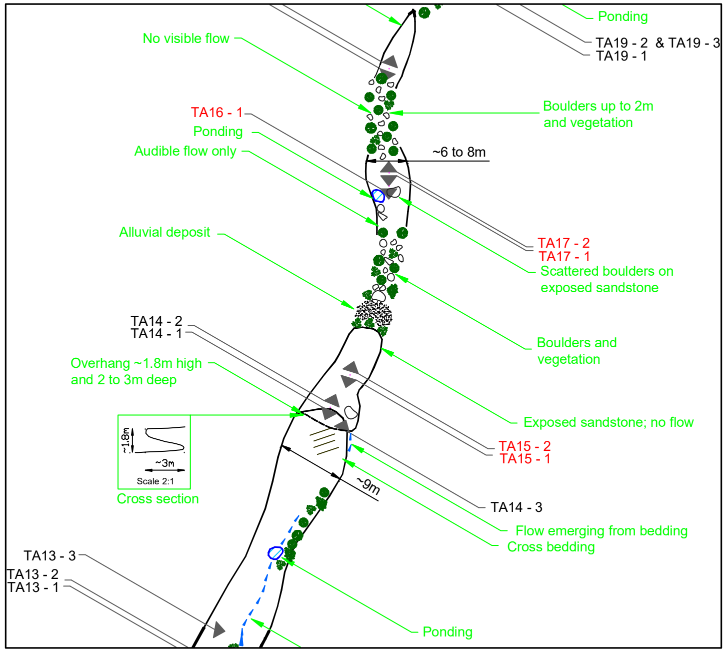
TA15-1 Rockbar downstream of overhang looking Upstream

TA15-2 Rockbar downstream of overhang looking Downstream

Notes (as at 5 January 2010)

- Rockbar approximately 13m long and up to 7m wide
- No visible flow across rockbar
- Alluvial deposit and vegetation at downstream end of rockbar leading into boulder field

- Boulder field opens up to rockbar 6 to 8m wide with scattered boulders and ponding
- Audible flow only
- Rockbar leads into boulder field at downstream end



TA16-1 Rockbar looking Upstream

TA17-1 Rockbar looking Upstream

TA17-2 Rockbar looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA15-1	310252	6214335	195
TA15-2	310252	6214335	15
TA16-1	310258	6214366	180
TA17-1	310258	6214364	180
TA17-2	310258	6214364	0

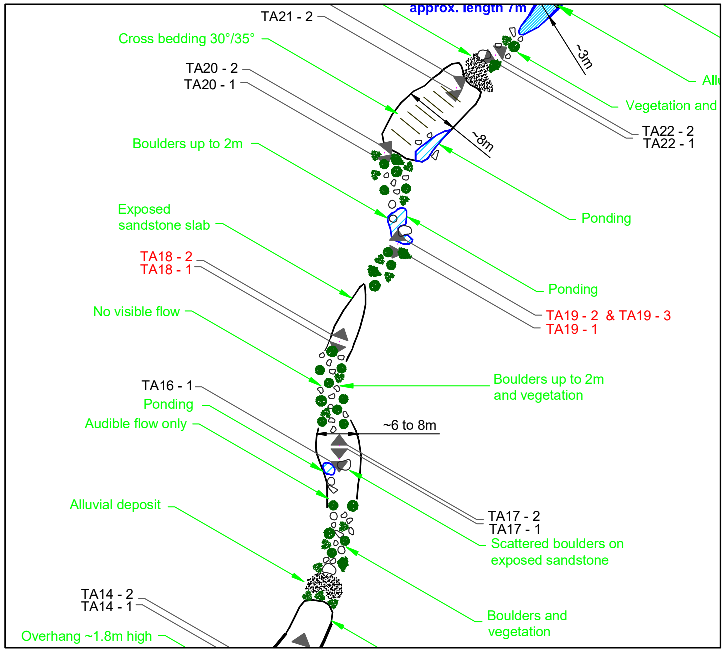
TRIBUTARY A STREAM MAPPING SUMMARY

TA18-1 Upstream end of rockbar looking Upstream

TA18-2 Upstream end of rockbar looking Downstream

Notes (as at 5 January 2010)

- No visible flow through boulder field and vegetation
- Rockbar downstream of boulder field is approximately 9m long and 4m wide, with vegetation at the downstream end
- Vegetation opens to ponding with scattered boulders up to 2m



TA19-1 Downstream of vegetation looking Upstream

TA19-2 Downstream of vegetation looking Downstream

TA19-3 Downstream of vegetation looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA18-1	310258	6214382	200
TA18-2	310258	6214382	20
TA19-1	310267	6214397	210
TA19-2	310267	6214397	0
TA19-3	310267	6214397	0

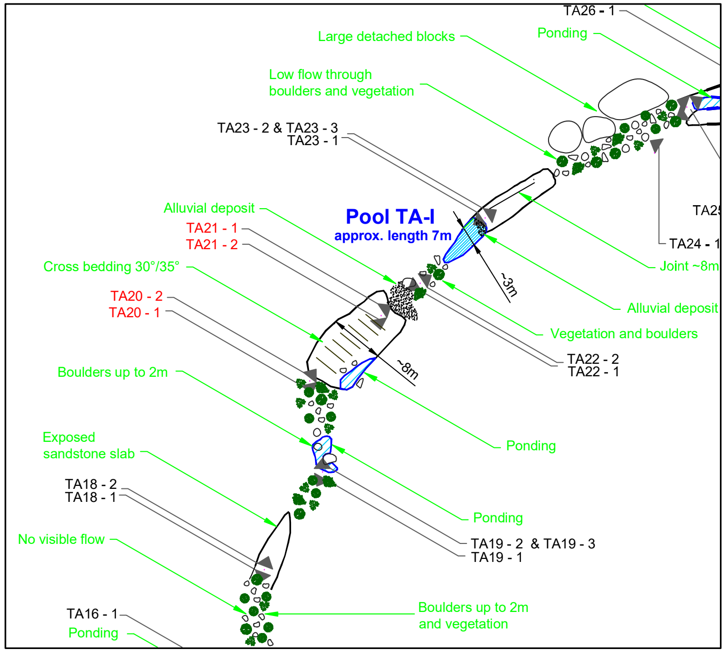
TRIBUTARY A STREAM MAPPING SUMMARY

TA20-1 Upstream end of rockbar looking Upstream

Notes (as at 5 January 2010)

- Rockbar is approximately 12m long and 8m wide with cross bedding and scattered vegetation debris
- Shallow ponding at eastern side of rockbar, with no visible flow downstream
- Alluvial deposit at downstream end of rockbar

TA20-2 Upstream end of rockbar looking Downstream



TA21-1 Downstream end of rockbar looking Downstream

TA21-2 Ponding at eastern side of rockbar

Photo Details

Photo ID	Easting	Northing	Bearing
TA20-1	310265	6214411	170
TA20-2	310265	6214411	40
TA21-1	310276	6214421	55
TA21-2	310276	6214421	170

TRIBUTARY A STREAM MAPPING SUMMARY

TA22-1 Near Upstream end of Pool TA-I looking Upstream

TA22-2 Near Upstream end of Pool TA-I looking Downstream

TA23-1 Downstream end of Pool TA-I looking Upstream

TA23-2 Downstream end of Pool TA-I looking Downstream

TA23-3 Joint downstream of Pool TA-I

Notes (as at 5 January 2010)

- Pool TA-I is approximately 7m long, 3m wide and 0.3m deep
- Base of the pool is sandstone with minor alluvial deposits at the downstream end, leaf litter and boulders up to 1m
- Boulder field and vegetation upstream of pool
- Rockbar downstream of the pool is approximately 12m long
- 8m long joint runs along rockbar on western side

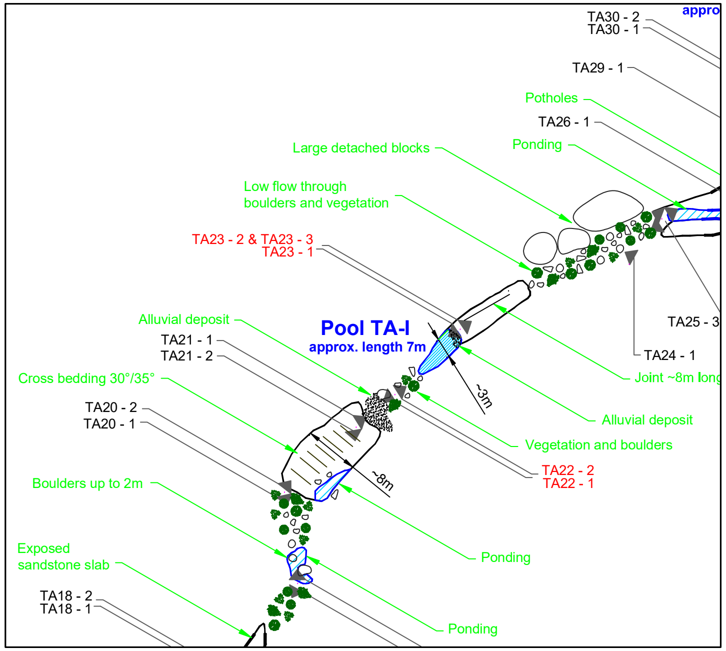


Photo Details

Photo ID	Easting	Northing	Bearing
TA22-1	310282	6214426	235
TA22-2	310282	6214426	55
TA23-1	310292	6214436	235
TA23-2	310292	6214436	55
TA23-3	310292	6214436	55

TRIBUTARY A STREAM MAPPING SUMMARY

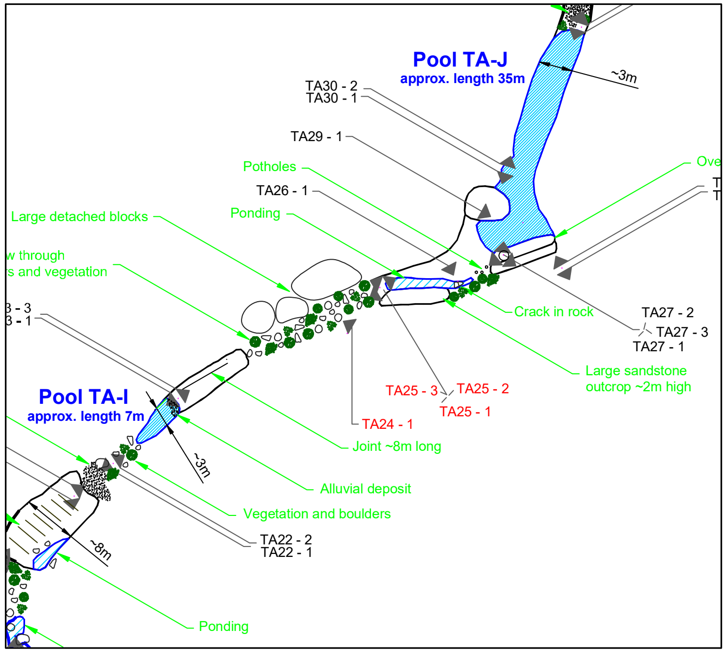
TA24-1 Large detached blocks on western bank

Notes (as at 5 January 2010)

- Low flow through boulder field, with shallow ponding and potholes downstream
- Large detached blocks on western bank up to 10m in size
- Large sandstone outcrop on eastern bank approximately 2m high

TA25-1 Downstream end of boulder field looking Upstream

TA25-2 Downstream end of boulder field looking Downstream



TA25-3 Large detached blocks on western bank

Photo Details

Photo ID	Easting	Northing	Bearing
TA24-1	310318	6214446	300
TA25-1	310323	6214453	240
TA25-2	310323	6214453	60
TA25-3	310323	6214453	290

TRIBUTARY A STREAM MAPPING SUMMARY

TA26-1 Cracking in rock

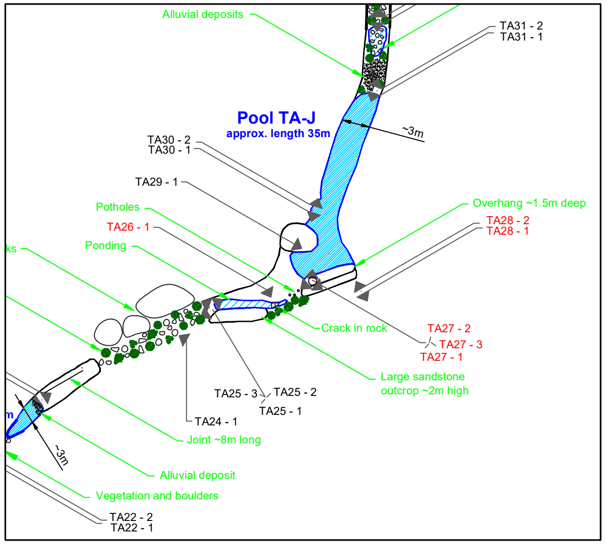
TA27-1 Upstream end of Pool TA-J looking Upstream

Notes (as at 5 January 2010)

- Cracking through rock surface at downstream end of ponding
- Exposed sandstone upstream of Pool TA-J
- No visible flow from minor tributary into Tributary A at confluence, but minor flow visible further downstream
- Approximate 3m change in height from Pool TA-J to minor tributary

TA27-2 Upstream end of Pool TA-J looking Downstream

TA27-3 Confluence of Tributary A and minor tributary



TA28-1 Minor tributary looking Upstream

TA28-2 Minor tributary looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA26-1	310335	6214454	150
TA27-1	310342	6214458	230
TA27-2	310342	6214458	5
TA27-3	310342	6214458	125
TA28-1	310351	6214456	150
TA28-2	310351	6214456	330

TRIBUTARY A STREAM MAPPING SUMMARY

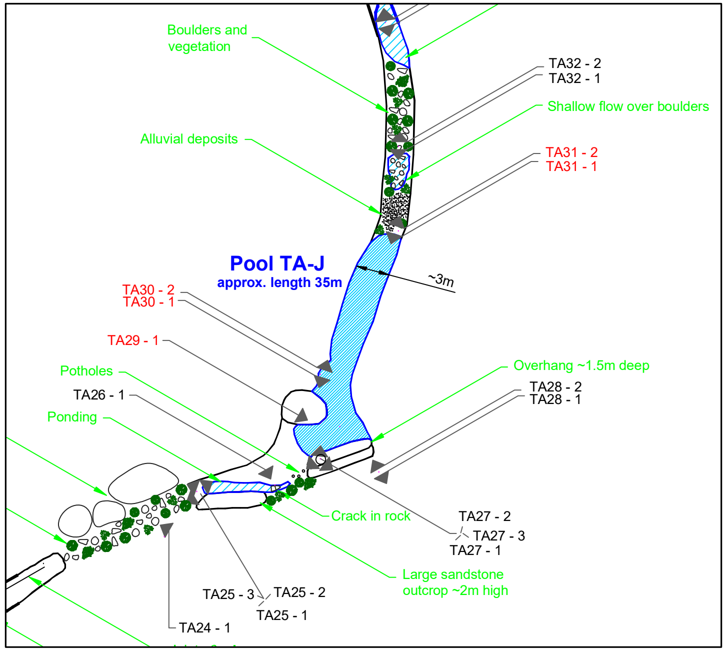
TA29-1 Upstream end of Pool TA-J looking to minor tributary

TA30-1 Part way along Pool TA-J looking Upstream

Notes (as at 5 January 2010)

- Pool TA-J approximately 35m long, 2 to 3m wide and up to 0.2m deep
- Base of the pool is sandstone with some alluvial deposits, and vegetation debris at the downstream end
- Overhang at upstream end of pool is approximately 1.5m deep
- Alluvial deposits and vegetation at downstream end of pool

TA30-2 Part way along Pool TA-J looking Downstream



TA31-1 Downstream end of Pool TA-J looking Upstream

TA31-2 Downstream end of Pool TA-J looking Downstream

Photo Details

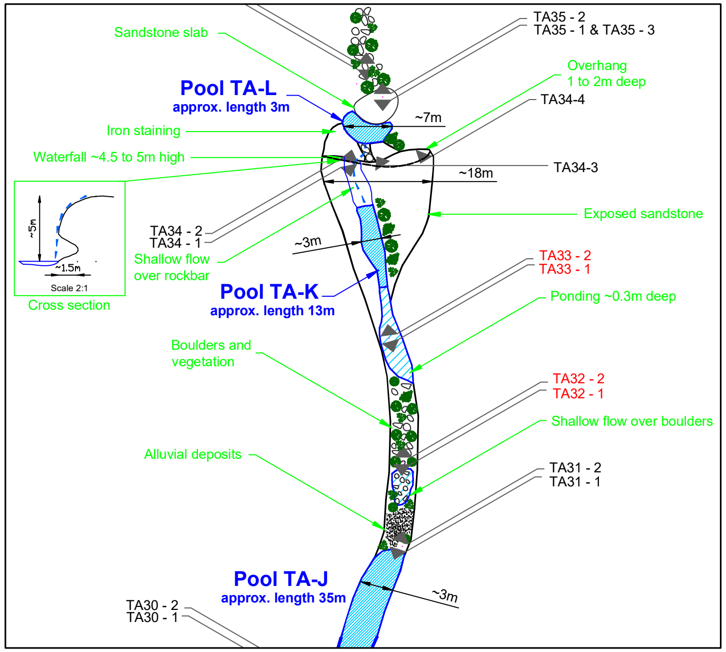
Photo ID	Easting	Northing	Bearing
TA29-1	310345	6214463	120
TA30-1	310342	6214471	200
TA30-2	310342	6214471	15
TA31-1	310354	6214493	200
TA31-2	310354	6214493	15

TRIBUTARY A STREAM MAPPING SUMMARY

TA32-1 Upstream end of boulder field looking Upstream

Notes (as at 5 January 2010)

- Ponding and shallow flow through boulder field
- Ponding upsteam of Pool TA-K up to 2m wide and 0.3m deep
- Pool TA-K approximately 12m long, 3m wide and 0.4m deep
- Base of pool is sandstone



TA32-2 Upstream end of boulder field looking Downstream

TA33-1 Rockbar upstream of Pool TA-K looking Upstream

TA33-2 Rockbar upstream of Pool TA-K looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA32-1	310354	6214506	180
TA32-2	310354	6214506	0
TA33-1	310352	6214525	165
TA33-2	310352	6214525	350

TRIBUTARY A STREAM MAPPING SUMMARY

TA34-1 At top of waterfall looking upstream toward Pool TA-K

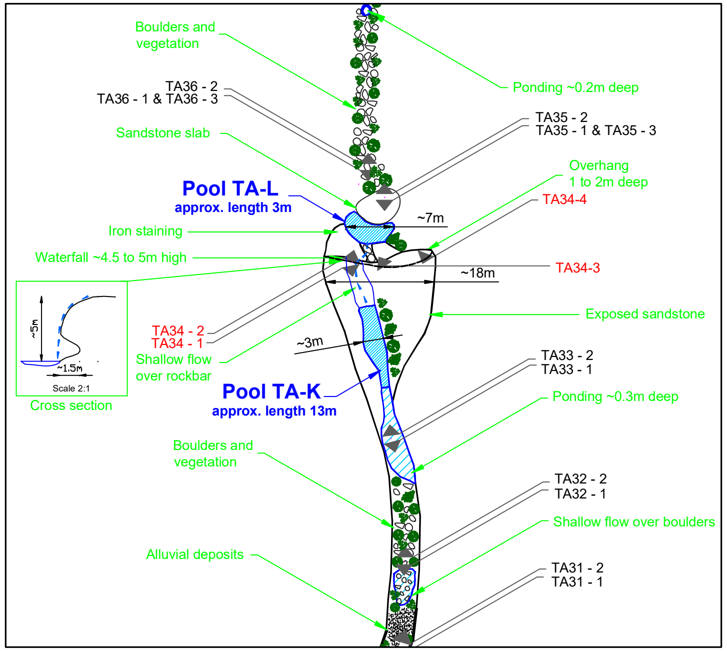
Notes (as at 5 January 2010)

- Waterfall drops approximately 4.5 to 5m
- Depth of overhang is approximately 1.5m
- Rockbar upstream of waterfall is approximately 18m wide

- Pool TA-L approximately 3m long, 7m wide and up to 0.7m deep at western side
- Base of the pool is sandstone with minor alluvial deposits
- Iron staining evident at western side and beneath waterfall

TA34-2 At top of waterfall looking Downstream

TA34-3 Pool TA-L below waterfall



TA34-4 At top of waterfall looking toward west bank

Photo Details

Photo ID	Easting	Northing	Bearing
TA34-1	310346	6214552	170
TA34-2	310346	6214552	15
TA34-3	310351	6214552	325
TA34-4	310357	6214553	200

TRIBUTARY A STREAM MAPPING SUMMARY

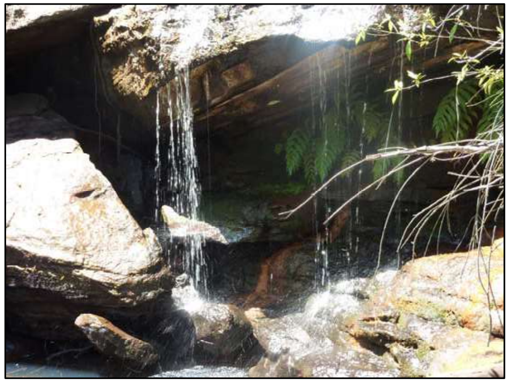
TA35-1 Downstream end of Pool TA-L looking Upstream

TA35-2 Downstream end of Pool TA-L looking Downstream

Notes (as at 5 January 2010)

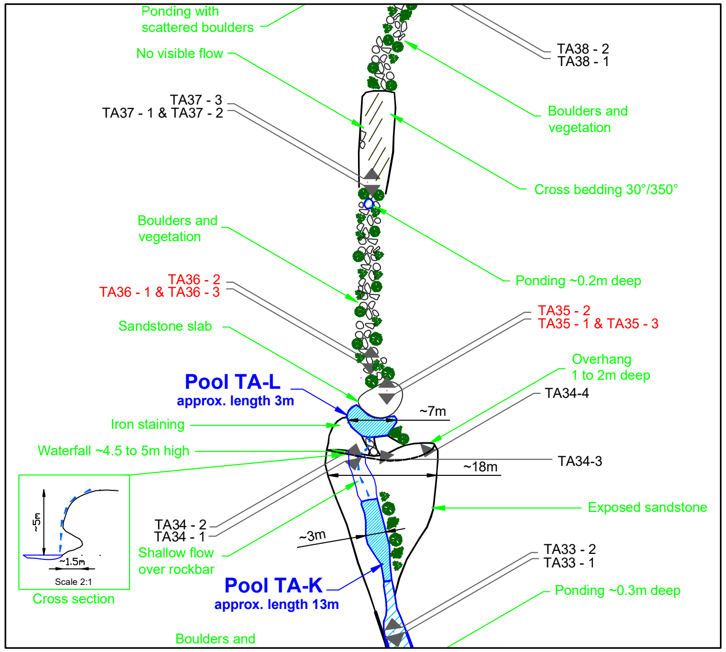
- Waterfall drops approximately 4.5 to 5m
- Depth of overhang is approximately 1.5m

- Pool TA-L approximately 3m long, 7m wide and up to 0.7m deep at western side
- Base of the pool is sandstone with minor alluvial deposits
- Iron staining evident at western side and beneath waterfall
- Boulder field and vegetation downstream of pool



TA35-3 Overhang

TA36-1 Downstream of Pool TA-L looking Upstream



TA36-2 Downstream of Pool TA-L looking Downstream

TA36-3 Waterfall

Photo Details

Photo ID	Easting	Northing	Bearing
TA35-1	310351	6214562	180
TA35-2	310351	6214562	0
TA35-3	310351	6214562	180
TA36-1	310347	6214564	180
TA36-2	310347	6214564	0
TA36-3	310347	6214564	180

TRIBUTARY A STREAM MAPPING SUMMARY

TA37-1 and TA37-2 Upstream end of rockbar looking Upstream

TA37-3 Upstream end of rockbar looking Downstream

TA38-1 Downstream end of boulder field looking Upstream

TA38-2 Downstream end of boulder field looking Downstream

Notes (as at 5 January 2010)

- Rockbar approximately 15m long and 5m wide
- Cross bedding and scattered debris
- No visible flow across rockbar
- Boulder field, vegetation and ponding upstream of rockbar
- Boulder field and vegetation downstream of rockbar

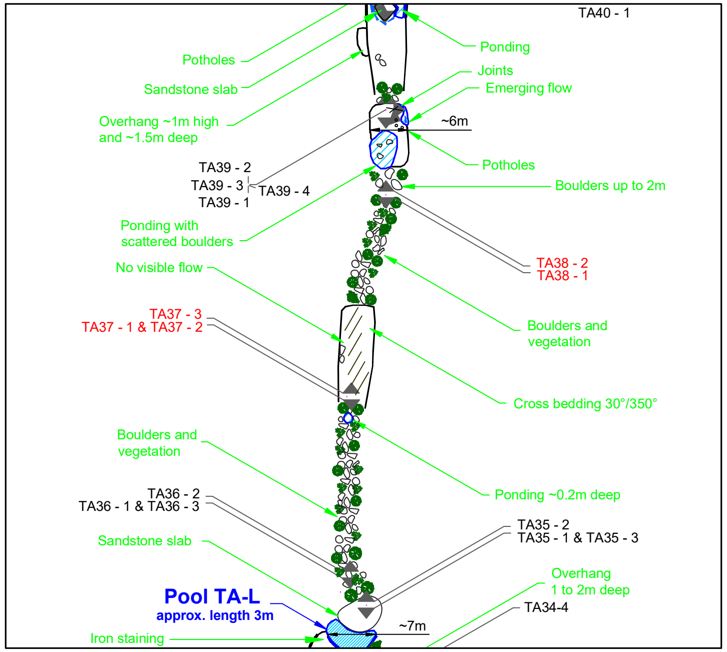


Photo Details

Photo ID	Easting	Northing	Bearing
TA37-1	310348	6214594	180
TA37-2	310348	6214594	180
TA37-3	310348	6214594	0
TA38-1	310354	6214625	180
TA38-2	310354	6214625	0

TRIBUTARY A STREAM MAPPING SUMMARY

TA39-1 Downstream end of rockbar looking Upstream

TA39-2 Downstream end of rockbar looking Downstream

TA39-3 Emerging flow on eastern side

TA39-4 Joints and potholes

Notes (as at 5 January 2010)

- Rockbar approximately 9m long and 6m wide
- Ponding at upstream end of rockbar on western side
- Flow emerges at downstream end of rockbar on eastern side
- Joints and potholes at downstream end

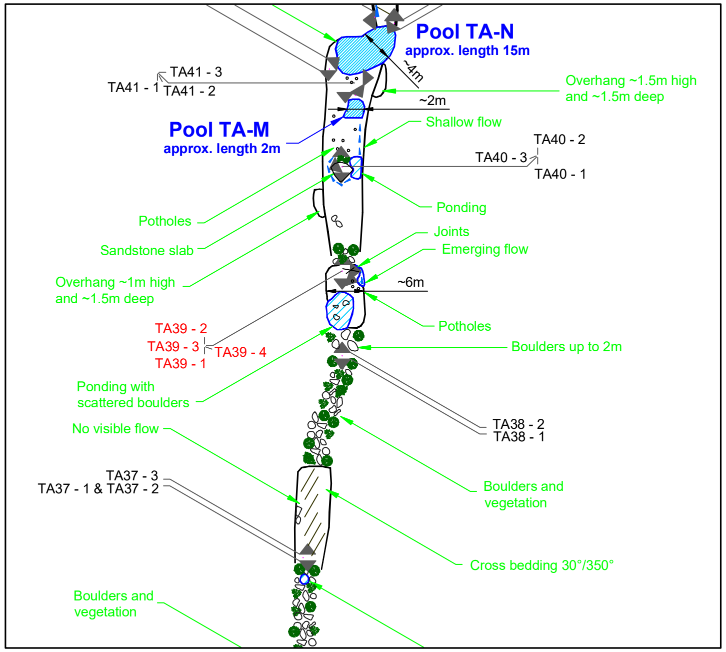


Photo Details

Photo ID	Easting	Northing	Bearing
TA39-1	310354	6214638	180
TA39-2	310354	6214638	0
TA39-3	310354	6214638	110
TA39-4	310354	6214638	90

TRIBUTARY A STREAM MAPPING SUMMARY


TA40-1 Rockbar upstream of Pool TA-M looking Upstream

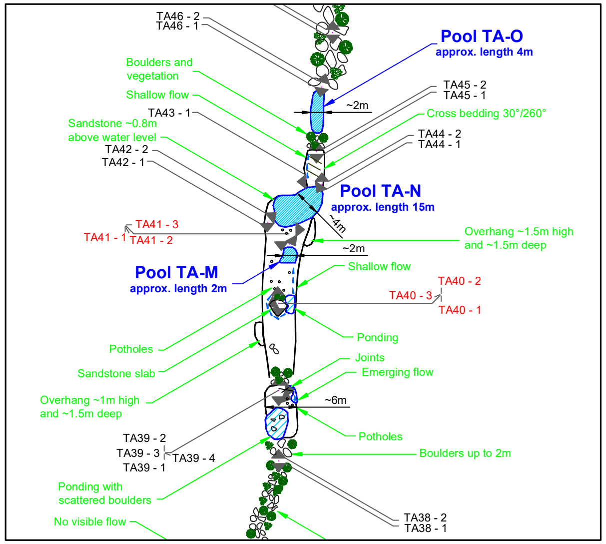

TA40-2 Rockbar upstream of Pool TA-M looking Downstream

Notes (as at 5 January 2010)

- Pool TA-M approximately 2.5m long, 2m wide and 0.6m deep
- Base of the pool is sandstone with alluvial deposits and small boulders
- Rockbar upstream of pool has ponding and many potholes
- No visible flow at upstream end of rockbar
- Flow path at downstream end of rockbar along eastern side toward Pool TA-M


TA40-3 Overhang on west bank


TA41-1 Downstream end of Pool TA-M looking Upstream




TA41-2 Pool TA-M


TA41-3 Overhang on east bank

Photo Details

Photo ID	Easting	Northing	Bearing
TA40-1	310354	6214654	180
TA40-2	310354	6214654	0
TA40-3	310354	6214654	245
TA41-1	310356	6214665	180
TA41-2	310356	6214665	150
TA41-3	310356	6214665	90

TRIBUTARY A STREAM MAPPING SUMMARY

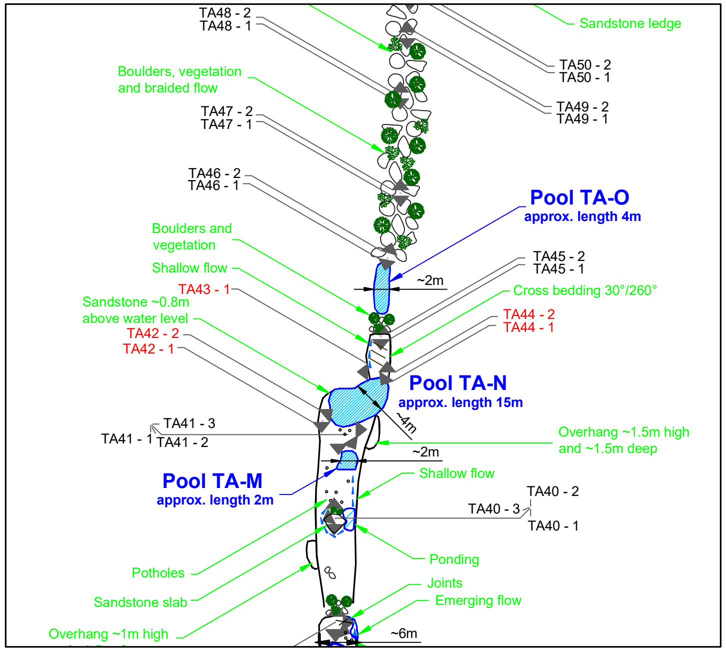
TA42-1 Upstream end of Pool TA-N looking Upstream

TA42-2 Upstream end of Pool TA-N looking Downstream

Notes (as at 5 January 2010)

- Pool TA-N approximately 15m long, 4m wide and 0.8m deep
- Base of the pool is sandstone with alluvial deposits
- Rockbar at upstream end is approximately 0.8m above water level
- Rockbar at downstream end is approximately 6m long and 3m wide with cross bedding
- Flow path down western side of rockbar

TA44-1 Downstream end of Pool TA-N looking Upstream



TA43-1 Overhang on west bank

TA44-2 Downstream end of Pool TA-N looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA42-1	310352	6214669	180
TA42-2	310352	6214669	50
TA43-1	310359	6214677	270
TA44-1	310362	6214676	215
TA44-2	310362	6214676	0

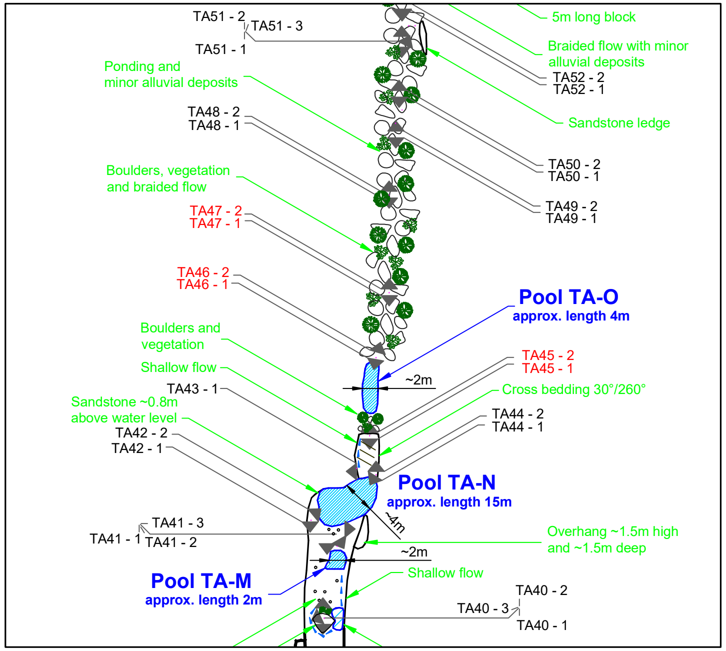
TRIBUTARY A STREAM MAPPING SUMMARY

TA45-1 Downstream end of rockbar looking Upstream

TA45-2 Downstream end of rockbar looking Downstream

Notes (as at 5 January 2010)

- Pool TA-O approximately 4m long, 2m wide and 0.2m deep
- Base of the pool is sandstone with alluvial deposits and small boulders
- Boulders, vegetation and braided flow downstream of pool



TA46-1 Downstream end of Pool TA-O looking Upstream

TA46-2 Downstream end of Pool TA-O looking Downstream

TA47-1 Boulder field looking Upstream

TA47-2 Boulder field looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA45-1	310361	6214682	180
TA45-2	310361	6214682	0
TA46-1	310362	6214694	190
TA46-2	310362	6214694	15
TA47-1	310364	6214704	180
TA47-2	310364	6214704	0

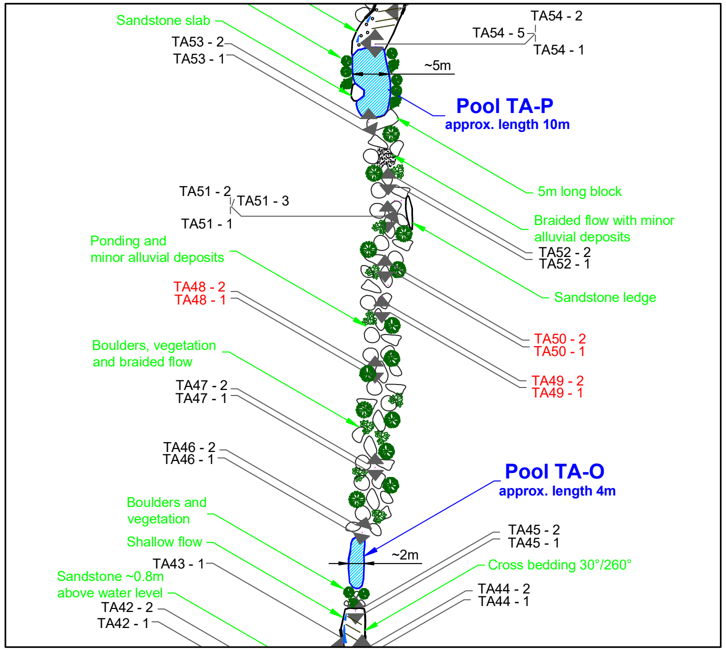
TRIBUTARY A STREAM MAPPING SUMMARY

TA48-1 Boulder field looking Upstream

TA48-2 Boulder field looking Downstream

Notes (as at 5 January 2010)

- Boulder field with vegetation, braided flow, minor alluvial deposits and minor ponding
- Boulder field extends over approximately 55m



TA49-1 Boulder field looking Upstream

TA49-1 Boulder field looking Downstream

TA50-1 Boulder field looking Upstream

TA50-2 Boulder field looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA48-1	310364	6214719	180
TA48-2	310364	6214719	0
TA49-1	310365	6214730	180
TA49-2	310365	6214730	0
TA50-1	310366	6214732	180
TA50-2	310366	6214732	0

TRIBUTARY A STREAM MAPPING SUMMARY

TA51-1 At sandstone ledge looking Upstream

TA51-2 At sandstone ledge looking Downstream

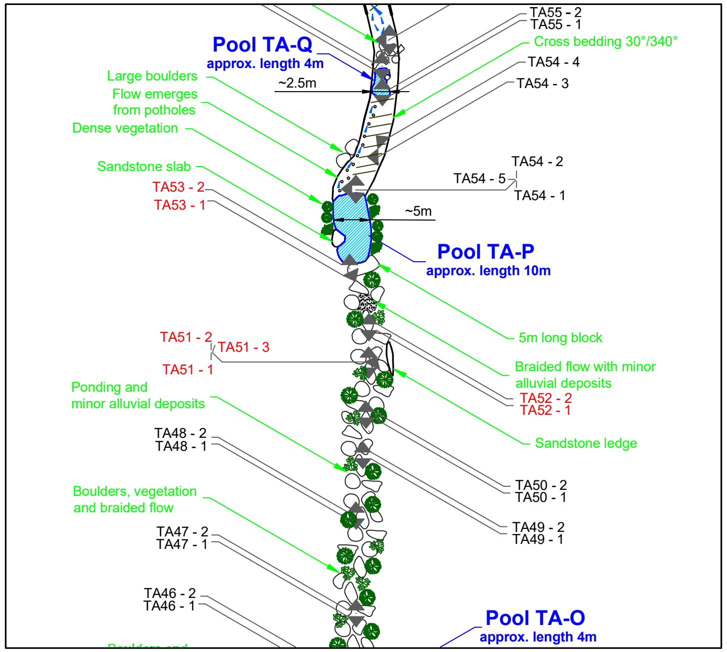
TA51-3 East bank

Notes (as at 5 January 2010)

- Boulder field with vegetation, braided flow, minor alluvial deposits and minor ponding
- Boulder field extends over approximately 55m

TA52-1 Boulder field looking Upstream

TA52-2 Boulder field looking Downstream



TA53-1 Upstream end of Pool TA-P looking Upstream

TA53-2 Upstream end of Pool TA-P looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA51-1	310367	6214745	180
TA51-2	310367	6214745	0
TA51-3	310367	6214745	20
TA52-1	310368	6214745	180
TA52-2	310368	6214745	0
TA53-1	310363	6214757	160
TA53-2	310363	6214757	0

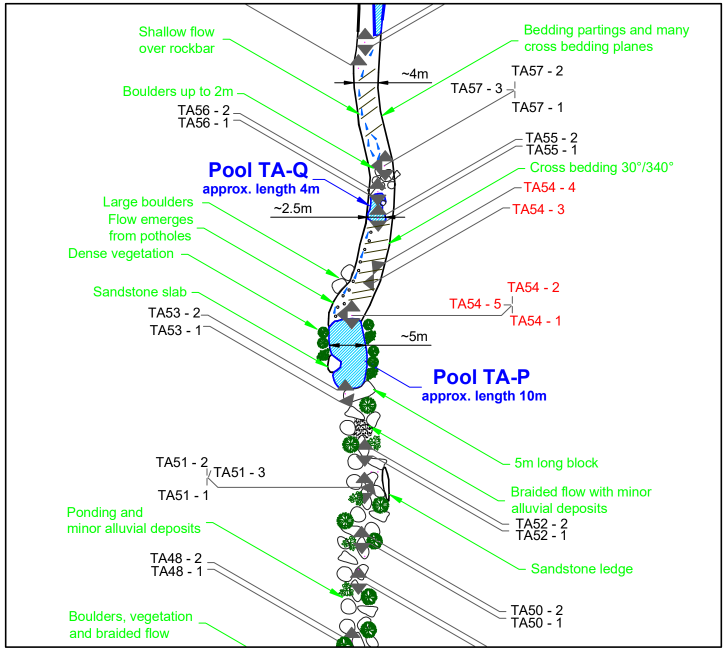
TRIBUTARY A STREAM MAPPING SUMMARY

TA54-1 Downstream end of Pool TA-P looking Upstream

TA54-2 Downstream end of Pool TA-P looking Downstream

Notes (as at 5 January 2010)

- Pool TA-P approximately 10m long, 5m wide and 0.7 to 1m deep
- Base of the pool is sandstone with alluvial deposits and boulders up to 1m
- Rockbar downstream of the pool is approximately 14m long and 4m wide
- Cross bedding along length of rockbar with many potholes
- Flow path down western side of rockbar



TA54-3 Cross bedding

TA54-4 Potholes at downstream end of rockbar

TA54-5 Potholes at upstream end of rockbar

Photo Details

Photo ID	Easting	Northing	Bearing
TA54-1	310364	6214769	180
TA54-2	310364	6214769	0
TA54-3	310368	6214775	270
TA54-4	310368	6214775	315
TA54-5	310364	6214769	270

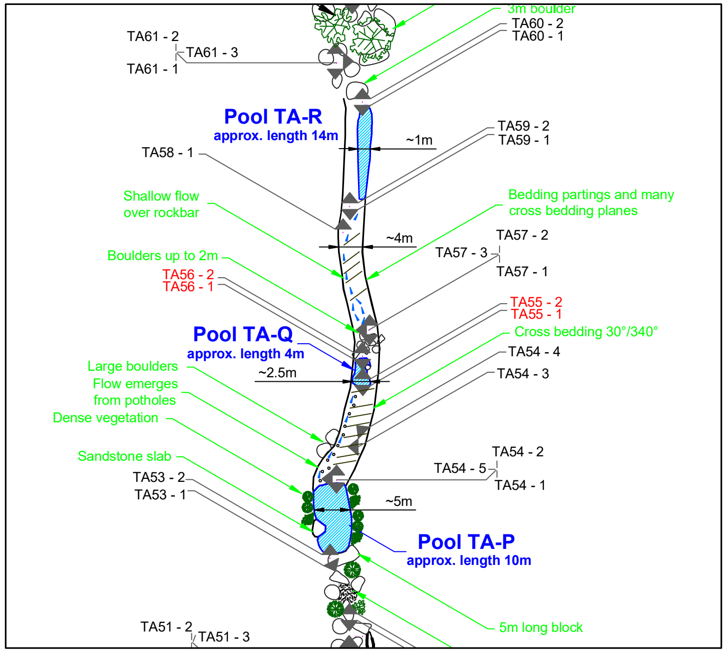
TRIBUTARY A STREAM MAPPING SUMMARY

TA55-1 Upstream end of Pool TA-Q looking Upstream

TA55-2 Upstream end of Pool TA-Q looking Downstream

Notes (as at 5 January 2010)

- Pool TA-Q approximately 4m long, 2.5m wide and 0.5m deep
- Base of the pool is sandstone with alluvial deposits and algae
- Rockbar with scattered boulders and minor ponding downstream of pool



TA56-1 Downstream end of Pool TA-Q looking Upstream

TA56-2 Downstream end of Pool TA-Q looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA55-1	310368	6214784	180
TA55-2	310368	6214784	0
TA56-1	310368	6214788	180
TA56-2	310368	6214788	0

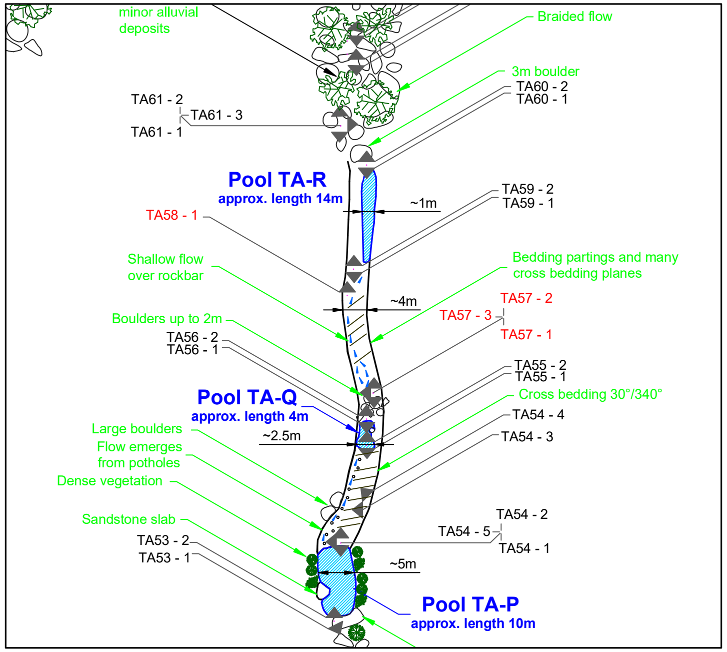
TRIBUTARY A STREAM MAPPING SUMMARY

TA57-1 Upstream end of rockbar looking Upstream

<u>Notes (as at 5 January 2010)</u>

- Rockbar approximately 20m long and 4m wide
- Cross bedding
- Flow path along western side of rockbar toward Pool TA-R

TA57-2 Upstream end of rockbar looking Downstream



TA57-3 West bank

TA58-1 Downstream end of rockbar looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA57-1	310369	6214792	180
TA57-2	310369	6214792	0
TA57-3	310369	6214792	270
TA58-1	310365	6214807	0

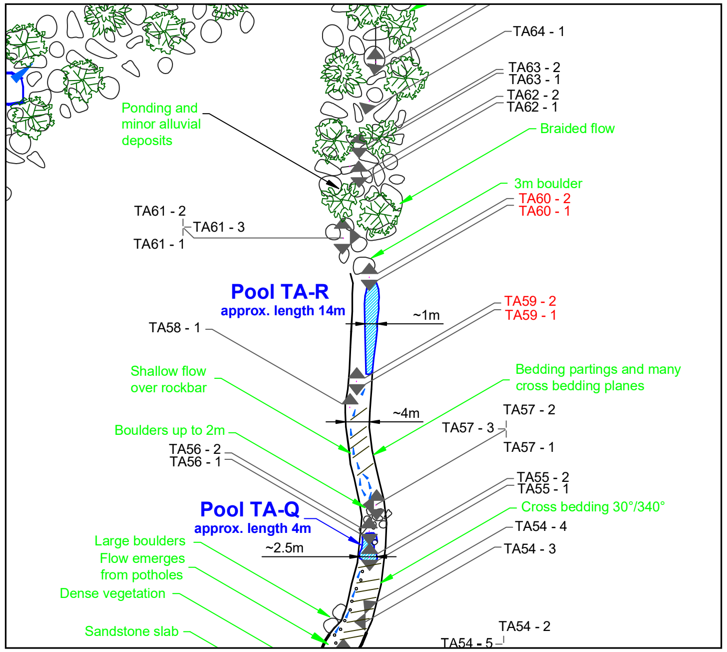
TRIBUTARY A STREAM MAPPING SUMMARY

TA59-1 Upstream end of Pool TA-R looking Upstream

TA59-2 Upstream end of Pool TA-R looking Downstream

Notes (as at 5 January 2010)

- Pool TA-R approximately 14m long, 1m wide and 0.3m deep
- Base of the pool is sandstone with minor alluvial deposits
- Boulder field, vegetation and braided flow downstream of pool



TA60-1 Downstream end of Pool TA-R looking Upstream

TA60-2 Downstream end of Pool TA-R looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA59-1	310366	6214811	180
TA59-2	310366	6214811	0
TA60-1	310368	6214827	180
TA60-2	310368	6214827	0

TRIBUTARY A STREAM MAPPING SUMMARY

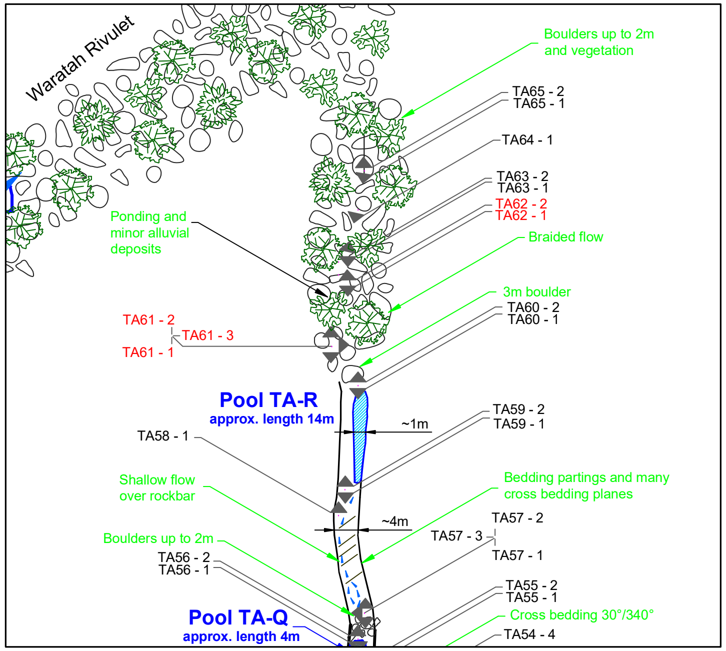
TA61-1 Boulder field looking Upstream

TA61-2 Boulder field looking Downstream

Notes (as at 5 January 2010)

- Boulder field extends over approximately 50m
- Boulders up to 2m, vegetation and braided flow

TA61-3 East bank



TA62-1 Boulder field looking Upstream

TA62-2 Boulder field looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TA61-1	310364	6214833	180
TA61-2	310364	6214833	0
TA61-3	310364	6214833	90
TA62-1	310365	6214844	180
TA62-2	310365	6214844	0

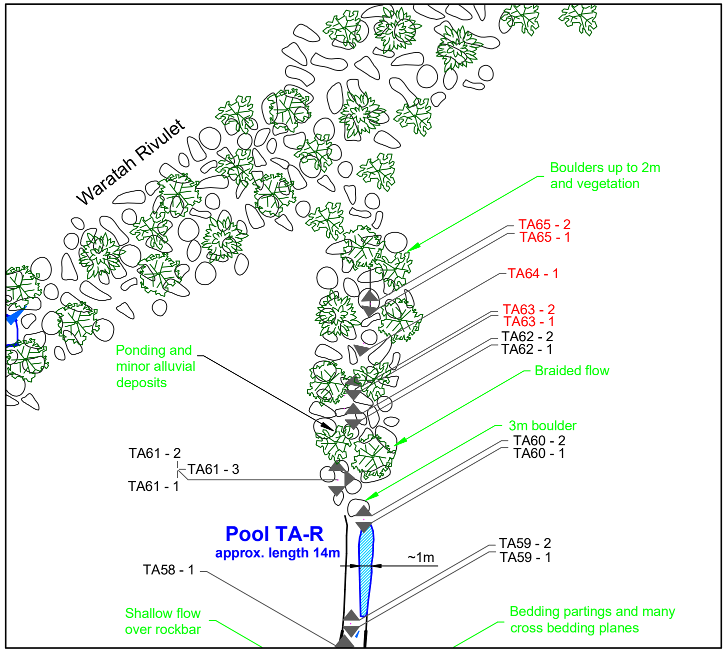
TRIBUTARY A STREAM MAPPING SUMMARY

TA63-1 Boulder field looking Upstream

TA63-2 Boulder field looking Downstream

Notes (as at 5 January 2010)

- Boulder field extends over approximately 50m
- Boulders up to 2m, vegetation and braided flow



TA64-1 Boulder field looking Upstream

TA65-1 Boulder field looking Upstream

TA65-2 Boulder field looking Downstream toward Waratah Rivulet

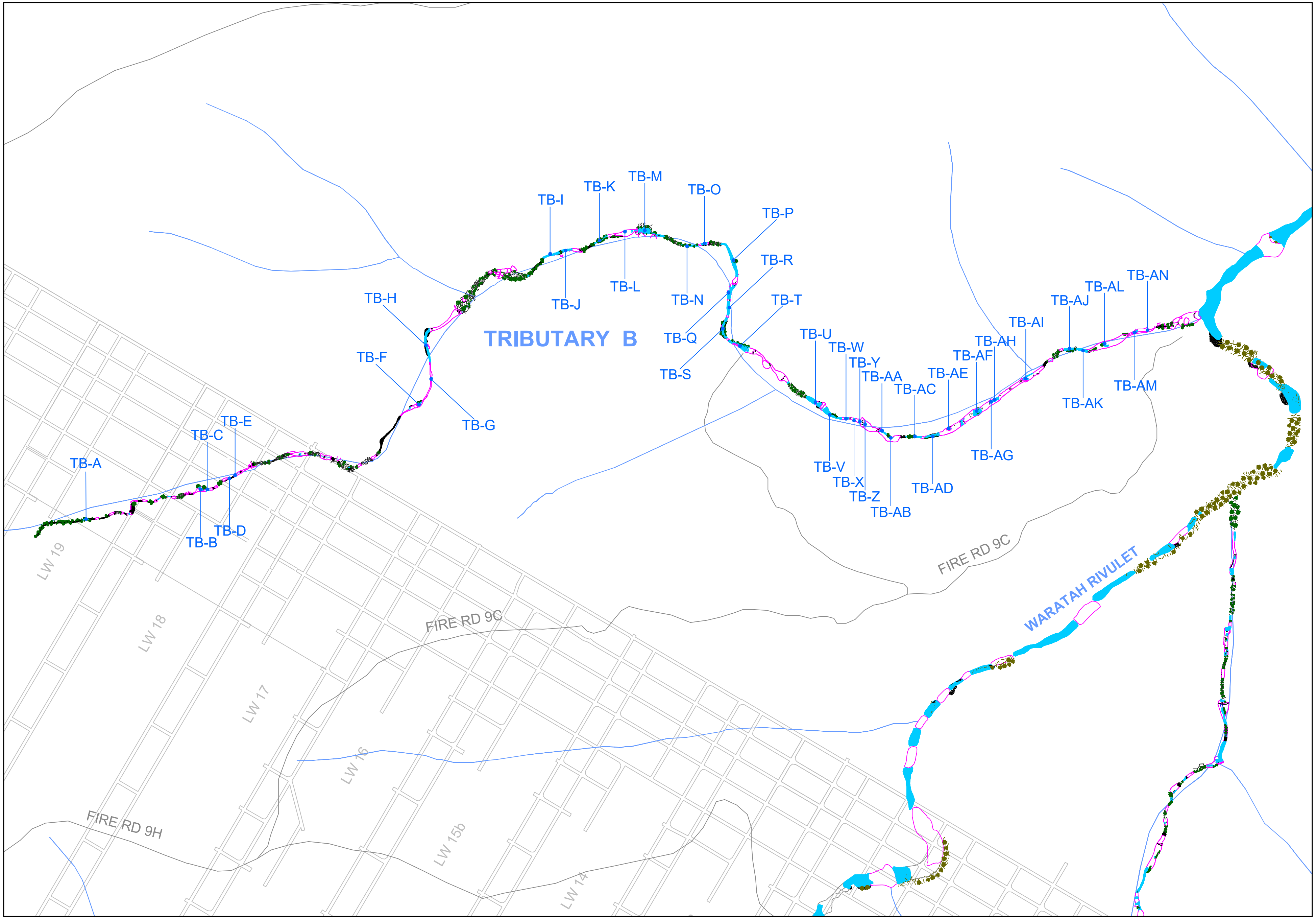
Photo Details

Photo ID	Easting	Northing	Bearing
TA63-1	310365	6214846	180
TA63-2	310365	6214846	10
TA64-1	310368	6214854	190
TA65-1	310369	6214860	190
TA65-2	310369	6214860	0

APPENDIX 4

TRIBUTARY B STREAM MAPPING AND PHOTOGRAPHIC RECORD

TRIBUTARY B – GENERAL LAYOUT



TRIBUTARY B STREAM MAPPING SUMMARY

Legend:

A-1	Photo Direction Arrow		Water flow
	Pool		Pooled Water
	Rockbar		Alluvial Deposits (Sand)
	Boulders		Potholes
	Cross bedding		Vegetation - shrubs, bushes and small trees
	Joint		Slope Direction

TRIBUTARY B STREAM MAPPING SUMMARY

TB001-1 Upstream end of Tributary B looking toward northern bank

TB002-1 Upstream end of Tributary B looking Upstream

TB002-2 Upstream end of Tributary B looking Downstream

TB002-3 Upstream end of Tributary B looking down

TB003-1 Upstream end of Tributary B looking down

TB004-1 Upstream end of Tributary B looking toward northern bank

Notes (as at 22 December 2009)

- Damp, sandy creek bed with alluvial deposits
- No flow visible
- Dense vegetation

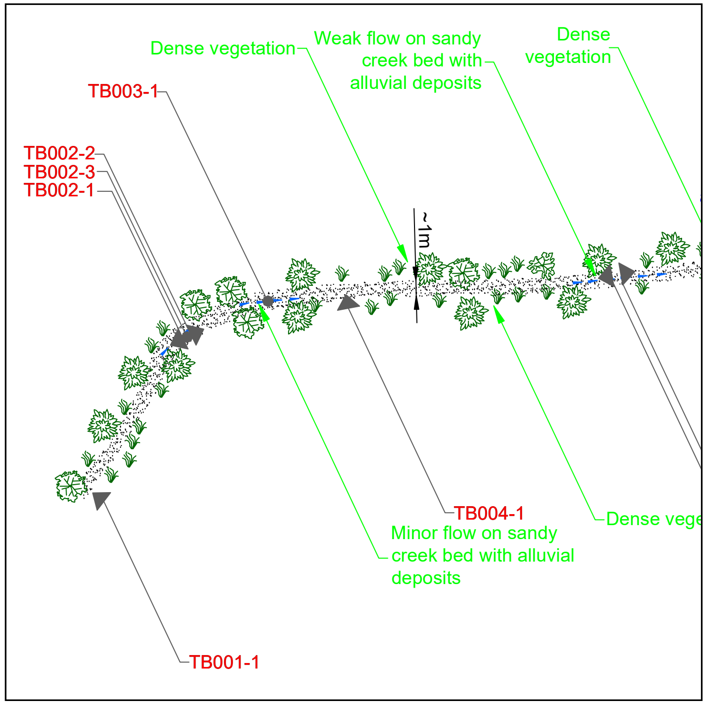


Photo Details

Photo ID	Easting	Northing	Bearing
TB001-1	308457	6214818	310
TB002-1	308466	6214836	240
TB002-2	308466	6214836	65
TB002-3	308466	6214836	-
TB003-1	308475	6214840	-
TB004-1	308484	6214839	350

TRIBUTARY B STREAM MAPPING SUMMARY

TB005-1 Upstream from Pool TB-A looking Upstream

TB005-2 Upstream from Pool TB-A looking Downstream

TB006-1 Midway along Pool TB-A looking Upstream

TB006-2 Midway along Pool TB-A looking Downstream

TB007-1 Downstream from Pool TB-A looking Upstream

TB007-2 Downstream from Pool TB-A looking Downstream

Notes (as at 22 December 2009)

- Pool TB-A approximately 8m long, 1m wide and 0.2m deep
- Base of the pool is alluvial with leaf litter
- Vegetation encroaches on pool from both sides
- Dense vegetation upstream of the pool
- Alluvial deposits downstream of the pool

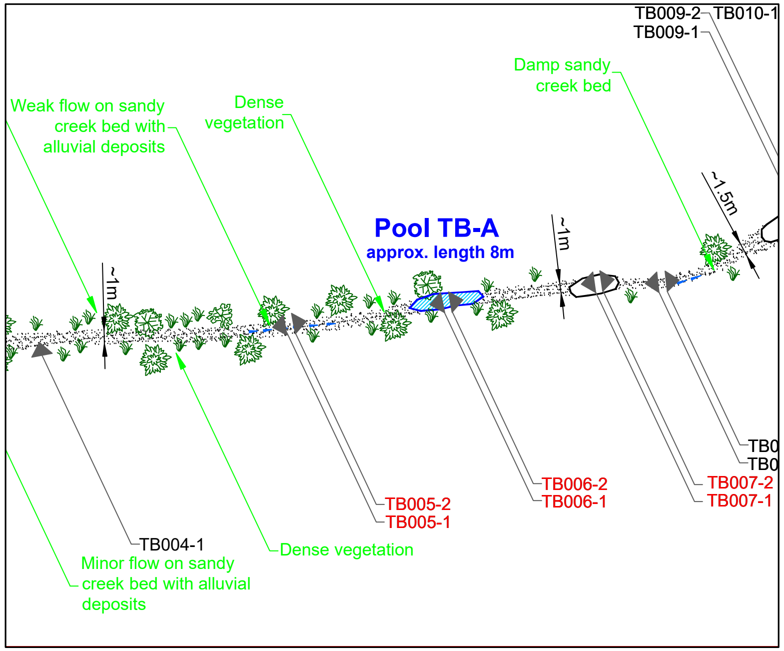


Photo Details

Photo ID	Easting	Northing	Bearing
TB005-1	308514	6214843	260
TB005-2	308514	6214843	80
TB006-1	308532	6214849	260
TB006-2	308532	6214849	85
TB007-1	308551	6214848	265
TB007-2	308551	6214848	80

TRIBUTARY B STREAM MAPPING SUMMARY

TB008-1 Downstream from Pool TB-A looking Upstream

TB008-2 Downstream from Pool TB-A looking Downstream

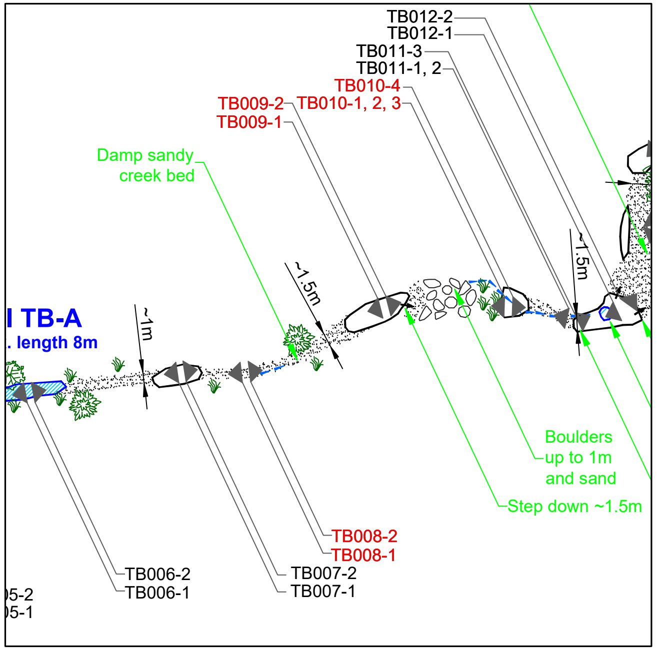
TB009-1 Downstream from Pool TB-A looking Upstream

Notes (as at 22 December 2009)

- Damp, sandy creek bed approximately 1m wide
- Flow path along southern side downstream of TB008
- Sandy banks with vegetation
- Rockbar at TB009 approximately 1.5m wide, with boulders downstream

TB009-2 Downstream from Pool TB-A looking Downstream

TB010-1 Downstream from Pool TB-A looking Upstream



TB010-2 Downstream from Pool TB-A looking Upstream

TB010-3 Downstream from Pool TB-A looking Upstream

TB010-4 Downstream from Pool TB-A looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB008-1	308559	6214848	265
TB008-2	308559	6214848	80
TB009-1	308576	6214856	250
TB009-2	308576	6214856	80
TB010-1	308591	6214856	275
TB010-2	308591	6214856	275
TB010-3	308591	6214856	275
TB010-4	308591	6214856	95

TRIBUTARY B STREAM MAPPING SUMMARY

TB011-1 Rockbar looking Upstream

TB011-2 Rockbar looking Upstream

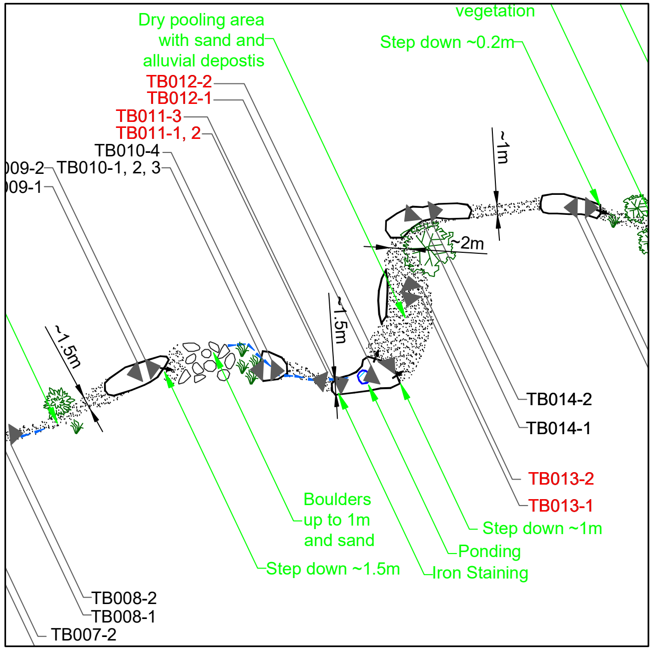
TB011-3 Rockbar looking Downstream

Notes (as at 22 December 2009)

- Rockbar at TB011 approximately 1.5m wide at upstream end
- Rockbar has ponding and iron staining downstream
- Step down approximately 1m at TB013 with alluvial deposits downstream

TB012-1 Rockbar looking Upstream

TB012-2 Rockbar looking Downstream



TB013-1 Dry creek bed looking Upstream

TB013-2 Dry creek bed looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB011-1	308599	6214854	285
TB011-2	308599	6214854	285
TB011-3	308599	6214854	65
TB012-1	308603	6214854	245
TB012-2	308603	6214854	70
TB013-1	308610	6214866	195
TB013-2	308610	6214866	345

TRIBUTARY B STREAM MAPPING SUMMARY

TB014-1 Rockbar looking Upstream

TB014-2 Rockbar looking Downstream

TB015-1 Rockbar looking Upstream

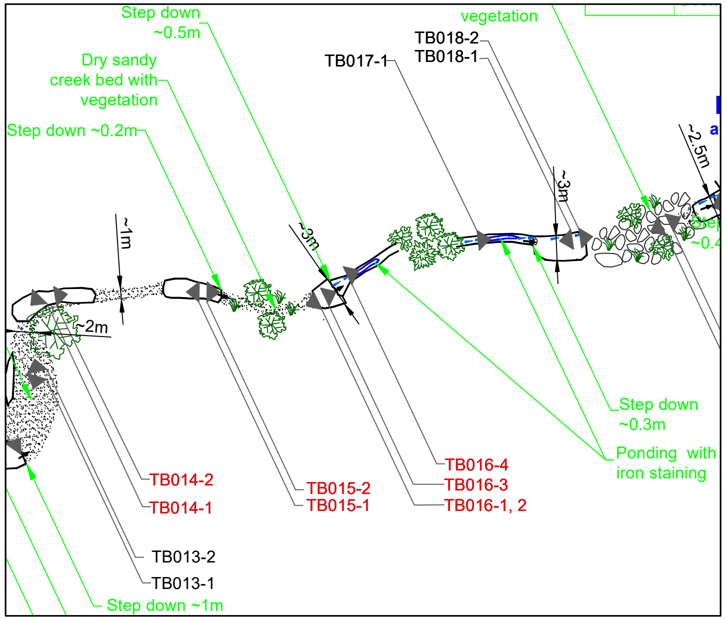
Notes (as at 22 December 2009)

- Rockbar at TB014 approximately 1m wide, with alluvial deposits upsteam and downstream
- Rockbar at TB015 approximately 1.5m wide, with alluvial deposits upsteam and vegetation downstream
- Ponding with iron staining at TB016

TB015-2 Rockbar looking Downstream

TB016- Looking Upstream

TB016-2 Looking Upstream



TB016-3 Looking Downstream

TB016-4 Ponding and iron staining looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB014-1	308610	6214875	285
TB014-2	308610	6214875	85
TB015-1	308628	6214876	180
TB015-2	308628	6214876	90
TB016-1	308644	6214875	245
TB016-2	308644	6214875	245
TB016-3	308644	6214875	65
TB016-4	308644	6214875	65

TRIBUTARY B STREAM MAPPING SUMMARY

TB017-1 Upstream from Pool TB-B looking Downstream

TB018-1 Upstream from Pool TB-B looking Upstream

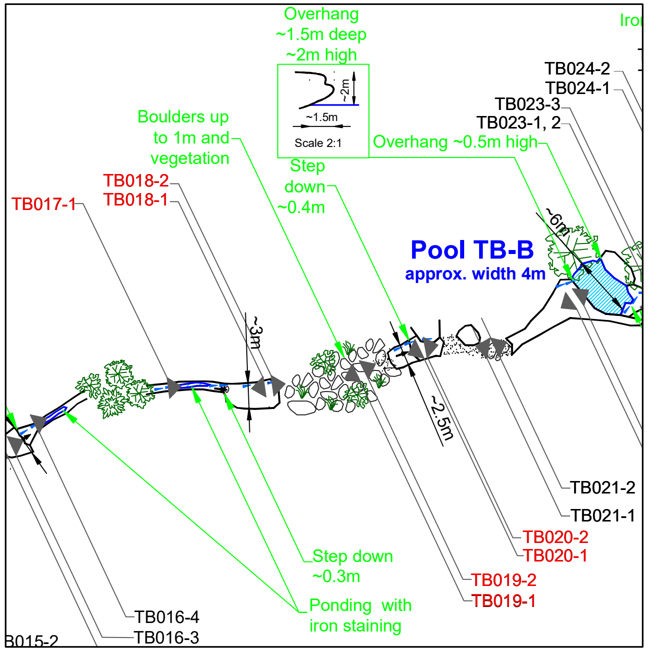
TB018-2 Upstream from Pool TB-B looking Downstream

Notes (as at 22 December 2009)

- Rockbar at TB018 approximately 6m long and 3m wide, with ponding and iron staining upstream
- Flow path along northern side of rockbar
- Vegetation and boulders up to 1m at TB019
- Rockbar at TB020 approximately 6m long and 2.5m wide
- Overhang on western bank approximately 2m high

TB019-1 Upstream from Pool TB-B looking Upstream

TB019-2 Upstream from Pool TB-B looking Downstream



TB020-1 Upstream from Pool TB-B looking Upstream

TB020-2 Upstream from Pool TB-B looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB017-1	308664	6214883	85
TB018-1	308676	6214883	260
TB018-2	308676	6214883	80
TB019-1	308690	6214879	245
TB019-2	308690	6214879	65
TB020-1	308694	6214887	240
TB020-2	308694	6214887	80

TRIBUTARY B STREAM MAPPING SUMMARY

TB021-1 Upstream from Pool TB-B looking Upstream

TB021-2 Upstream from Pool TB-B looking Downstream

TA022-2 Upstream end of Pool TB-B looking Downstream

TB022-1 Upstream end of Pool TB-B looking Upstream

TB022-3 Upstream end of Pool TB-B looking to overhang on eastern bank

Notes (as at 22 December 2009)

- Pool TB-B approximately 6m long, 4m wide and up to 1m deep
- Base of the pool is sandstone
- Rockbar upstream of the pool is approximately 8m wide at the downstream end
- Flow path along northern side of rockbar into Pool TB-B
- Overhang at upsteam end of pool approximately 2m high and 1.5m deep
- Overhang at eastern side of pool approximately 0.5m high

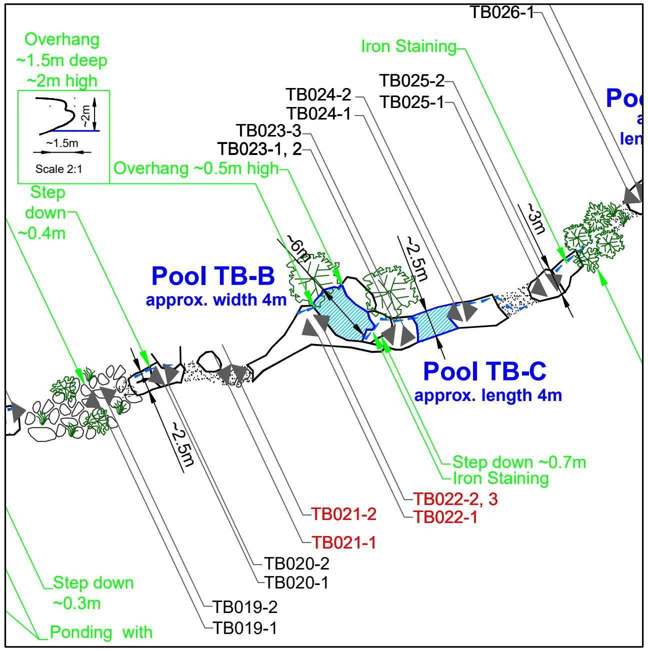


Photo Details

Photo ID	Easting	Northing	Bearing
TB021-1	308703	6214887	280
TB021-2	308703	6214887	65
TB022-1	308717	6214892	240
TB022-2	308717	6214892	60
TB022-3	308717	6214892	60

TRIBUTARY B STREAM MAPPING SUMMARY

TB023-1 Downstream end of Pool TB-B looking Upstream

TB023-2 Upstream from Pool TB-C looking Upstream

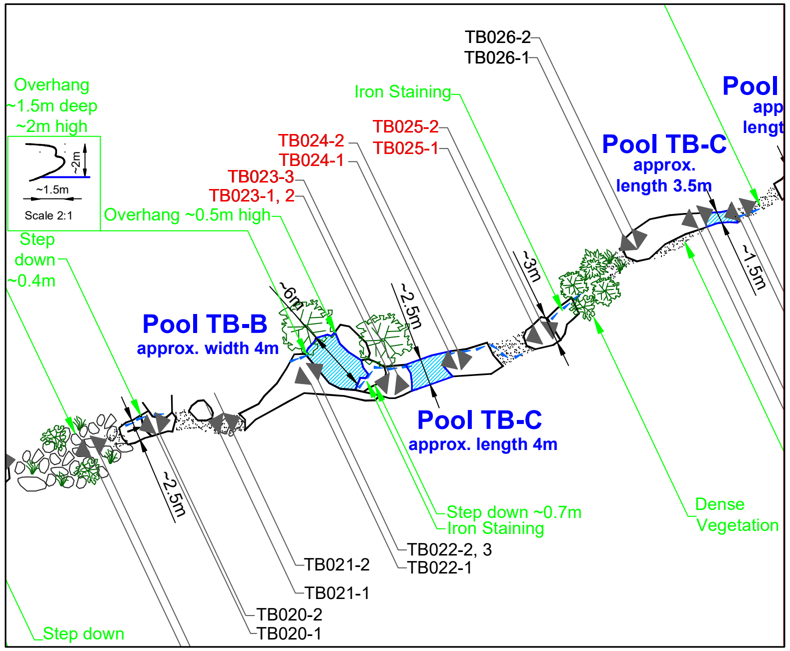
TB023-3 Upstream from Pool TB-C looking Downstream

Notes (as at 22 December 2009)

- Pool TB-C approximately 4m long, 2.5m wide and 0.2m deep
- Base of the pool is sandstone with scattered vegetation at the upstream end
- Flow path along northern side of rockbar into Pool TB-C
- Rockbar upstream of the pool is approximately 5m long and 2.5m wide

TB024-1 Downstream end of Pool TB-C looking Upstream

TB024-2 Downstream end of Pool TB-C looking Downstream



TB025-1 Downstream from Pool TB-C looking Upstream

TB025-2 Downstream from Pool TB-C looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB023-1	308720	6214893	275
TB023-2	308720	6214893	275
TB023-3	308720	6214893	95
TB024-1	308731	6214895	245
TB024-2	308731	6214895	80
TB025-1	308742	6214897	245
TB025-2	308742	6214897	55

TRIBUTARY B STREAM MAPPING SUMMARY

TB026-1 Upstream from Pool TB-D looking Upstream

TB026-2 Upstream from Pool TB-D looking Downstream

TB027-1 Upstream end of Pool TB-D looking Upstream

Notes (as at 22 December 2009)

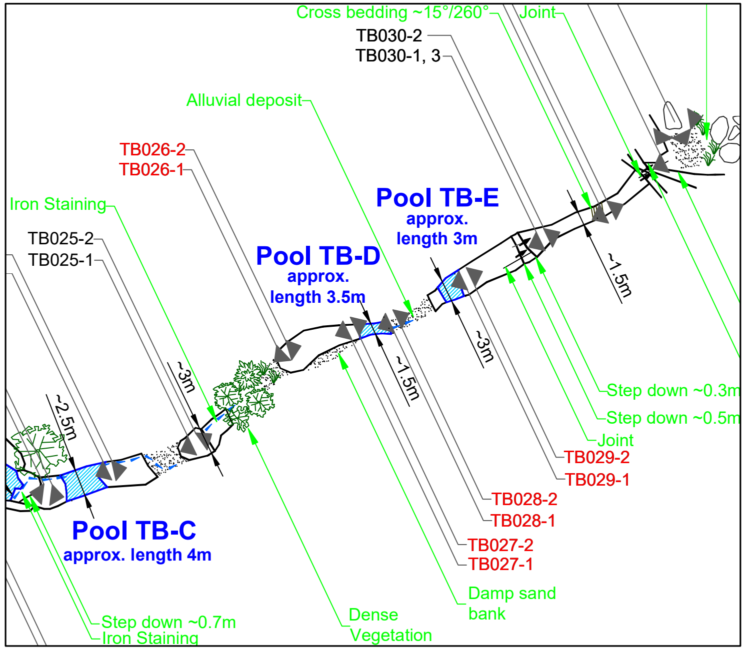
- Pool TB-D approximately 3.5m long, 1.5m wide and 0.2m deep
- Base of the pool is sandstone with alluvial deposits
- Rockbar upstream of the pool is approximately 10m long with scattered vegetation debris
- Rockbar and alluvial deposits downstream of the pool

- Pool TB-E approximately 3m long, 3m wide and 0.5m deep
- Base of the pool is sandstone with alluvial deposits

TB027-2 Upstream end of Pool TB-D looking Downstream

TB028-1 Downstream end of Pool TB-D looking Upstream

TB028-2 Downstream end of Pool TB-D looking Downstream



TB029-1 Downstream end of Pool TB-E looking Upstream

TB029-2 Downstream end Pool TB-E looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB026-1	308752	6214909	215
TB026-2	308752	6214909	70
TB027-1	308760	6214912	245
TB027-2	308760	6214912	65
TB028-1	308765	6214911	245
TB028-2	308765	6214911	65
TB029-1	308774	6214918	245
TB029-2	308774	6214918	65

TRIBUTARY B STREAM MAPPING SUMMARY

TB030-1 Downstream from Pool TB-E looking Upstream

TB030-2 Downstream from Pool TB-E looking Downstream

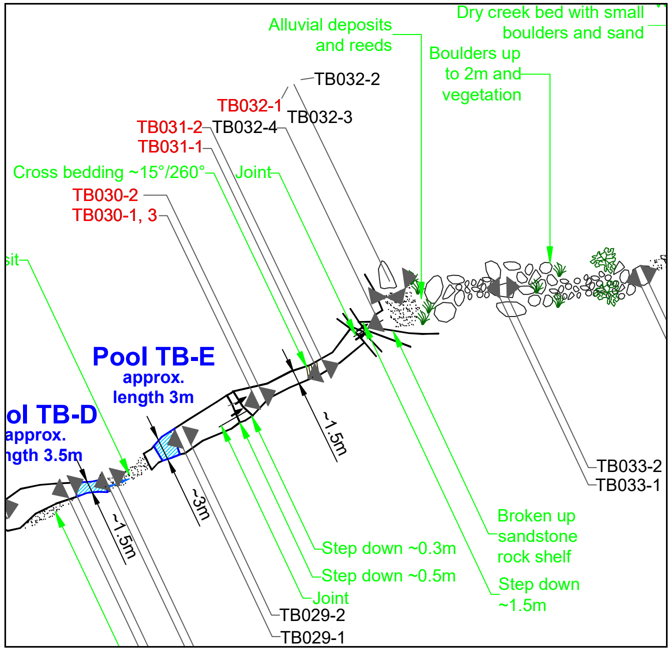
TB030-3 Downstream from Pool TB-E looking Upstream

Notes (as at 22 December 2009)

- Approximate 0.8m change in height along rockbar downstream of Pool TB-E toward TB030
- Rockbar at TB031 approximately 1.5m wide with cross bedding and scattered vegetation debris

TB031-1 Downstream from Pool TB-E looking Upstream

TB031-2 Downstream from Pool TB-E looking Downstream



TB032-1 Downstream from Pool TB-E looking Upstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB030-1	308781	6214922	245
TB030-2	308781	6214922	65
TB030-3	308781	6214922	245
TB031-1	308791	6214927	245
TB031-2	308791	6214927	65
TB032-1	308799	6214937	205

TRIBUTARY B STREAM MAPPING SUMMARY

TB032-2 Downstream from Pool TB-E looking Downstream

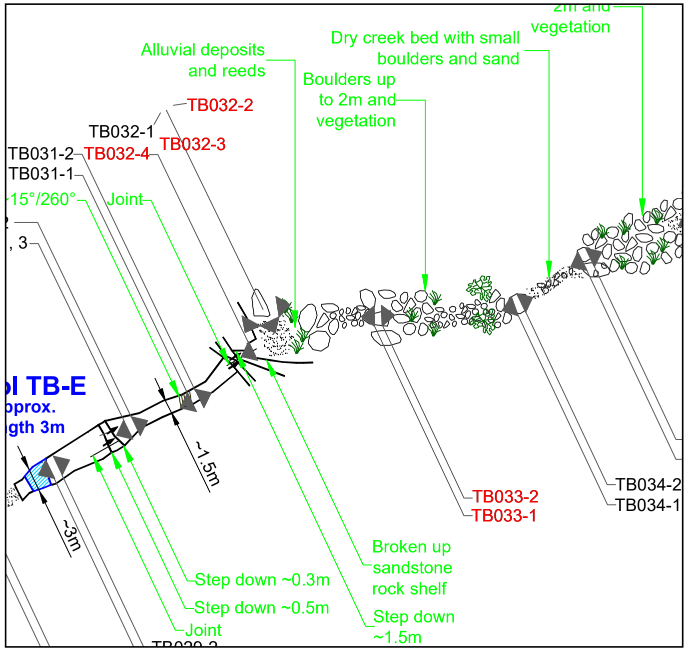
TB032-3 Downstream from Pool TB-E looking toward southern bank

Notes (as at 22 December 2009)

- Alluvial deposits and reeds at TB032
- Boulders up to 2m and vegetation downstream
- No flow visible
- Approximate 1.5m change in height at TB032

TB032-4 Joint

TB033-1 Downstream from Pool TB-E looking Upstream



TB033-2 Downstream from Pool TB-E looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB032-2	308799	6214937	85
TB032-3	308799	6214937	155
TB032-4	308799	6214937	245
TB033-1	308813	6214936	270
TB033-2	308813	6214936	90

TRIBUTARY B STREAM MAPPING SUMMARY

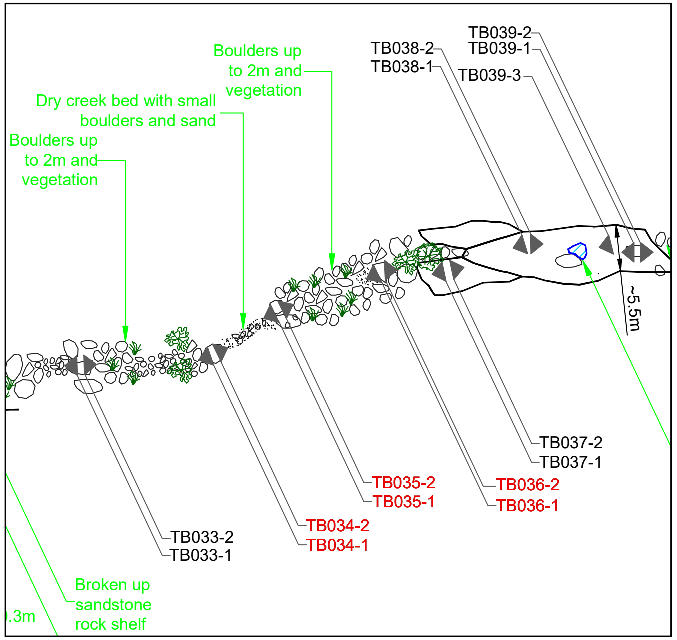
TB034-1 Boulder field looking Upstream

Notes (as at 22 December 2009)

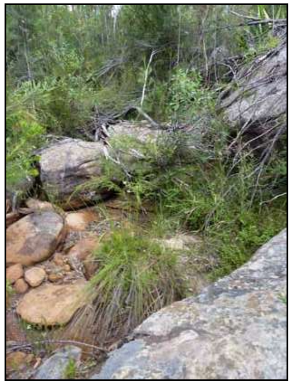
- Boulders up to 2m and vegetation
- Dry creek bed with small boulders and alluvial deposits
- No flow visible

TB034-2 Boulder field looking Downstream

TB035-1 Dry creek bed looking Upstream



TB035-2 Boulder field looking Downstream



TB036-1 Boulder field looking Upstream

TB036-2 Boulder field looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB034-1	308830	6214937	250
TB034-2	308830	6214937	50
TB035-1	308838	6214943	245
TB035-2	308838	6214943	65
TB036-1	308851	6214948	245
TB036-2	308851	6214948	85

TRIBUTARY B STREAM MAPPING SUMMARY

TB037-1 Rockbar looking Upstream

TB037-2 Rockbar looking Downstream

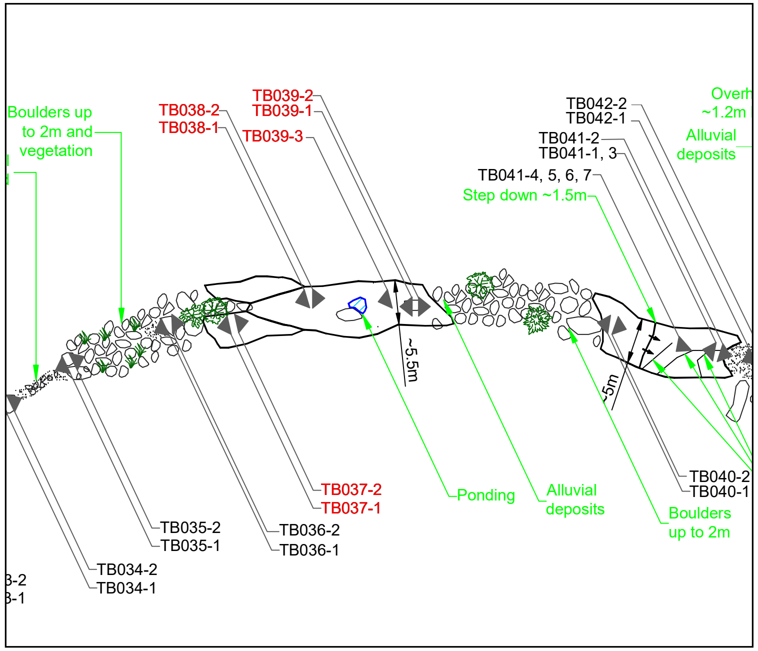
TB038-1 Rockbar looking Upstream

Notes (as at 22 December 2009)

- Rockbar at TB038 approximately 25m long and 5.5m wide with minor ponding
- Boulders and vegetation both upstream and downstream of the rockbar

TB038-2 Rockbar looking Downstream

TB039-1 Rockbar looking Upstream



TB039-2 Rockbar looking Downstream

TB039-3 Ponding

Photo Details

Photo ID	Easting	Northing	Bearing
TB037-1	308857	6214947	260
TB037-2	308857	6214947	80
TB038-1	308870	6214952	250
TB038-2	308870	6214952	90
TB039-1	308884	6214949	270
TB039-2	308884	6214949	90
TB039-3	308884	6214949	255

TRIBUTARY B STREAM MAPPING SUMMARY

TB040-1 Rockbar looking Upstream

TB040-2 Rockbar looking Downstream

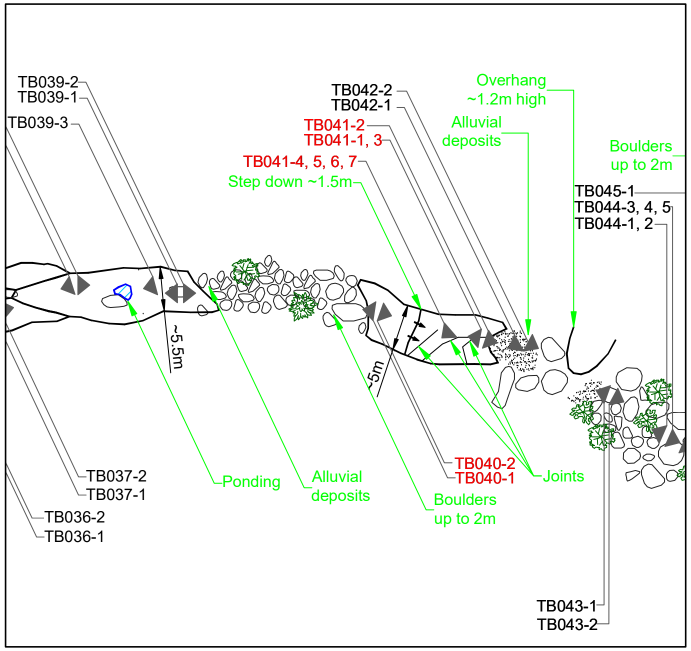
TB041-1 Rockbar looking Upstream

Notes (as at 22 December 2009)

- Rockbar at TB040 approximately 18m long and 5m wide, with a step down of approximately 1.5m half way along
- Rockbar has many joints
- No visible flow

TB041-2 Rockbar looking Downstream

TB041-3 Joints



TB041-4 Joint

TB041-5 Joint

TB041-6 Joint

TB041-7 Joint

Photo Details

Photo ID	Easting	Northing	Bearing
TB040-1	308908	6214951	275
TB040-2	308908	6214951	105
TB041-1	308913	6214946	280
TB041-2	308913	6214946	110
TB041-3	308913	6214946	280
TB041-4	308913	6214946	230
TB041-5	308913	6214946	230
TB041-6	308913	6214946	230
TB041-7	308913	6214946	230

TRIBUTARY B STREAM MAPPING SUMMARY

TB042-1 Rockbar looking Upstream

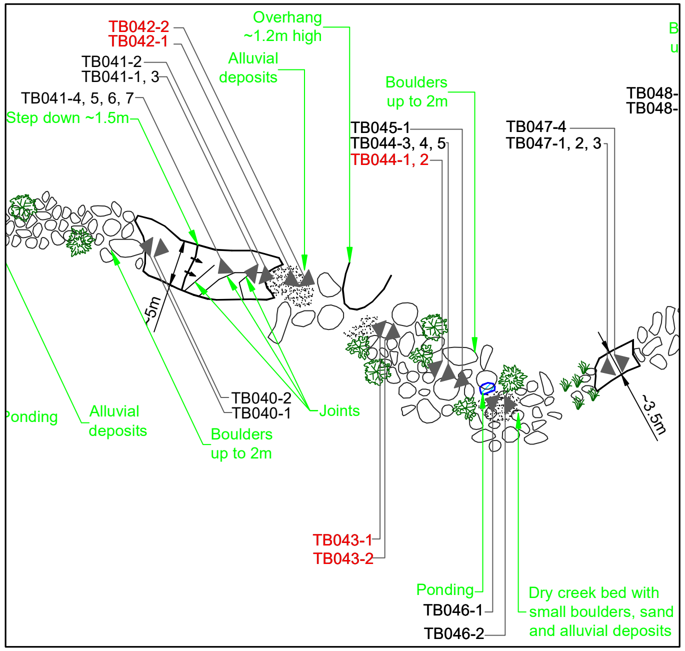
TB042-2 Rockbar looking Downstream

TB043-1 Boulder field looking Upstream

Notes (as at 22 December 2009)

- Alluvial depsoits, large boulders and scattered vegetation at TB042 and TB043
- No flow visible
- Overhang on northern bank approximately 1.2m high

TB043-2 Boulder field looking Downstream



TB044-1 Boulder field looking Upstream

TB044-2 Boulder field looking Upstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB042-1	308927	6214944	240
TB042-2	308927	6214944	120
TB043-1	308940	6214937	285
TB043-2	308940	6214937	115
TB044-1	308947	6214932	295
TB044-2	308947	6214932	295

TRIBUTARY B STREAM MAPPING SUMMARY

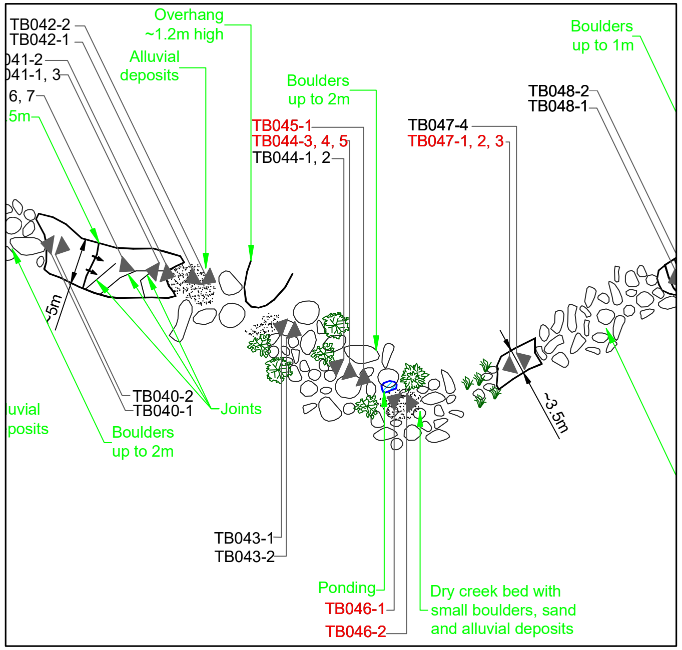
TB044-3 Boulder field looking Downstream

TB044- Boulder field looking Downstream

TB044-5 Boulder field looking Downstream

Notes (as at 22 December 2009)

- Minor ponding and alluvial deposits at TB046
- Rockbar at TB047 approximately 6m long and 3.5m wide, with boulders downstream and vegetation upstream



TB045-1 Dry creek bed looking Upstream

TB046-1 Boulder field looking Upstream

TB046-2 Boulder field looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB044-3	308947	6214932	115
TB044-4	308947	6214932	115
TB044-5	308947	6214932	115
TB045-1	308947	6214932	115
TB046-1	308949	6214925	295
TB046-2	308949	6214925	90
TB047-1	308969	6214933	245
TB047-2	308969	6214933	245
TB047-3	308969	6214933	245

TB047-1 Rockbar looking Upstream

TB047-2 Rockbar looking Upstream

TB047-3 Rockbar looking Upstream

TRIBUTARY B STREAM MAPPING SUMMARY

TB047-4 Rockbar looking Downstream

TB048-1 Rockbar looking Upstream

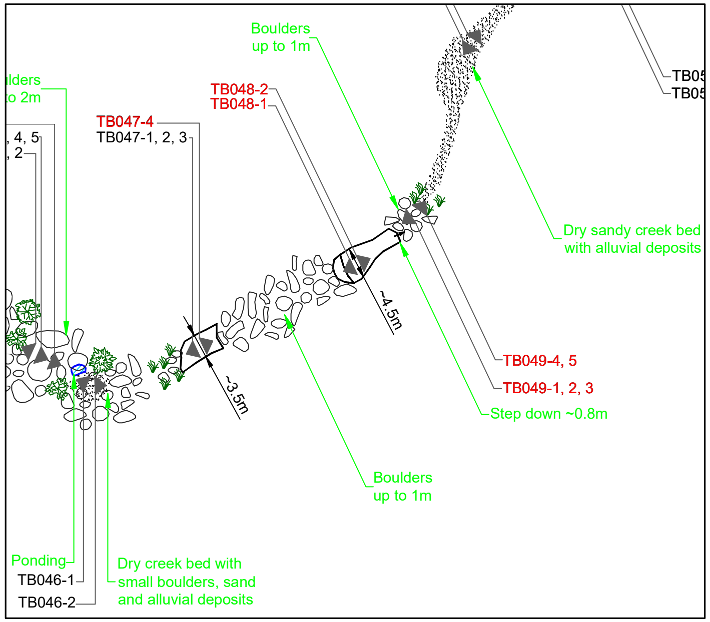
Notes (as at 22 December 2009)

- Rockbar at TB048 approximately 10m long and 4.5m wide
- Rockbar has a step down of approximately 0.4m at the upstream end
- Rockbar has a step down of approximately 0.8m at the downstream end

TB048-2 Rockbar looking Downstream

TB049-1 Rockbar looking Upstream

TB049-2 Rockbar looking Upstream



TB049-3 Rockbar looking Upstream

TB049-4 Sandy creek bed looking Downstream

TB049-5 Sandy creek bed looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB047-4	308969	6214933	65
TB048-1	308992	6214944	245
TB048-2	308992	6214944	65
TB049-1	309000	6214951	235
TB049-2	309000	6214951	235
TB049-3	309000	6214951	235
TB049-4	309000	6214951	40
TB049-5	309000	6214951	40

TRIBUTARY B STREAM MAPPING SUMMARY

TB050-1 Sandy creek bed looking Upstream

TB050-2 Sandy creek bed looking Downstream

TB051-1 Sandy creek bed looking Upstream

TB051-2 Sandy creek bed looking Downstream

TB052-1 Sandy creek bed looking Upstream

TB052-2 Sandy creek bed looking Downstream

TB053-1 Sandy creek bed looking Upstream

TB053-2 Sandy creek bed looking Downstream

TB054-1 Dry sandstone creek bed looking Upstream

TB054-2 Dry sandstone creek bed looking Downstream

Notes (as at 22 December 2009)

- Alluvial deposits extend over approximately 65m downstream between TB049 and TB053
- Alluvial deposits open up to dry sandstone creek bed at TB054

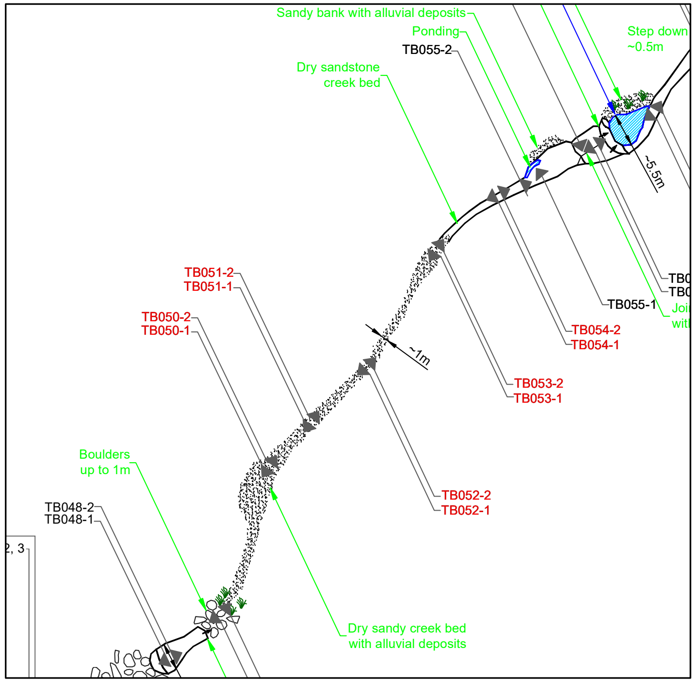


Photo Details

Photo ID	Easting	Northing	Bearing
TB050-1	309008	6214975	215
TB050-2	309008	6214975	35
TB051-1	309010	6214986	215
TB051-2	309010	6214986	35
TB052-1	309026	6214988	230
TB052-2	309026	6214988	45
TB053-1	309035	6215010	210
TB053-2	309035	6215010	35
TB054-1	309045	6215019	245
TB054-2	309045	6215019	65

TRIBUTARY B STREAM MAPPING SUMMARY

TB055-1 Upstream from Pool TB-F looking toward northern bank

TB055-2 Upstream from Pool TB-F looking Downstream

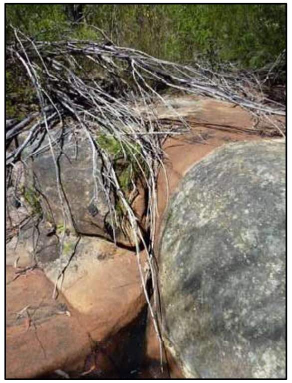
TB056-1 Upstream end of Pool TB-F looking Upstream

Notes (as at 22 December 2009)

- Minor ponding at TB055 with scattered vegetation debris and alluvial deposits on northern bank
- Joint along centre of rockbar at TB056

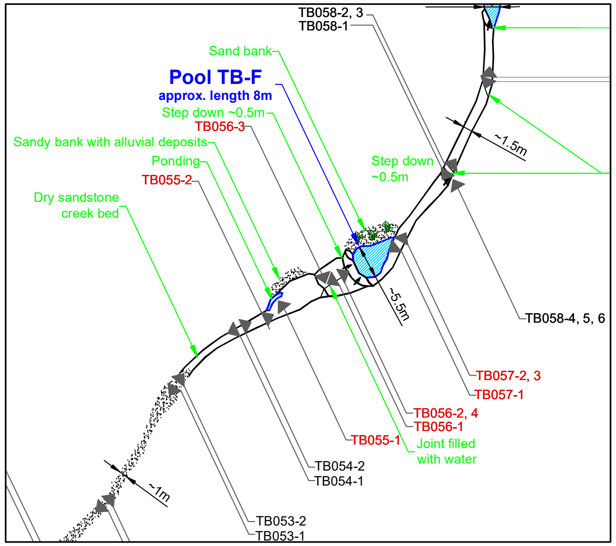
- Pool TB-F approximately 8m long, 5.5m wide and 0.5 m deep
- Sand deposit on northern bank
- Rockbar upstream steps down approximately 0.5m to Pool TB-F
- No flow visible downstream of pool

TB056-2 Upstream end of Pool TB-F looking Downstream



TB056-3 Joint

TB056-4 Joint



TB057-1 Downstream end of Pool TB-F looking Upstream

TB057-2 Downstream end of Pool TB-F looking Downstream

TB057-3 Downstream end of Pool TB-F looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB055-1	309052	6215022	325
TB055-2	309052	6215022	65
TB056-1	309057	6215026	240
TB056-2	309057	6215026	60
TB056-3	309057	6215026	155
TB056-4	309057	6215026	60
TB057-1	309070	6215032	235
TB057-2	309070	6215032	30
TB057-3	309070	6215032	30

TRIBUTARY B STREAM MAPPING SUMMARY

TB058-1 Downstream from Pool TB-F looking Upstream

TB058-2 Downstream from Pool TB-F looking Downstream

TB058-3 Downstream from Pool TB-F looking Downstream

TB058-4 Joint

TB058-5 Joint

TB058-6 Joint

TB059-1 Upstream from Pool TB-G looking Upstream

TB059-2 Upstream from Pool TB-G looking Downstream

TB059-3 Joint

TB060-1 Downstream end of Pool TB-G looking Upstream

TB060-2 Downstream end of Pool TB-G looking Downstream

Notes (as at 22 December 2009)

- Rockbar at TB058 approximately 1.5m wide, with a step down of approximately 0.5m
- Water-filled joints across rockbar at TB058 and TB059
- Step down of approximately 0.8m at upstream end of Pool TB-G

- Pool TB-G approximately 5m long, 2m wide and 0.5m deep
- Base of the pool is sandstone
- Exposed sandstone with scattered vegetation debris downstream of the pool

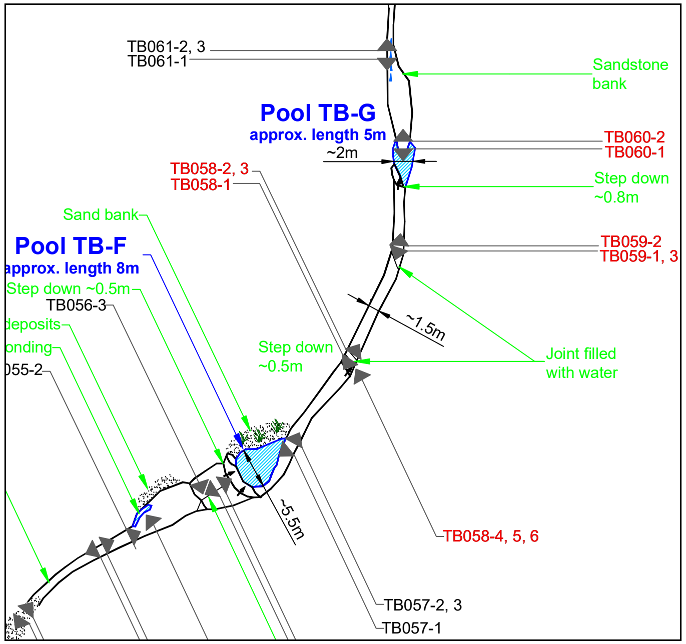


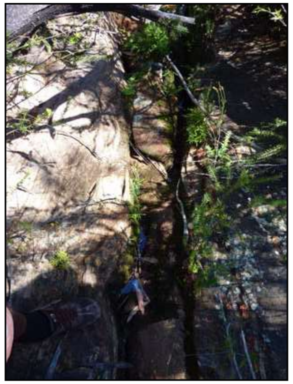
Photo Details

Photo ID	Easting	Northing	Bearing
TB058-1	309077	6215042	215
TB058-2	309077	6215042	30
TB058-3	309077	6215042	30
TB058-4	309077	6215042	330
TB058-5	309077	6215042	330
TB058-6	309077	6215042	330
TB059-1	309084	6215057	195
TB059-2	309084	6215057	10
TB059-3	309084	6215057	195
TB060-1	309085	6215072	180
TB060-2	309085	6215072	0

TRIBUTARY B STREAM MAPPING SUMMARY

TB061-1 Downstream from Pool TB-G looking Upstream

TB061-2 Downstream from Pool TB-G looking Downstream



TB061-3 Joint

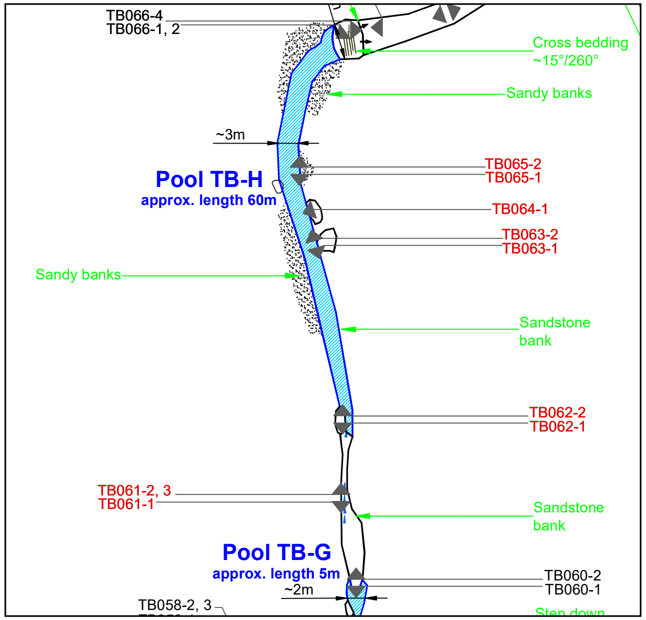
Notes (as at 22 December 2009)

- Flow path along western side of rockbar at TB061
- Pool TB-H approximately 60m long, up to 3m wide and up to 0.4m deep
- Base of the pool is sandstone with vegetation encroaching on both sides
- Vegetation debris across pool at many locations
- Alluvial deposits on banks at downstream end of pool

TB062-1 Upstream end of Pool TB-H looking Upstream

TB062-2 Upstream end of Pool TB-H looking Downstream

TB063-1 Midway along Pool TB-H looking Upstream



TB063-2 Midway along Pool TB-H looking Downstream

TB064-1 Midway along Pool TB-H looking toward western bank

TB065-1 Midway along Pool TB-H looking Upstream

TB065-2 Midway along Pool TB-H looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB061-1	309082	6215084	180
TB061-2	309082	6215084	0
TB061-3	309082	6215084	0
TB062-1	309086	6215095	180
TB062-2	309086	6215095	0
TB063-1	309080	6215120	165
TB063-2	309080	6215120	345
TB064-1	309079	6215125	250
TB065-1	309077	6215130	180
TB065-2	309077	6215130	0

TRIBUTARY B STREAM MAPPING SUMMARY

TB066-1 Downstream end of Pool TB-H looking Upstream

TB066-2 Downstream end of Pool TB-H looking Upstream

TB066-3 Downstream end of Pool TB-H looking Upstream

TB066-4 Downstream end of Pool TB-H looking Downstream

TB067-1 Downstream of Pool TB-H looking Upstream

TB067-2 Downstream of Pool TB-H looking Downstream

TB068-1 Downstream of Pool TB-H looking Upstream

TB068-2 Downstream of Pool TB-H looking Downstream

Notes (as at 22 December 2009)

- Rockbar at downstream end of Pool TB-H approximately 4m long and 5m wide with cross bedding
- Approximate 1m step down at downstream end of rockbar
- Rockbar approximately 50m long through TB067 and TB068, with much vegetation debris
- No flow visible on rockbar

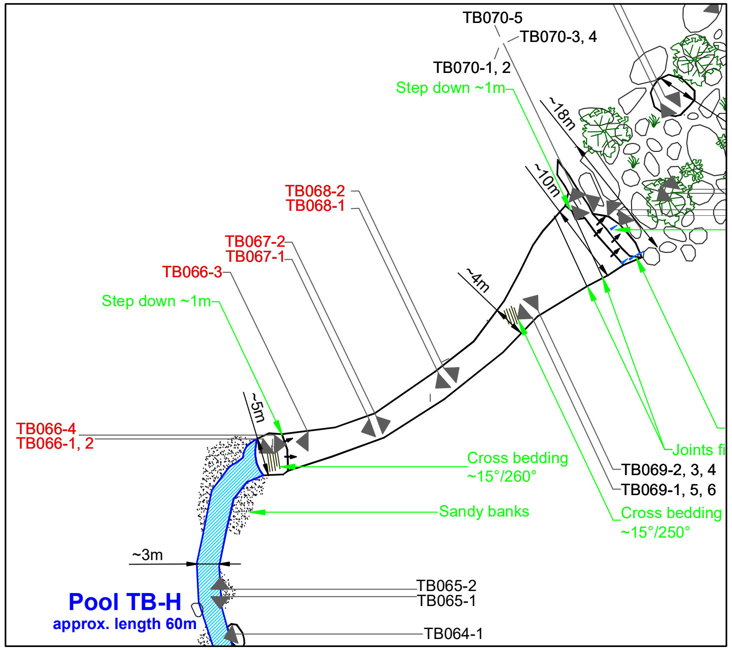


Photo Details

Photo ID	Easting	Northing	Bearing
TB066-1	309084	6215150	235
TB066-2	309084	6215150	235
TB066-3	309084	6215150	270
TB066-4	309084	6215150	90
TB067-1	309098	6215151	250
TB067-2	309098	6215151	70
TB068-1	309104	6215156	235
TB068-2	309104	6215156	45

TRIBUTARY B STREAM MAPPING SUMMARY


TB069-1 Rockbar looking Upstream


TB069-2 Rockbar looking Downstream


TB069-3 Cross bedding

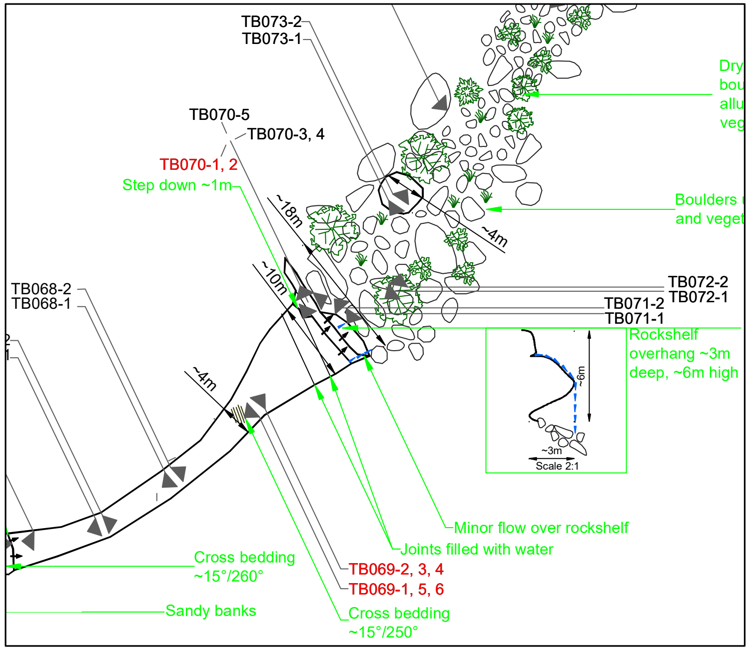
Notes (as at 22 December 2009)

- Rockbar at TB069 approximately 4m wide with cross bedding
- Rockbar widens to approximately 10m at TB070, with a step down of approximately 1m
- Joints across width of rockbar at downstream end


TB069-4 Cross bedding


TB069-5 Joint with water


TB069-6 Joint with water




TB070-1 Rockshelf looking Upstream


TB070-2 Rockshelf looking Upstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB069-1	309115	6215167	225
TB069-2	309115	6215167	35
TB069-3	309115	6215167	35
TB069-4	309115	6215167	35
TB069-5	309115	6215167	225
TB069-6	309115	6215167	225
TB070-1	309126	6215181	200
TB070-2	309126	6215181	200

TRIBUTARY B STREAM MAPPING SUMMARY

TB070-3 Looking Downstream from high rockshelf

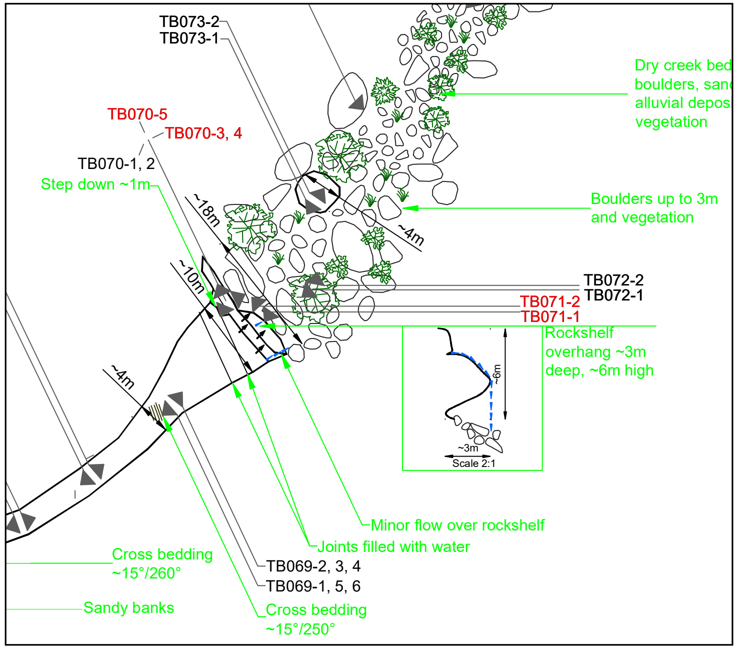
Notes (as at 22 December 2009)

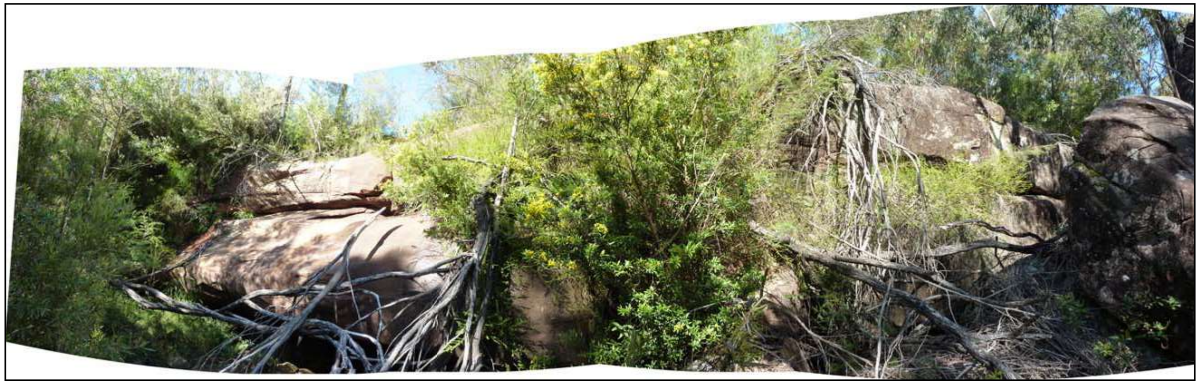
- Rockshelf approximately 6m high and 3m deep at TB071
- Minor flow over rockshelf on southern side
- Boulders and vegetation at base of rockshelf and downstream

TB070-4 Looking Downstream from top of rockshelf

TB070-5 Joint

TB071-2 Looking North West along rockshelf





TB071-1 Looking Upstream to rockshelf

Photo Details

Photo ID	Easting	Northing	Bearing
TB070-3	309126	6215181	70
TB070-4	309126	6215181	70
TB070-5	309126	6215181	335
TB071-1	309131	6215182	205
TB071-2	309131	6215182	215

TRIBUTARY B STREAM MAPPING SUMMARY

TB072-1 Boulder field looking Upstream

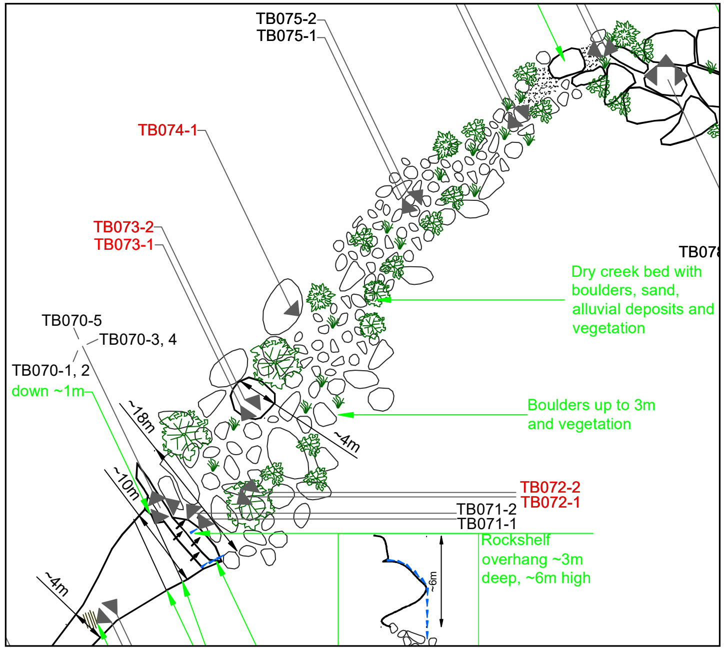
TB072-2 Boulder field looking Downstream

TB073-1 Boulder field looking Upstream

Notes (as at 21 & 22 December 2009)

- Boulder field and vegetation through TB072, TB073 and TB074, with boulders up to 3m
- Minor alluvial deposits
- No flow visible

TB073-2 Boulder field looking Downstream



TB074-1 Boulder field looking toward eastern bank

Photo Details

Photo ID	Easting	Northing	Bearing
TB072-1	309133	6215178	230
TB072-2	309133	6215178	35
TB073-1	309137	6215195	205
TB073-2	309137	6215195	35
TB074-1	309141	6215208	135

TRIBUTARY B STREAM MAPPING SUMMARY

TB075-1 Dry creek bed looking Upstream

TB075-2 Dry creek bed looking Downstream

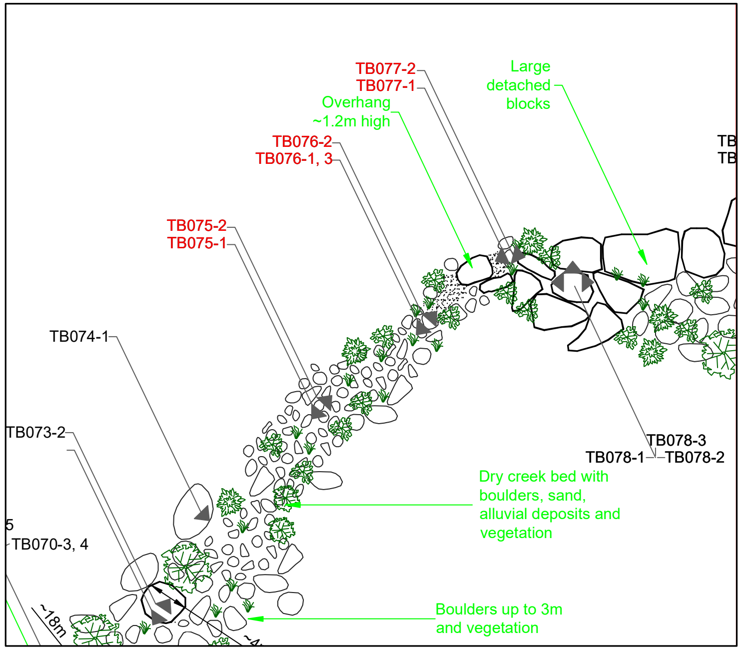
TB076-1 Dry creek bed looking Upstream

Notes (as at 21 December 2009)

- Boulder field and vegetation through TB075, TB076 and TB077, with minor alluvial deposits
- No flow visible

TB076-2 Dry creek bed looking Downstream

TB076-3 Dry creek bed looking Upstream



TB077-1 Boulder field looking Upstream

TB077-2 Boulder field looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB075-1	309157	6215224	220
TB075-2	309157	6215224	45
TB076-1	309173	6215234	225
TB076-2	309173	6215234	35
TB076-3	309173	6215234	225
TB077-1	309183	6215242	245
TB077-2	309183	6215242	100

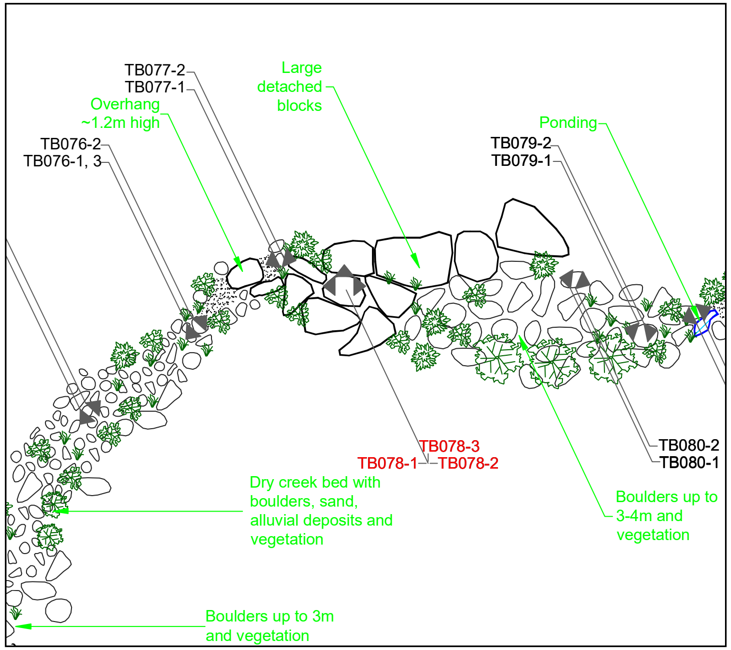
TRIBUTARY B STREAM MAPPING SUMMARY

TB078-1 Large detached blocks looking Upstream

Notes (as at 21 December 2009)

- Large detached blocks on northern bank and tributary path
- No flow visible through boulder field

TB078-2 Large detached blocks looking Downstream



TB078-3 Large detached blocks looking toward northern bank

Photo Details

Photo ID	Easting	Northing	Bearing
TB078-1	309192	6215239	270
TB078-2	309192	6215239	90
TB078-3	309192	6215239	0

TRIBUTARY B STREAM MAPPING SUMMARY

TA079-1 Boulder field looking Upstream

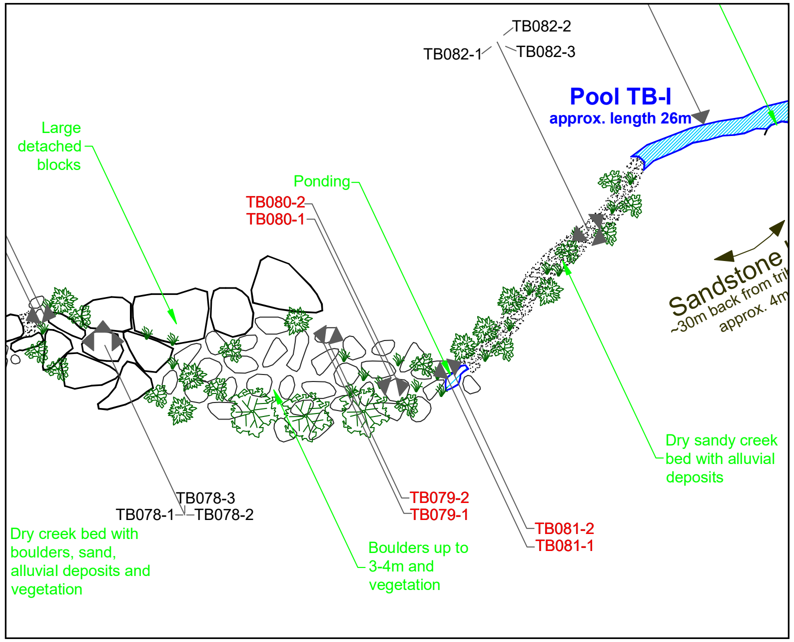
TA079-2 Boulder field looking Downstream

Notes (as at 21 December 2009)

- Large boulders and vegetation through TB079 and TB080
- No flow visible
- Ponding and alluvial deposits at TB081, with vegetation downstream

TA080-1 Boulder field looking Upstream

TA080-2 Boulder field looking Downstream



TA081-1 Upstream of Pool TB-I looking Upstream

TA081-2 Upstream of Pool TB-I looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB079-1	309223	6215242	290
TB079-2	309223	6215242	75
TB080-1	309232	6215234	275
TB080-2	309232	6215234	115
TB081-1	309238	6215235	245
TB081-2	309238	6215235	65

TRIBUTARY B STREAM MAPPING SUMMARY

TB082-1 Upstream of Pool TB-I looking Upstream

TB082-2 Upstream of Pool TB-I looking Downstream

TB082-3 Upstream of Pool TB-I looking toward southern bank

TB083-1 Midway along Pool TB-I looking toward southern bank

TB084-1 Downstream end of Pool TB-I looking Upstream

TB084-2 Overhang

<u>Notes (as at 21 December 2009)</u>

- Dry creek bed with alluvial deposits upstream of Pool TB-I

- Pool TB-I approximately 26m long, up to 3.5m wide and 0.5m deep
- Base of the pool is sandstone
- Overhang on southern bank approximately 1.8m high and 1m deep
- Alluvial deposits downstream of pool

- Sandstone ledge up to 4m high on southern side of Pool TB-I at a distance of approximately 30m

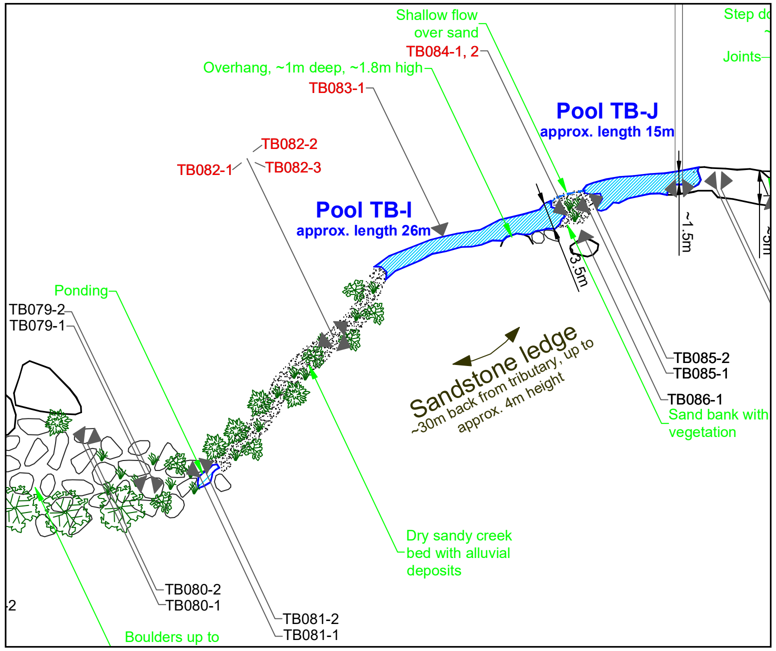


Photo Details

Photo ID	Easting	Northing	Bearing
TB082-1	309256	6215256	235
TB082-2	309256	6215256	50
TB082-3	309256	6215256	110
TB083-1	309273	6215270	165
TB084-1	309290	6215270	245
TB084-2	309290	6215270	245

TRIBUTARY B STREAM MAPPING SUMMARY

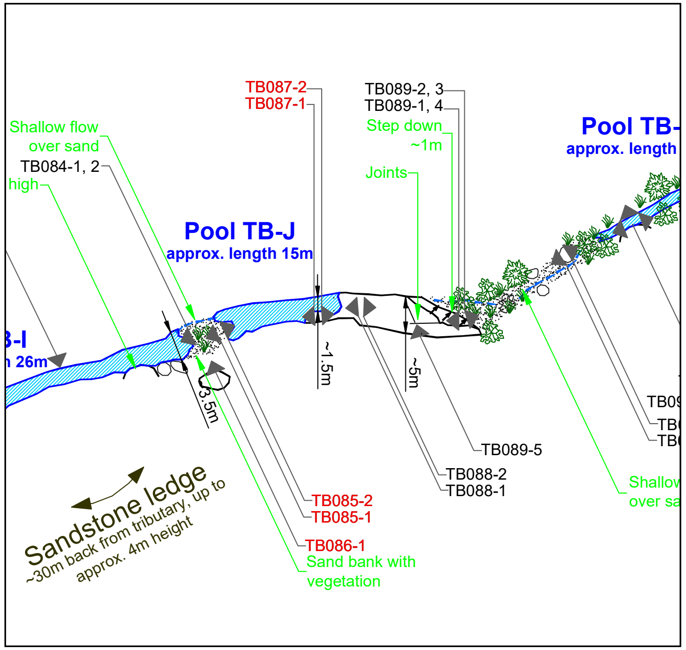
TB085-1 Upstream end of Pool TB-J looking Upstream

TB085-2 Upstream end of Pool TB-J looking Downstream

Notes (as at 21 December 2009)

- Pool TB-J approximately 5m long, 1.5m wide and 0.3m deep
- Base of the pool is alluvial at the upstream end and sandstone at the downstream end
- Sand bank with vegetation upstream of the pool
- Shallow flow along northern side of sand bank at upstream end of pool

TB086-1 Between Pools TB-I and TB-J looking toward northern bank



TB087-1 Along Pool TB-J looking Upstream

TB087-2 Along Pool TB-J looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB085-1	309294	6215273	245
TB085-2	309294	6215273	65
TB086-1	309300	6215265	340
TB087-1	309310	6215276	265
TB087-2	309310	6215276	85

TRIBUTARY B STREAM MAPPING SUMMARY

TB088-1 Downstream end of Pool TB-J looking Upstream

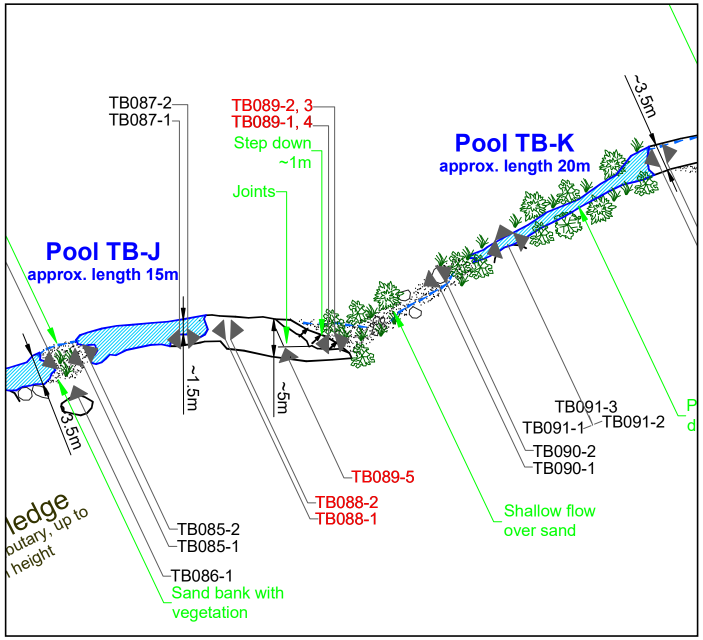
TB088-2 Downstream end of Pool TB-J looking Downstream

Notes (as at 21 December 2009)

- Rockbar downstream of Pool TB-J approximately 19m long and up to 5m wide
- Joints across rockbar at TB089
- Step down approximately 1m at downstream end of rockbar
- Vegetation and alluvial deposits downstream of rockbar

TB089-1 Downstream of Pool TB-J looking Upstream

TB089-2 Downstream of Pool TB-J looking Downstream



TB089-3 Downstream of Pool TB-J looking Downstream

TB089-4 Joint

TB089-5 Joint

Photo Details

Photo ID	Easting	Northing	Bearing
TB088-1	309312	6215274	265
TB088-2	309312	6215274	90
TB089-1	309323	6215274	270
TB089-2	309323	6215274	70
TB089-3	309323	6215274	70
TB089-4	309323	6215274	270
TB089-5	309323	6215274	345

TRIBUTARY B STREAM MAPPING SUMMARY

TB090-1 Upstream of Pool TB-K looking Upstream

TB090-2 Upstream of Pool TB-K looking Downstream

TB091-1 Near upstream end of Pool TB-K looking Upstream

TB091-2 Near upstream end of Pool TB-K looking Downstream

TB091-3 Near upstream end of Pool TB-K looking toward northern bank

Notes (as at 21 December 2009)

- Pool TB-K approximately 20m long, up to 3.5m wide at the downstream end, and 0.5m deep
- Base of the pool is sandstone with vegetation encroaching on both sides
- Shallow flow over sand upstream of pool

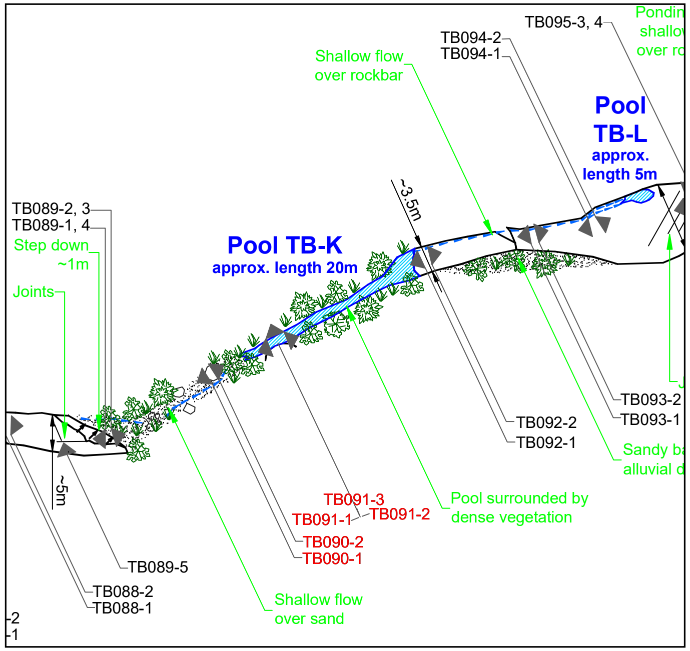


Photo Details

Photo ID	Easting	Northing	Bearing
TB090-1	309339	6215283	235
TB090-2	309339	6215283	55
TB091-1	309348	6215287	250
TB091-2	309348	6215287	70
TB091-3	309348	6215287	340

TRIBUTARY B STREAM MAPPING SUMMARY

TB092-1 Downstream end of Pool TB-K looking Upstream

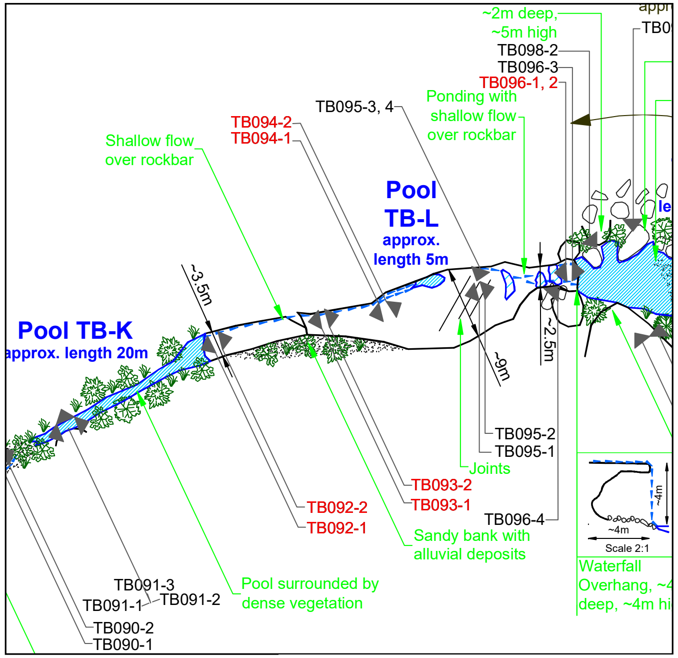
TB092-2 Downstream end of Pool TB-K looking Downstream

<u>Notes (as at 21 December 2009)</u>

- Rockbar downstream of Pool TB-K approximately 3.5m wide
- Flow path along northern side of rockbar into Pool TB-L
- Pool TB-L approximately 5m long, 1.5m wide and 0.2m deep
- Base of the pool is sandstone

TB093-1 Upstream of Pool TB-L looking Upstream

TB094-1 Upstream end of Pool TB-L looking Upstream



TB093-2 Upstream of Pool TB-L looking Downstream

TB094-2 Upstream end of Pool TB-L looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB092-1	309367	6215299	245
TB092-2	309367	6215299	80
TB093-1	309384	6215301	260
TB093-2	309384	6215301	75
TB094-1	309396	6215296	260
TB094-2	309396	6215296	55

TRIBUTARY B STREAM MAPPING SUMMARY

TB095-1 Downstream of Pool TB-L looking Upstream

TB095-2 Downstream of Pool TB-L looking Downstream

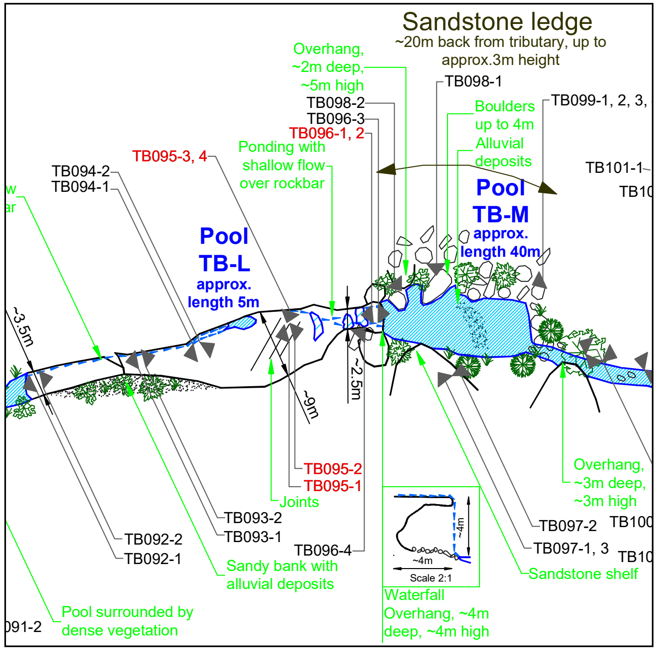
Notes (as at 21 December 2009)

- Rockbar downstream of Pool TB-L approximately 9m wide, with several joints at TB095
- Ponding and shallow flow over rockbar downstream

TB095-3 Joint

TB095-4 Joint

TB096-1 Upstream of Pool TB-M looking Upstream



TB096-2 Upstream end of Pool TB-M looking Upstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB095-1	309406	6215311	250
TB095-2	309406	6215311	75
TB095-3	309406	6215311	195
TB095-4	309406	6215311	195
TB096-1	309413	6215308	270
TB096-2	309413	6215308	270

TRIBUTARY B STREAM MAPPING SUMMARY

TB096-3 Upstream end of Pool TB-M looking Downstream

TB096-4 Upstream end of Pool TB-M looking toward overhang on northern bank

TB097-1 Near upstream end of Pool TB-M looking toward overhang on northern bank

TB097-2 Near upstream end of Pool TB-M looking toward northern bank

TB097-3 Sandstone shelf on southern bank near upstream end of Pool TB-M

Notes (as at 21 December 2009)

- Pool TB-M approximately 40m long, up to 7m wide and up to 1m deep at the upstream end
- Base of the pool is sandstone
- Alluvial deposits and vegetation across pool
- Waterfall at upstream end of pool drops approximately 4m, with depth of overhang approximately 4m
- Small boulders at base of waterfall
- Overhang on northern bank approximately 5m high and 2m deep
- Steep slope toward sandstone ledge with large boulders along northern bank of Pool TB-M

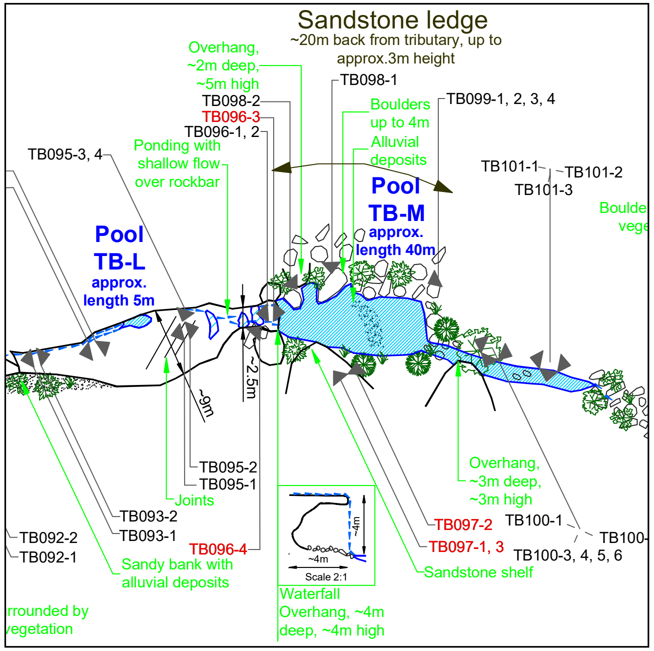


Photo Details

Photo ID	Easting	Northing	Bearing
TB096-3	309416	6215311	85
TB096-4	309416	6215311	45
TB097-1	309439	6215295	320
TB097-2	309439	6215295	0
TB097-3	309439	6215295	320

TRIBUTARY B STREAM MAPPING SUMMARY

TB098-1 Near Upstream end of Pool TB-M looking toward southern bank

Notes (as at 21 December 2009)

- Pool TB-M approximately 40m long, up to 7m wide and up to 1m deep at the upstream end
- Base of the pool is sandstone
- Alluvial deposits and vegetation across pool (TB098-2)

TB098-2 Near Upstream end of Pool TB-M looking toward southern bank

TB099-1 Midway along Pool TB-M looking toward waterfall at Upstream end of pool

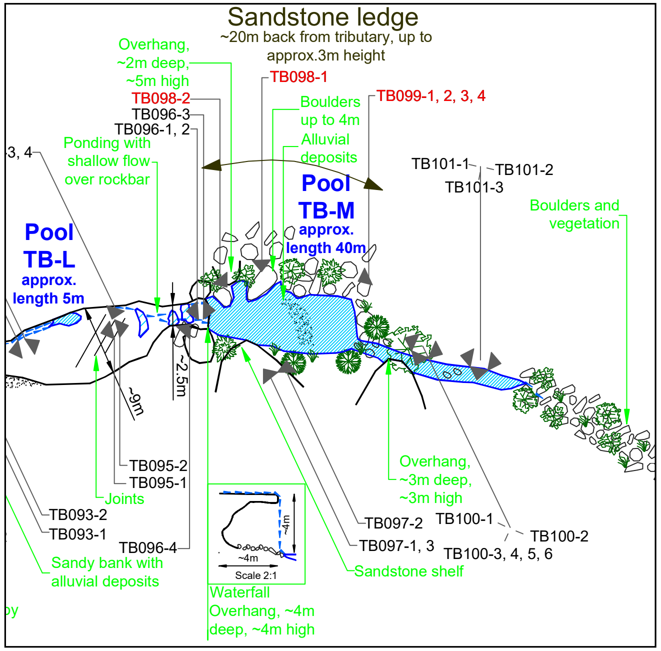


Photo Details

Photo ID	Easting	Northing	Bearing
TB098-1	309416	6215311	175
TB098-2	309416	6215311	145
TB099-1	309444	6215304	245
TB099-2	309444	6215304	245
TB099-3	309444	6215304	245
TB099-4	309444	6215304	245

TB099-2 Midway along Pool TB-M looking toward waterfall at Upstream end of pool

TB099-3 Midway along Pool TB-M looking toward southern bank

TB099-4 Midway along Pool TB-M looking toward southern bank

TRIBUTARY B STREAM MAPPING SUMMARY

TB100-1 Near Downstream end of Pool TB-M looking Upstream

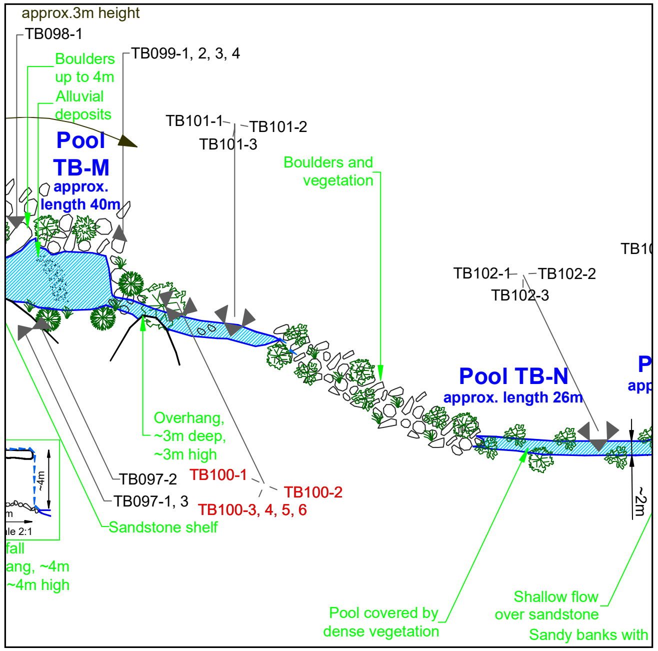
TB0100-2 Near Downstream end of Pool TB-M looking Downstream

Notes (as at 21 December 2009)

- Pool TB-M approximately 2m wide at downstream end
- Boulders and vegetation downstream of pool
- Overhang on southern bank approximately 3m high and 3m deep
- Alluvial deposits beneath overhang

TB100-3 Near Downstream end of Pool TB-M looking toward southern bank

TB100-4 Near Downstream end of Pool TB-M looking toward southern bank



TB100-5 Overhang on southern bank

TB100-6 Overhang on southern bank

Photo Details

Photo ID	Easting	Northing	Bearing
TB100-1	309454	6215304	295
TB100-2	309454	6215304	115
TB100-3	309454	6215304	205
TB100-4	309454	6215304	205
TB100-5	309454	6215304	205
TB100-6	309454	6215304	205

TRIBUTARY B STREAM MAPPING SUMMARY

TB101-1 Downstream end of Pool TB-M looking Upstream

TB0101-2 Downstream end of Pool TB-M looking Downstream

TB101-3 Downstream end of Pool TB-M looking toward southern bank

TB102-1 Midway along Pool TB-N looking Upstream

TB0102-2 Midway along Pool TB-N looking Downstream

TB102-3 Midway along Pool TB-N looking toward southern bank

Notes (as at 21 December 2009)

- Pool TB-N approximately 26m long and 2m wide
- Base of the pool not visible
- Vegetation encroaches on both sides of pool
- Shallow flow over sandstone downstream of pool

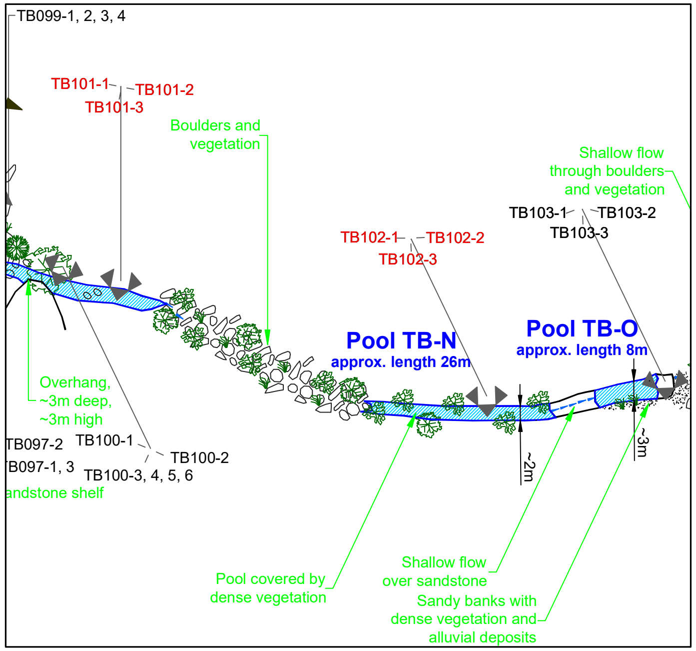


Photo Details

Photo ID	Easting	Northing	Bearing
TB101-1	309456	6215296	280
TB101-2	309456	6215296	190
TB101-3	309456	6215296	100
TB102-1	309502	6215284	270
TB102-2	309502	6215284	90
TB102-3	309502	6215284	180

TRIBUTARY B STREAM MAPPING SUMMARY

TB103-1 Downstream end of Pool TB-O looking Upstream

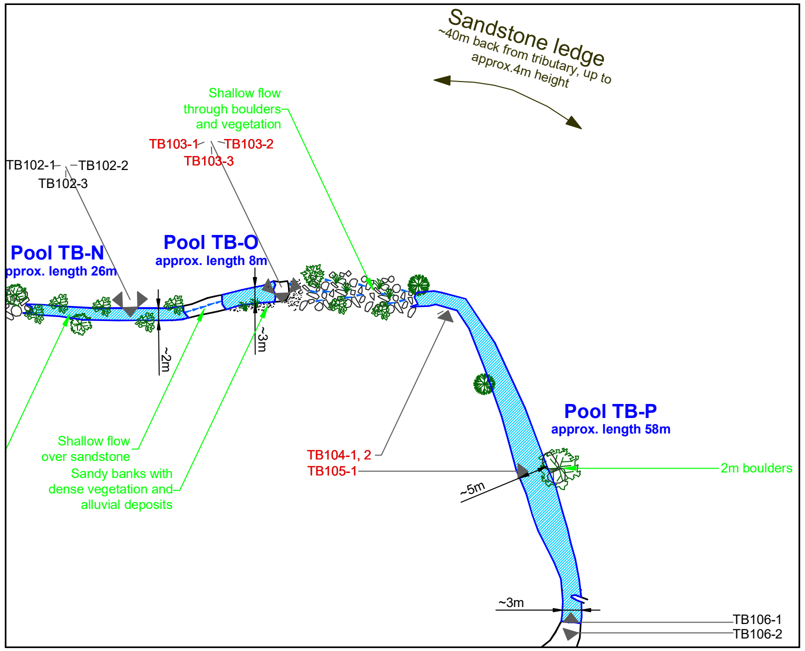
TB103-2 Downstream end of Pool TB-O looking Downstream

Notes (as at 21 December 2009)

- Pool TB-O approximately 8m long, 3m wide and 0.4m deep
- Base of the pool is sandstone with vegetation debris at the downstream end
- Alluvial deposits on southern bank at downstream end of the pool
- Shallow flow through boulders and vegetation downstream into Pool TB-P
- Sandstone ledge up to 4m high on northern side of Pool TB-P at a distance of approximately 40m (TB104)
- Boulders up to 2m on eastern bank (TB105)

TB103-3 Downstream end of Pool TB-O looking toward southern bank

TB104-1 Near upstream end of Pool TB-P looking toward sandstone ledge



TB104-2 Near upstream end of Pool TB-P looking toward sandstone ledge

TB105-1 Midway along Pool TB-P looking toward eastern bank

Photo Details

Photo ID	Easting	Northing	Bearing
TB103-1	309526	6215287	250
TB103-2	309526	6215287	100
TB103-3	309526	6215287	180
TB104-1	309552	6215283	25
TB104-2	309552	6215283	25
TB105-1	309564	6215257	90

TRIBUTARY B STREAM MAPPING SUMMARY

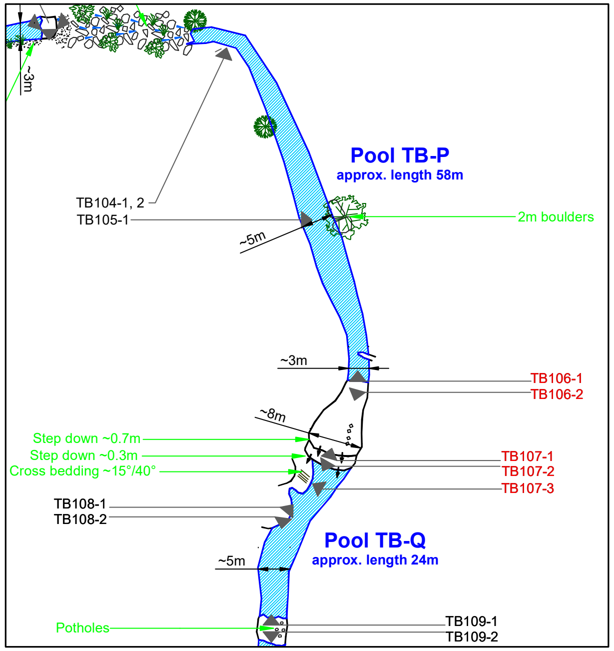
TB106-1 Downstream end of Pool TB-P looking Upstream

TB106-2 Downstream end of Pool TB-P looking Downstream

Notes (as at 21 December 2009)

- Pool TB-P approximately 58m long and 3 to 5m wide
- Base of the pool not visible
- Rockbar downstream of Pool TB-P is approximately 12m long and 8m wide
- No flow visible on rockbar, but minor ponding evident
- Approximate 1m change in height along rockbar approaching Pool TB-Q

TB107-1 Upstream end of Pool TB-Q looking Upstream



TB107-2 Upstream end of Pool TB-Q looking Downstream

TB107-3 Upstream end of Pool TB-Q looking toward western bank

Photo Details

Photo ID	Easting	Northing	Bearing
TB106-1	309574	6215234	0
TB106-2	309574	6215234	200
TB107-1	309568	6215228	15
TB107-2	309568	6215228	210
TB107-3	309568	6215228	300

TRIBUTARY B STREAM MAPPING SUMMARY

TB108-1 Midway along Pool TB-Q looking Upstream

TB108-2 Midway along Pool TB-Q looking Downstream

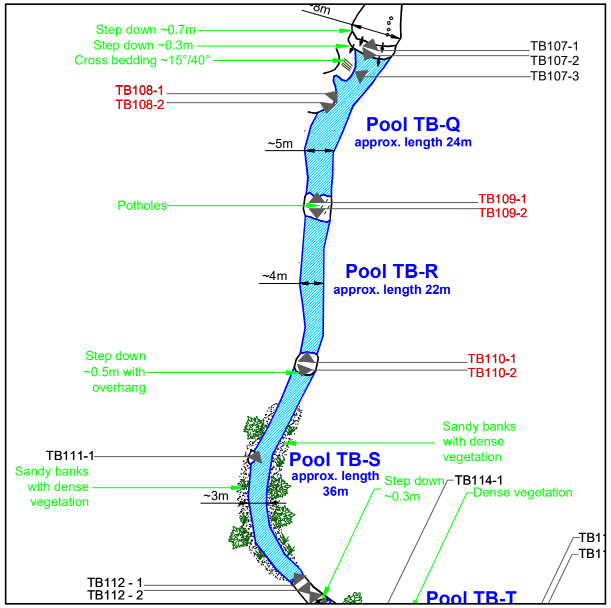
Notes (as at 21 December 2009)

- Pool TB-Q approximately 24m long, 5m wide and 1m deep
- Base of the pool is sandstone
- Rockbar downstream of pool approximately 4m long and 4.5m wide

- Pool TB-R approximately 22m long, 4m wide and 0.5m deep
- Base of the pool is sandstone
- Scattered vegetation debris at downstream end of pool

TB109-1 Downstream end of Pool TB-Q looking Upstream

TB109-2 Upstream end of Pool TB-R looking Downstream



TB110-1 Downstream end of Pool TB-R looking Upstream

TB110-2 Upstream end of Pool TB-S looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB108-1	309562	6215213	40
TB108-2	309562	6215213	190
TB109-1	309560	6215196	0
TB109-2	309560	6215196	180
TB110-1	309559	6215170	5
TB110-2	309559	6215170	205

TRIBUTARY B STREAM MAPPING SUMMARY

TB111-1 Midway along Pool TB-S looking Upstream

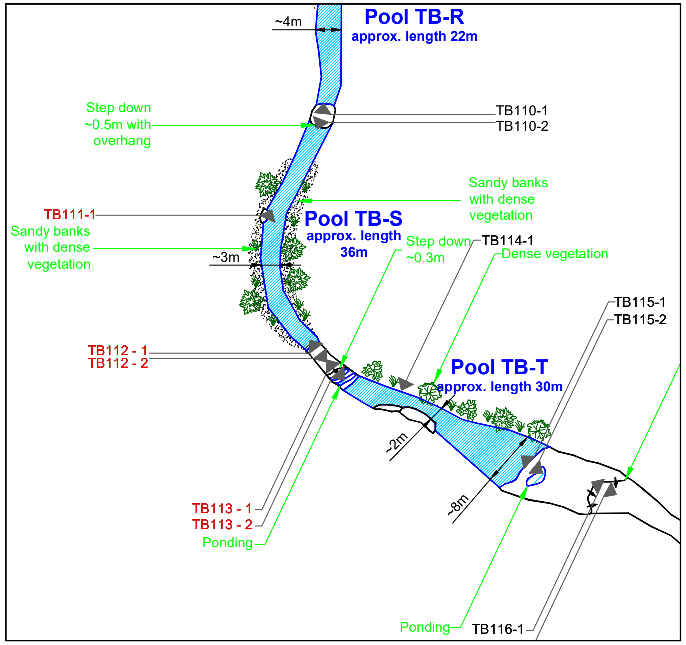
TB112-1 Downstream end of Pool TB-S looking Upstream

Notes (as at 21 December 2009)

- Pool TB-S approximately 36m long, 3m wide and 0.3m deep
- Base of the pool is sandstone
- Sandy banks and dense vegetation on both sides of pool
- Rockbar downstream of pool approximately 5m long with a step down of approximately 0.3m at the downstream end
- Shallow ponding on rockbar

TB112-1 Downstream end of Pool TB-S looking Downstream

TB113-1 Upstream of Pool TB-T looking Upstream



TB113-2 Upstream of Pool TB-T looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB111-1	309556	6215156	25
TB112-1	309558	6215135	325
TB112-2	309558	6215135	145
TB113-1	309559	6215132	325
TB113-2	309559	6215132	135

TRIBUTARY B STREAM MAPPING SUMMARY

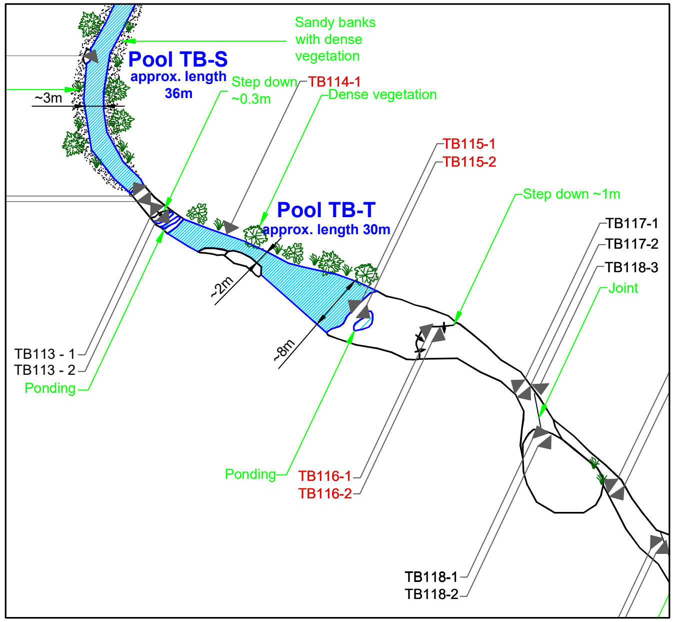
Notes (as at 15 & 21 December 2009)

- Pool TB-T approximately 30m long, 2 to 8m wide and 0.3m deep
- Base of the pool is sandstone with algae
- Sandstone ledge on southern bank and dense vegetation on northern bank
- Ponding and potholes on wide rockbar at downstream end of pool
- Rockbar steps down approximately 1m at TB116

TB114-1 Midway along Pool TB-T looking toward southern bank

TB115-1 Downstream end of Pool TB-T looking Upstream

TB115-2 Downstream end of Pool TB-T looking Downstream



TB116-1 Downstream of Pool TB-T looking Upstream

TB116-2 Downstream of Pool TB-T looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB114-1	309572	6215129	210
TB115-1	309589	6215116	310
TB115-2	309589	6215116	130
TB116-1	309601	6215114	295
TB116-2	309601	6215114	115

TRIBUTARY B STREAM MAPPING SUMMARY

TB117-1 Downstream of Pool TB-T looking Upstream

TB117-2 Downstream of Pool TB-T looking Downstream

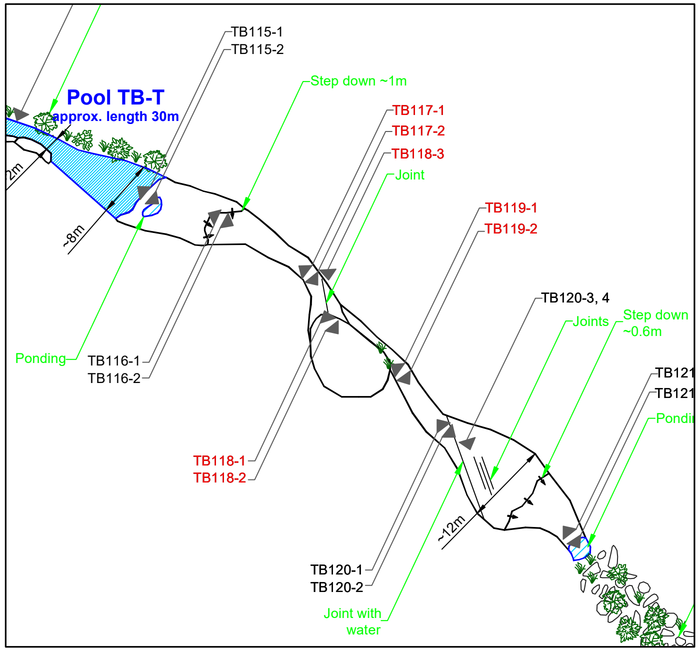
Notes (as at 15 December 2009)

- Rockbar downstream of Pool TB-T extends through TB117, TB118 and TB119
- No flow visible

TB118-1 Downstream of Pool TB-T looking Upstream

TB118-2 Downstream of Pool TB-T looking Downstream

TB118-3 Joint



TB119-1 Downstream of Pool TB-T looking Upstream

TB119-2 Downstream of Pool TB-T looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB117-1	309614	6215105	305
TB117-2	309614	6215105	145
TB118-1	309615	6215097	340
TB118-2	309615	6215097	145
TB118-3	309615	6215097	175
TB119-1	309628	6215091	305
TB119-2	309628	6215091	145

TRIBUTARY B STREAM MAPPING SUMMARY

TB120-1 Rockbar looking Upstream

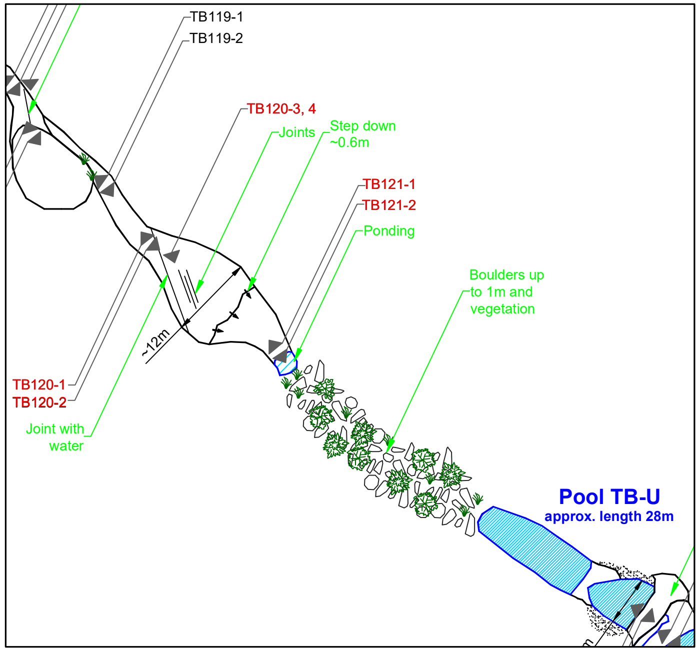
TB120-3 Joint with water

TB120-4 Joint

Notes (as at 15 December 2009)

- Rockbar between TB120 and TB121 approximately 12m wide and 24m long, with many joints
- Step down of approximately 0.6m approaching TB121
- Ponding at downstream end of rockbar leading into boulder field

TB120-2 Rockbar looking Downstream



TB121-1 Upstream of Pool TB-U looking Upstream

TB121-2 Upstream of Pool TB-U looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB120-1	309635	6215082	320
TB120-2	309635	6215082	125
TB120-3	309635	6215082	160
TB120-4	309635	6215082	160
TB121-1	309654	6215066	320
TB121-2	309654	6215066	150

TRIBUTARY B STREAM MAPPING SUMMARY

TB122-1 Downstream end of Pool TB-U looking Upstream

TB122-2 Downstream end of Pool TB-U looking Downstream

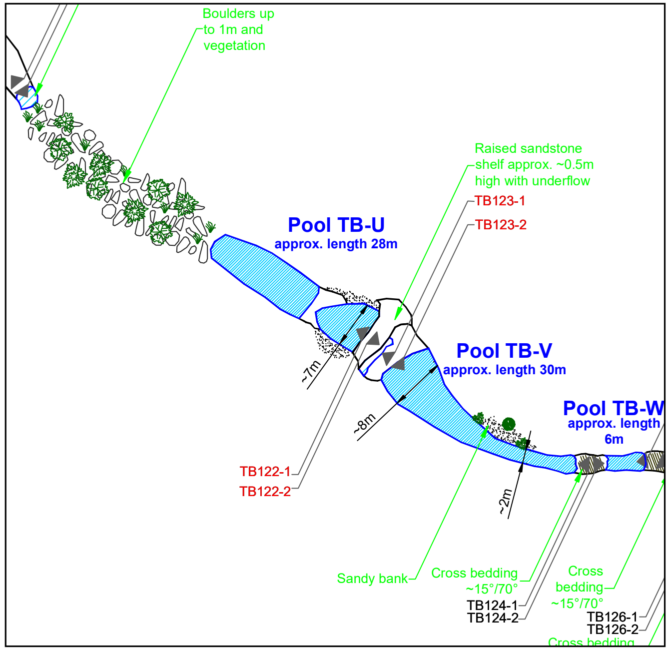
Notes (as at 15 December 2009)

- Pool TB-U approximately 28m long, 7m wide and 0.5m deep
- Base of the pool is sandstone with alluvial deposits on the northern and southern banks at the downstream end

- Pool TB-V approximately 30m long, 8m wide at the upstream end, 2m wide at the downstream end, and up to 1m deep
- Base of the pool is sandstone with alluvial deposits

- Rockbar between Pools TB-U and TB-V approximately 6.5m long and 11m wide, with raised sandstone shelf approximately 0.5m high with underflow

TB123-1 Upstream end of Pool TB-V looking Upstream



TB123-2 Upstream end of Pool TB-V looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB122-1	309707	6215027	300
TB122-2	309707	6215027	130
TB123-1	309711	6215024	305
TB123-2	309711	6215024	140

TRIBUTARY B STREAM MAPPING SUMMARY

TB124-1 Downstream end of Pool TB-V looking Upstream

TB124-2 Upstream end of Pool TB-W looking Downstream

Notes (as at 15 December 2009)

- Rockbar between Pools TB-V and TB-W approximately 5m long and 2m wide with some cross bedding evident

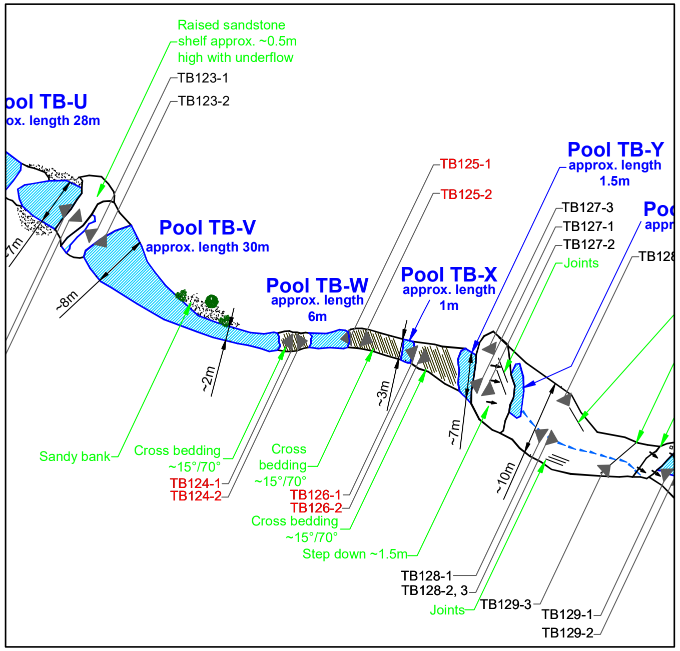
- Pool TB-W approximately 6m long, 2.5m wide and 0.5m deep
- Base of the pool is sandstone with alluvial deposits

- Pool TB-X approximately 1m long, 3m wide and 0.4 m deep
- Base of the pool is sandstone with alluvial deposits

- Rockbar between Pools TB-W and TB-X approximately 8m long and 3m wide, with cross bedding evident along the whole length of the rockbar

TB125-1 Downstream end of Pool TB-W looking Upstream

TB125-2 Downstream end of Pool TB-W looking Downstream



TB126-1 Downstream end of Pool TB-X looking Upstream

TB126-2 Downstream end of Pool TB-X looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB124-1	309744	6215006	275
TB124-2	309744	6215006	85
TB125-1	309753	6215010	265
TB125-2	309753	6215010	115
TB126-1	309762	6215005	285
TB126-2	309762	6215005	115

TRIBUTARY B STREAM MAPPING SUMMARY

TB127-1 Downstream end of Pool TB-Y looking Upstream

TB127-2 Downstream end of Pool TB-Y looking Downstream

TB127-3 Joint

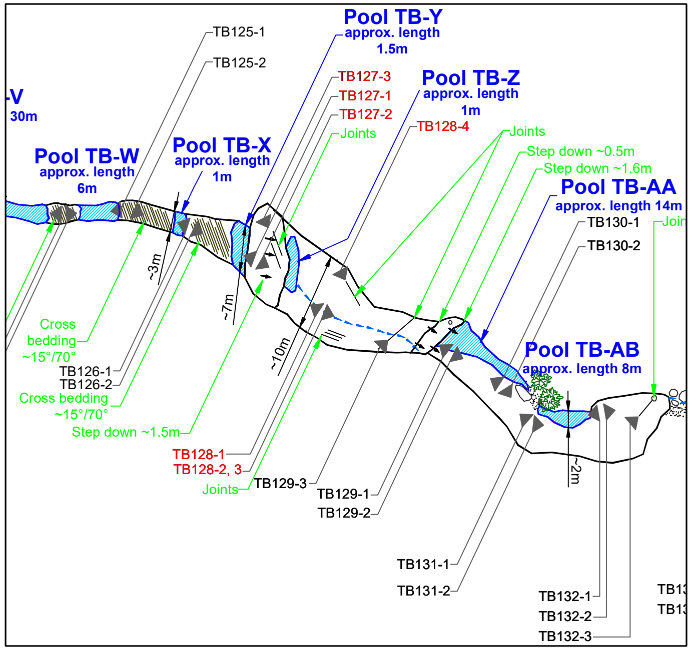
Notes (as at 15 December 2009)

- Pool TB-Y approximately 1.5m long, 7m wide and 0.2m deep
- Base of the pool is sandstone

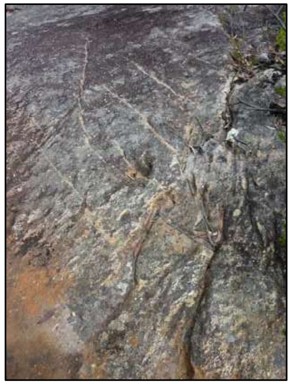
- Pool TB-Z approximately 1m long, 8m wide and 0.2m deep
- Base of the pool is sandstone

- Rockbar between Pools TB-Y and TB-Z approximately 6.5m long and 14m wide, with several joints
- Approximate 1.5m change in height between Pools TB-Y and TB-Z

TB128-1 Downstream end of Pool TB-Z looking Upstream



TB128-2 Downstream end of Pool TB-Z looking Downstream



TB128-3 Joints

TB128-4 Joint

Photo Details

Photo ID	Easting	Northing	Bearing
TB127-1	309772	6215000	290
TB127-2	309772	6215000	120
TB127-3	309772	6215000	155
TB128-1	309783	6214996	305
TB128-2	309783	6214996	110
TB128-3	309783	6214996	110
TB128-4	309783	6214996	155

TRIBUTARY B STREAM MAPPING SUMMARY

TB129-1 Upstream end of Pool TB-AA looking Upstream

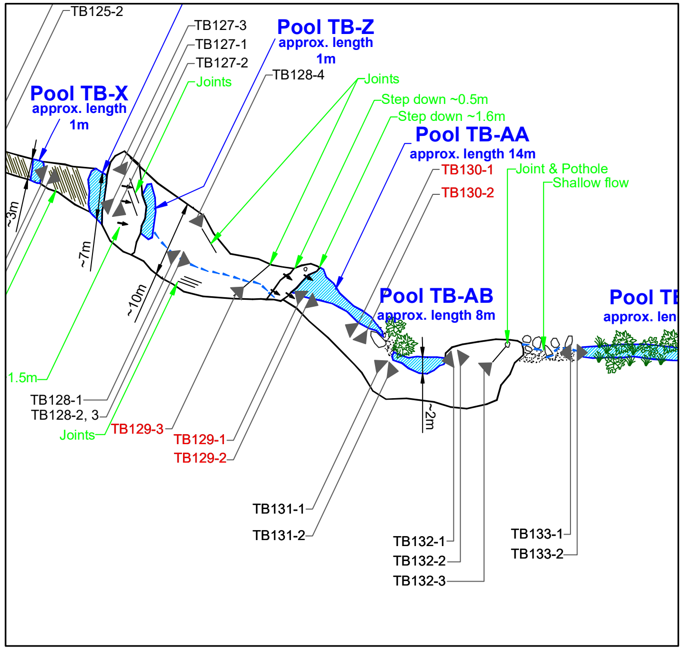
Notes (as at 15 December 2009)

- Pool TB-AA approximately 14m long, 1 to 5.5m wide and 0.5m deep
- Base of the pool is sandstone with alluvial deposits

- Rockbar upstream of Pool TB-AA approximately 23m long and up to 10m wide at the upstream end
- Flow path down centre of rockbar between Pools TB-Z and TB-AA, but no flow visible
- Approximate 2.1m change in height between Pools TB-Z and TB-AA

TB129-2 Upstream end of Pool TB-AA looking Downstream

TB129-3 Joint



TB130-1 Downstream end of Pool TB-AA looking Upstream

TB130-2 Downstream end of Pool TB-AA looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB129-1	309800	6214988	310
TB129-2	309800	6214988	115
TB129-3	309800	6214988	50
TB130-1	309809	6214979	300
TB130-2	309809	6214979	145

TRIBUTARY B STREAM MAPPING SUMMARY

TB131-1 Upstream end of Pool TB-AB looking Upstream

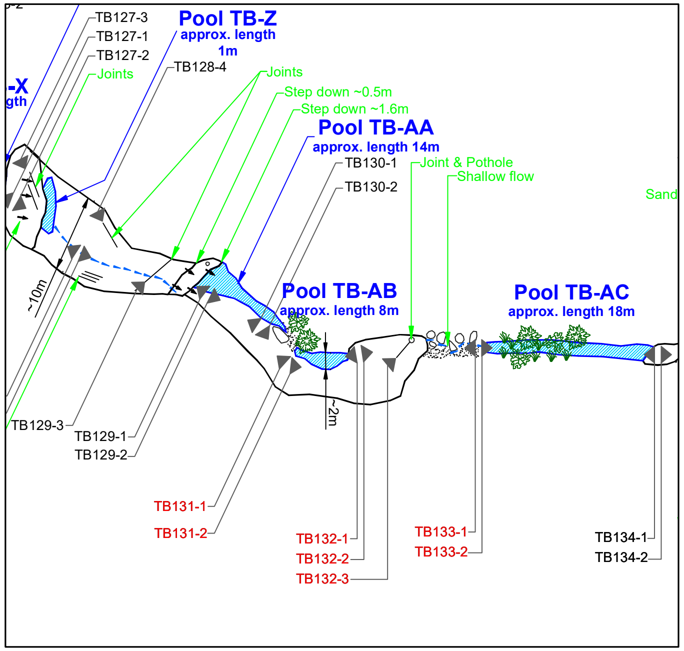
TB131-2 Upstream end of Pool TB-AB looking Downstream

Notes (as at 15 December 2009)

- Pool TB-AB approximately 8m long, 2m wide and 0.2m deep
- Base of the pool is sandstone with alluvial deposits
- Rockbar downstream of the pool approximately 10m wide with long joint and pothole
- Shallow flow over small boulders and alluvial deposits in to Pool TB-AC

TB132-1 Downstream end of Pool TB-AB looking Upstream

TB132-2 Downstream end of Pool TB-AB looking Downstream



TB132-3 Joint and pothole

TB133-1 Upstream end of Pool TB-AC looking Upstream

TB133-2 Upstream end of Pool TB-AC looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB131-1	309814	6214973	315
TB131-2	309814	6214973	95
TB132-1	309824	6214977	260
TB132-2	309824	6214977	80
TB132-3	309824	6214977	50
TB133-1	309842	6214978	270
TB133-2	309842	6214978	90

TRIBUTARY B STREAM MAPPING SUMMARY

TB134-1 Downstream end of Pool TB-AC looking Upstream

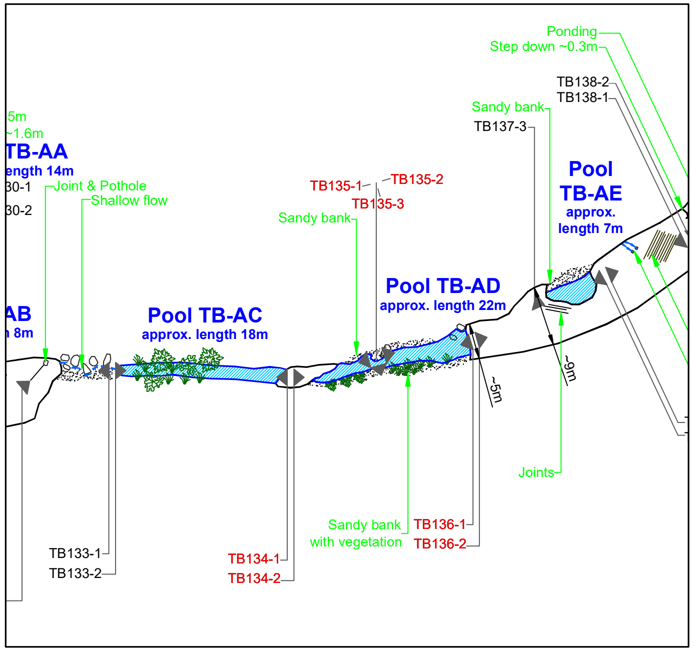
TB134-2 Upstream end of Pool TB-AD looking Downstream

Notes (as at 15 December 2009)

- Pool TB-AC approximately 18m long, 2m wide and 0.2m deep
- Base of the pool is sandstone with alluvial deposits on southern bank

- Pool TB-AD approximately 22m long, up to 4.5m wide at the downstream end, and 0.5m deep

- Rockbar between Pools TB-AC and TB-AD approximately 7m long



TB135-1 Midway along Pool TB-AD looking Upstream

TB135-2 Midway along Pool TB-AD looking Downstream

TB135-3 Midway along Pool TB-AD looking toward southern bank

TB136-1 Downstream end of Pool TB-AD looking Upstream

TB136-2 Downstream end of Pool TB-AD looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB134-1	309869	6214977	270
TB134-2	309869	6214977	90
TB135-1	309882	6214980	255
TB135-2	309882	6214980	75
TB135-3	309882	6214980	165
TB136-1	309897	6214982	255
TB136-2	309897	6214982	75

TRIBUTARY B STREAM MAPPING SUMMARY

TB137-1 Downstream end of Pool TB-AE looking Upstream

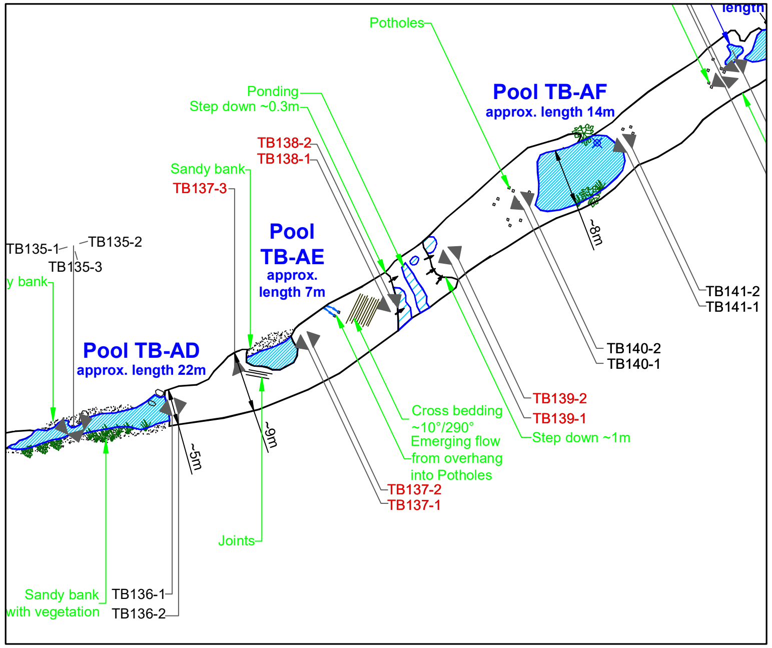
TB137-2 Downstream end of Pool TB-AE looking Downstream

Notes (as at 15 December 2009)

- Pool TB-AE approximately 7m long, 3.5m wide and 0.5m deep
- Base of the pool is sandstone with alluvial deposits and scattered vegetation debris on the northern bank
- Rockbar downstream of the pool approximately 16m long with cross bedding
- Rockbar steps down approximately 0.3m at TB138, with ponding downstream (TB138-2)
- Rockbar steps down approximately 1m at TB139 (TB139-1)

TB137-3 Joints

TB138-1 Downstream of Pool TB-AE looking Upstream



TB138-2 Downstream of Pool TB-AE looking Downstream

TB139-1 Upstream of Pool TB-AF looking Upstream

TB139-2 Upstream of Pool TB-AF looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB137-1	309916	6214992	245
TB137-2	309916	6214992	65
TB137-3	309916	6214992	100
TB138-1	309929	6214998	245
TB138-2	309929	6214998	55
TB139-1	309938	6215005	240
TB139-2	309938	6215005	50

TRIBUTARY B STREAM MAPPING SUMMARY

TB140-1 Upstream end of Pool TB-AF looking Upstream

TB140-2 Upstream end of Pool TB-AF looking Downstream

TB141-1 Downstream end of Pool TB-AF looking Upstream

TB141-2 Downstream end of Pool TB-AF looking Downstream

Notes (as at 15 December 2009)

- Pool TB-AF approximately 14m long, 8m wide and up to 1.5m deep
- Base of the pool is sandstone with alluvial deposits
- Rockbar upstream of the pool has many potholes and no flow visible
- Rockbar downstream of the pool approximately 9m wide with many potholes at the downstream end

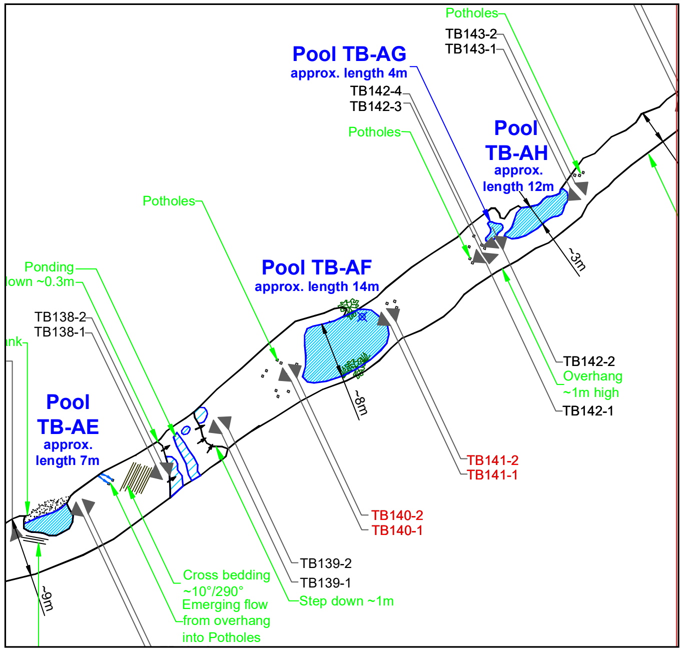


Photo Details

Photo ID	Easting	Northing	Bearing
TB140-1	309950	6215011	235
TB140-2	309950	6215011	60
TB141-1	309963	6215022	235
TB141-2	309963	6215022	55

TRIBUTARY B STREAM MAPPING SUMMARY

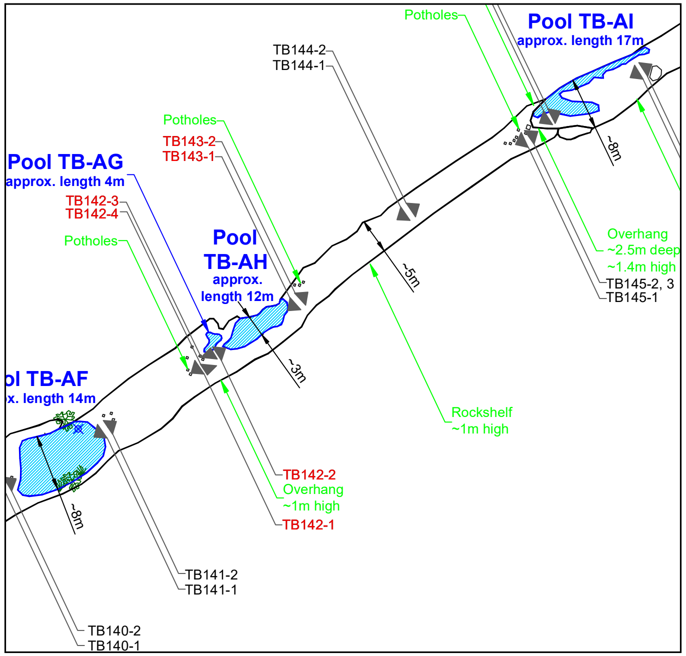
TB142-1 Upstream end of Pool TB-AG looking Upstream

TB142-2 Upstream end of Pool TB-AG looking Downstream

Notes (as at 15 December 2009)

- Pool TB-AG approximately 4m long, up to 2m wide and 0.3m deep
- Base of the pool is sandstone with alluvial deposits

- Pool TG-AH approximately 12m long, 3m wide and 0.5m deep
- Base of the pool is sandstone with alluvial deposits
- Overhang on southern bank approximately 1m high



TB142-3 Pool TB-AG Looking toward northern bank

TB142-4 Overhang along southern bank Upstream of Pool TB-AG

TB143-1 Downstream end of Pool TB-AH looking Upstream

TB143-2 Downstream end of Pool TB-AH looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB142-1	309977	6215032	235
TB142-2	309977	6215032	55
TB142-3	309977	6215032	185
TB142-4	309977	6215032	5
TB143-1	309993	6215041	225
TB143-2	309993	6215041	45

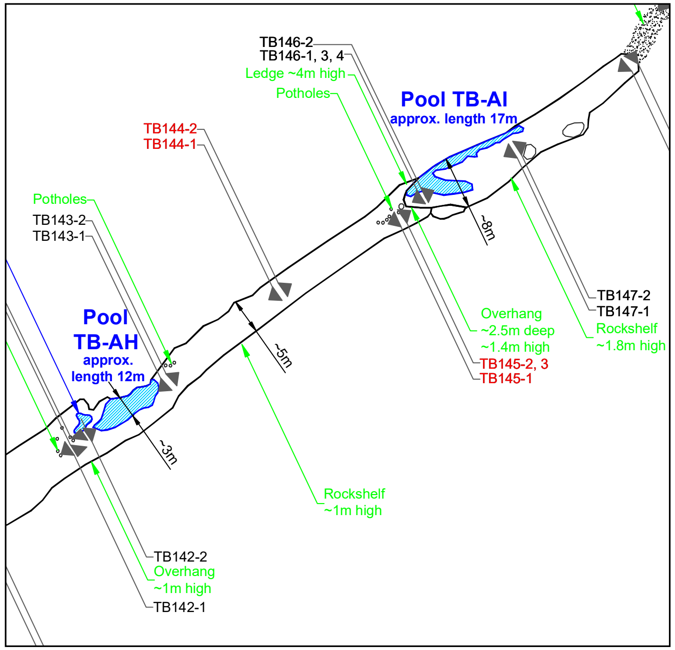
TRIBUTARY B STREAM MAPPING SUMMARY

TB144-1 Downstream of Pool TB-AH looking Upstream

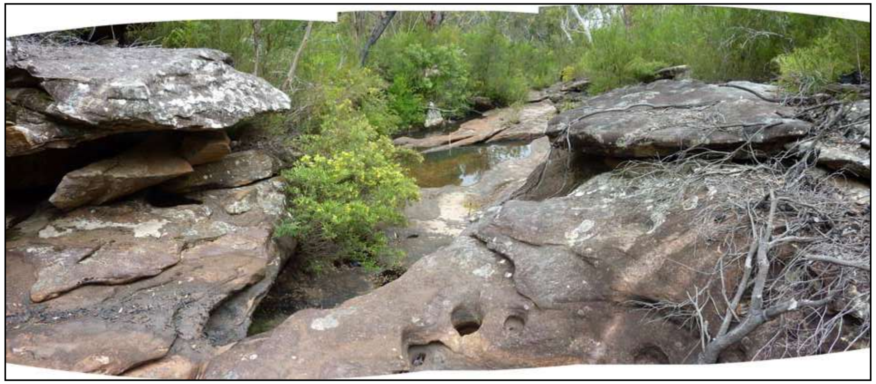
TB144-2 Downstream of Pool TB-AH looking Downstream

Notes (as at 15 December 2009)

- Rockbar between Pools TB-AH and TB-AI approximately 45m long and 5m wide, with many potholes
- Overhang at downstream end of rockbar approximately 1.4m high and 2.5m deep



TB145-1 Upstream of Pool TB-AI looking Upstream



TB145-2 Upstream of Pool TB-AI looking Downstream

TB145-3 Pothole in overhang

Photo Details

Photo ID	Easting	Northing	Bearing
TB144-1	310008	6215056	235
TB144-2	310008	6215056	55
TB145-1	310032	6215061	245
TB145-2	310032	6215061	55
TB145-3	310032	6215061	55

TRIBUTARY B STREAM MAPPING SUMMARY

TB146-1 Upstream end of Pool TB-AI looking Upstream

TB146-2 Upstream end of Pool TB-AI looking Downstream

TB146-3 Pothole in overhang

TB146-4 Pothole in overhang

Notes (as at 15 December 2009)

- Pool TB-AI approximately 17m long, up to 4m wide at the upstream end, and 0.3m deep
- Base of the pool is sandstone with alluvial deposits
- Overhang approximately 1.4m high and 2.5m deep, with large potholes

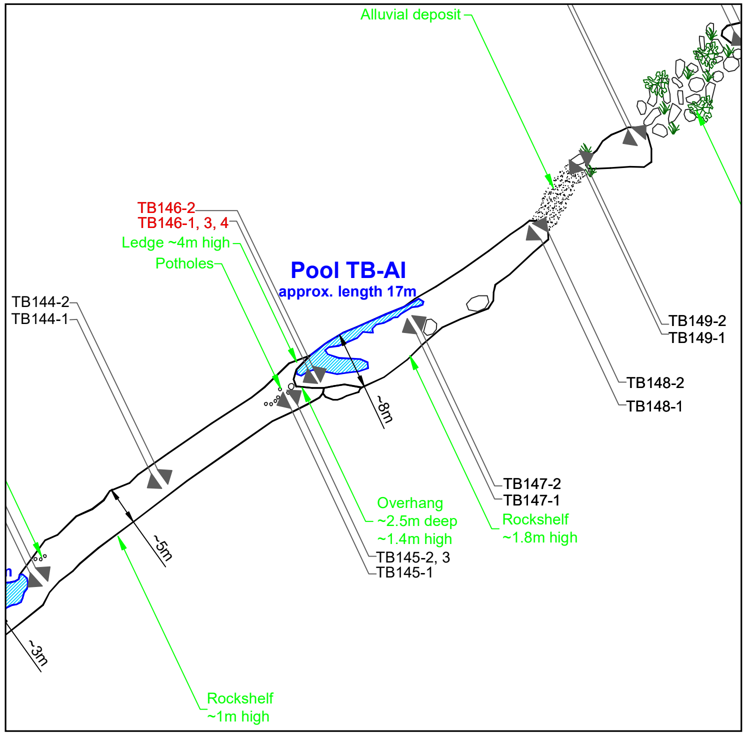


Photo Details

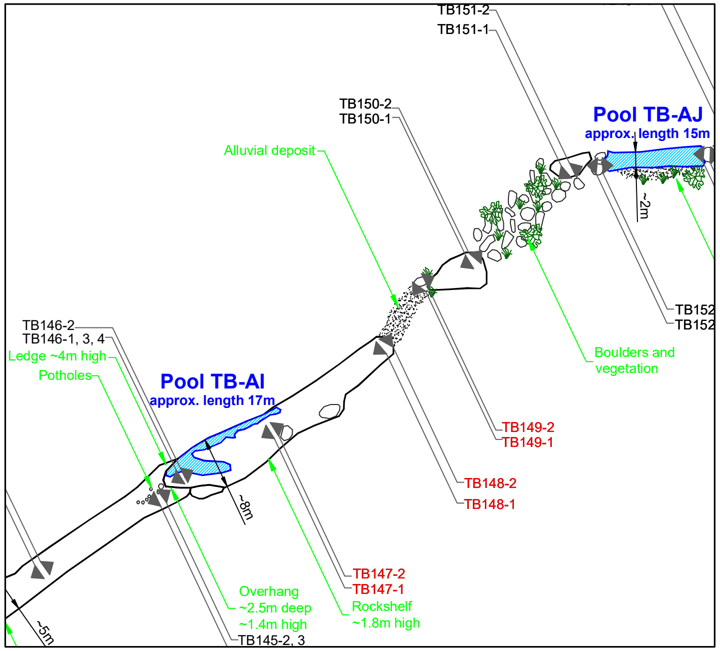
Photo ID	Easting	Northing	Bearing
TB146-1	310046	6215079	235
TB146-2	310046	6215079	65
TB146-3	310046	6215079	235
TB146-4	310046	6215079	235

TRIBUTARY B STREAM MAPPING SUMMARY

TB147-1 Downstream end of Pool TB-AI looking Upstream

Notes (as at 15 December 2009)

- Pool TB-AI approximately 17m long, up to 4m wide at the upstream end, and 0.3m deep
- Base of the pool is sandstone with alluvial deposits
- Alluvial deposits and scattered vegetation debris between TB148 and TB149



TB147-2 Downstream end of Pool TB-AI looking Downstream

TB148-1 Downstream of Pool TB-AI looking Upstream

TB148-2 Downstream of Pool TB-AI looking Downstream

TB149-1 Downstream of Pool TB-AI looking Upstream

TB149-2 Downstream of Pool TB-AI looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB147-1	310046	6215079	240
TB147-2	310046	6215079	60
TB148-1	310062	6215089	235
TB148-2	310062	6215089	30
TB149-1	310076	6215099	215
TB149-2	310076	6215099	65

TRIBUTARY B STREAM MAPPING SUMMARY

TB150-1 Upstream of Pool TB-AJ looking Upstream

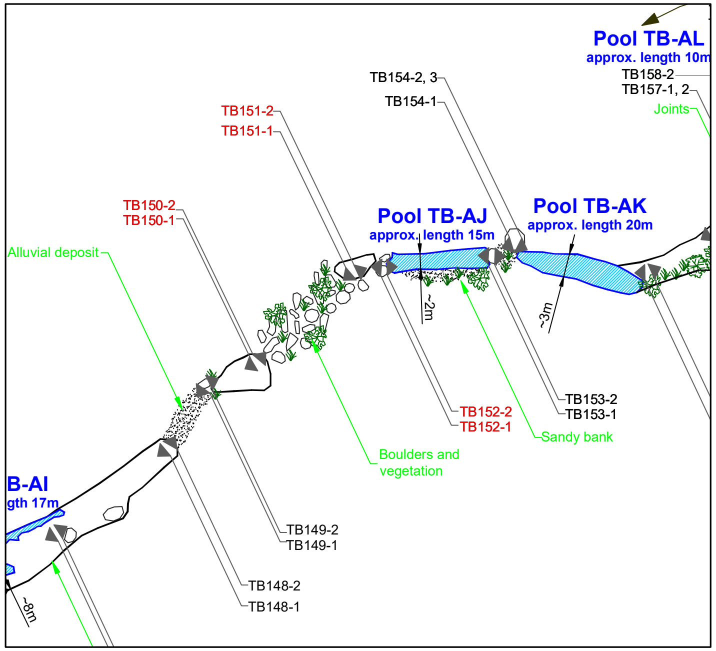
TB150-2 Upstream of Pool TB-AJ looking Downstream

Notes (as at 15 December 2009)

- Boulder field and vegetation upstream of Pool TB-AJ
- Pool TB-AJ approximately 15m long, 2m wide and 0.3m deep
- Base of the pool is sandstone with alluvial deposits

TB151-1 Upstream of Pool TB-AJ looking Upstream

TB151-2 Upstream of Pool TB-AJ looking Downstream



TB152-1 Upstream end of Pool TB-AJ looking Upstream

TB152-2 Upstream end of Pool TB-AJ looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB150-1	310076	6215099	240
TB150-2	310076	6215099	40
TB151-1	310090	6215117	230
TB151-2	310090	6215117	65
TB152-1	310095	6215116	280
TB152-2	310095	6215116	85

TRIBUTARY B STREAM MAPPING SUMMARY

TB153-1 Downstream end of Pool TB-AJ looking Upstream

TB153-2 Downstream end of Pool TB-AJ looking Downstream

TB154-1 Upstream end of Pool TB-AK looking Upstream

Notes (as at 15 December 2009)

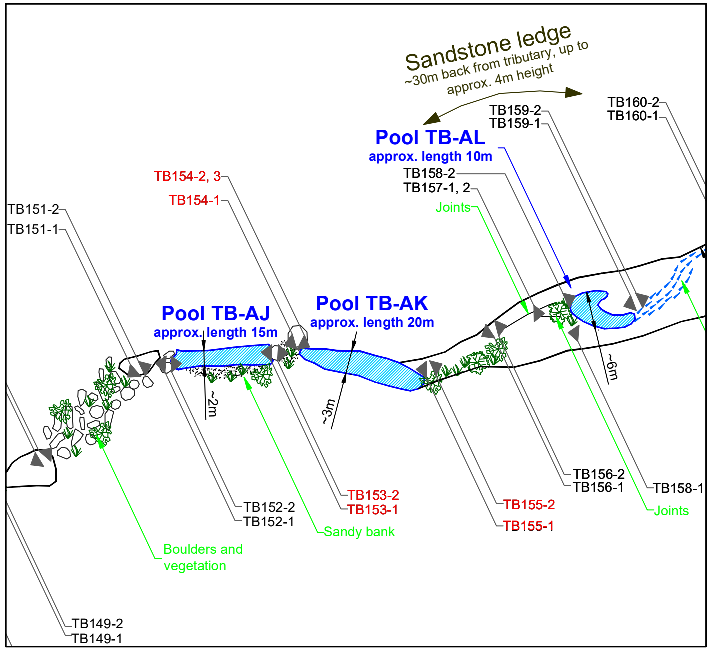
- Pool TB-AJ approximately 15m long, 2m wide and 0.3m deep
- Base of the pool is sandstone with alluvial deposits

- Pool TB-AK approximately 20m long, 3m wide and 0.3m deep
- Base of the pool is sandstone with alluvial deposits

- Vegetation and alluvial deposits between Pools TB-AJ and TB-AK
- No flow visible downstream of Pool TB-AK

TB154-2 Upstream end of Pool TB-AK looking Downstream

TB154-3 Upstream end of Pool TB-AK looking Downstream



TB155-1 Downstream end of Pool TB-AK looking Upstream

TB155-2 Downstream end of Pool TB-AK looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB153-1	310111	6215118	275
TB153-2	310111	6215118	95
TB154-1	310115	6215120	255
TB154-2	310115	6215120	120
TB154-3	310115	6215120	120
TB155-1	310135	6215117	270
TB155-2	310135	6215117	65

TRIBUTARY B STREAM MAPPING SUMMARY

TB156-1 Downstream of Pool TB-AK looking Upstream

TB156-2 Downstream of Pool TB-AK looking Downstream

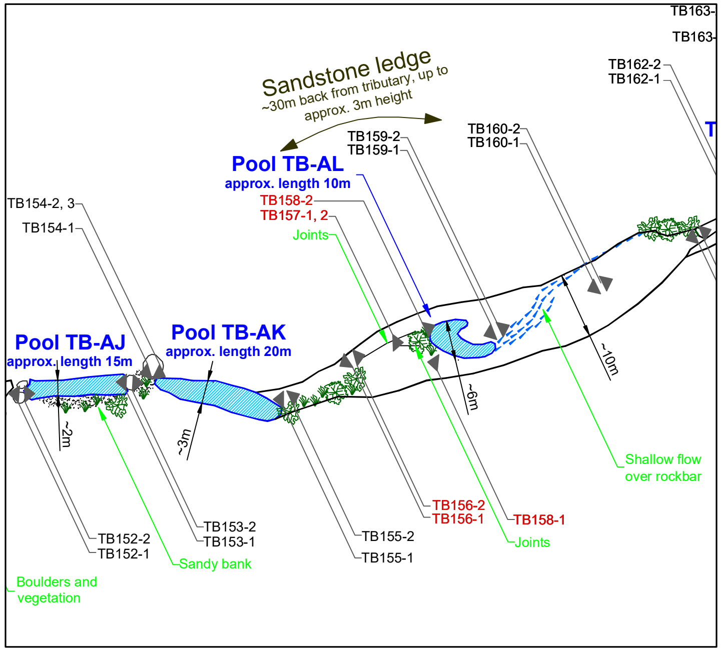
TB157-1 Joint

Notes (as at 15 December 2009)

- Rockbar upstream of Pool TB-AL approximately 23m long and up to 10m wide, with joints at the downstream end
- Pool TB-AL approximately 10m long, 6m wide and 0.3m deep
- Base of the pool is sandstone with algae at the downstream end
- Sandstone ledge up to 3m high on northern side of Pool TB-AL at a distance of approximately 30m

TB157-2 Joint

TB158-1 Upstream end of Pool TB-AL looking Upstream



TB158-2 Upstream end of Pool TB-AL looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB156-1	310146	6215121	235
TB156-2	310146	6215121	75
TB157-1	310152	6215122	85
TB157-2	310152	6215122	85
TB158-1	310156	6215126	275
TB158-2	310156	6215126	65

TRIBUTARY B STREAM MAPPING SUMMARY

TB159-1 Downstream end of Pool TB-AL looking Upstream

TB159-2 Downstream end of Pool TB-AL looking Downstream

TB160-1 Downstream of Pool TB-AL looking Upstream

TB160-2 Downstream of Pool TB-AL looking Downstream

Notes (as at 15 December 2009)

- Pool TB-AL approximately 10m long, 6m wide and 0.3m deep
- Base of the pool is sandstone with algae at the downstream end
- Shallow flow over 10m wide rockbar downstream of the pool

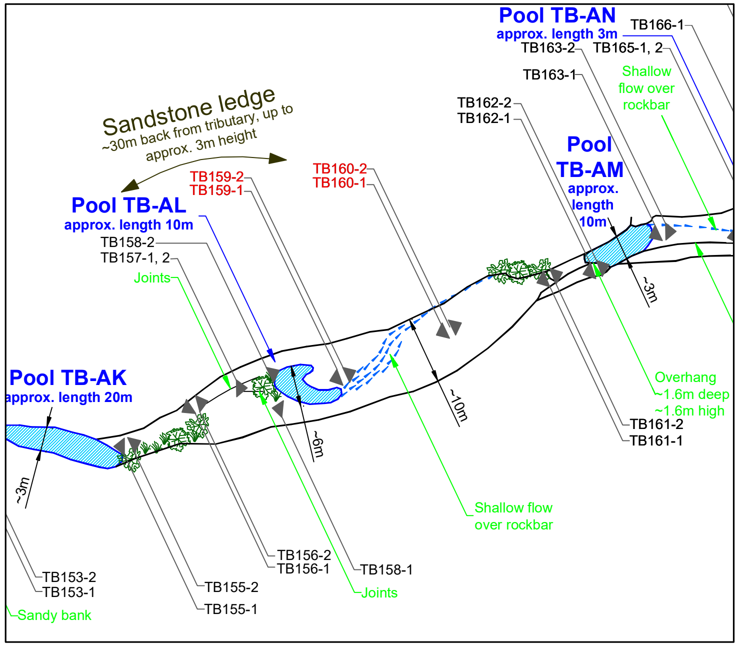


Photo Details

Photo ID	Easting	Northing	Bearing
TB159-1	310168	6215124	250
TB159-2	310168	6215124	65
TB160-1	310183	6215133	245
TB160-2	310183	6215133	65

TRIBUTARY B STREAM MAPPING SUMMARY

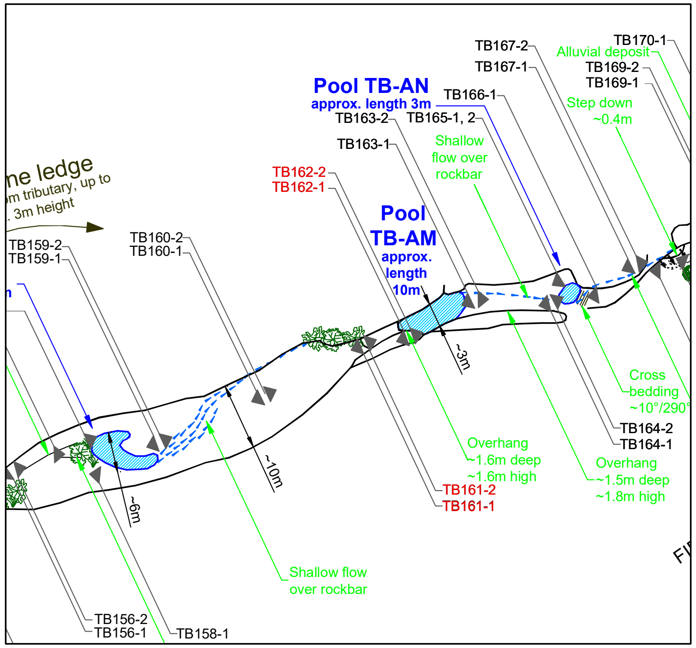
TB161-1 Upstream of Pool TB-AM looking Upstream

TB161-2 Upstream of Pool TB-AM looking Downstream

Notes (as at 15 December 2009)

- Pool TB-AM approximately 10m long, 3m wide and 0.3m deep
- Base of the pool is sandstone
- Approximate 1.6m change in height from rockbar at TB162 down to Pool TB-AM

TB162-1 Upstream end of Pool TB-AM looking Upstream



TB162-2 Upstream end of Pool TB-AM looking Downstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB161-1	310199	6215140	245
TB161-2	310199	6215140	65
TB162-1	310204	6215142	250
TB162-2	310204	6215142	70

TRIBUTARY B STREAM MAPPING SUMMARY

TB163-1 Downstream end of Pool TB-AM looking Upstream

TB163-2 Downstream end of Pool TB-AM looking Downstream

<u>Notes (as at 15 December 2009)</u>

- Pool TB-AM approximately 10m long, 3m wide and 0.3m deep
- Base of the pool is sandstone
- Overhang at upstream end of pool approximately 1.6m high and 1.6m deep

- Pool TB-AN approximately 3m long, 2.5m wide and 0.2m deep
- Base of the pool is sandstone

- Rockbar between Pools TB-AM and TB-AN approximately 16m long and 4m wide, with shallow flow
- Overhang on southern bank approximately 1.8m high and 1.5m deep, and runs along the length of the rockbar

TB164-1 Upstream end of Pool TB-AN looking Upstream

TB164-2 Upstream end of Pool TB-AN looking Downstream

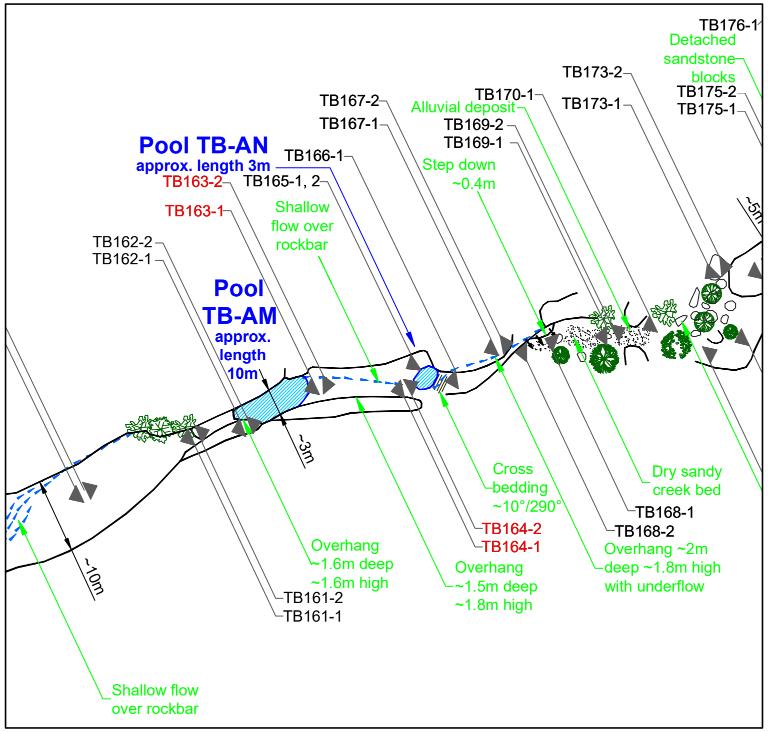


Photo Details

Photo ID	Easting	Northing	Bearing
TB163-1	310213	6215148	245
TB163-2	310213	6215148	90
TB164-1	310226	6215147	255
TB164-2	310226	6215147	65

TRIBUTARY B STREAM MAPPING SUMMARY

TB165-1 Midway along Pool TB-AN looking Upstream

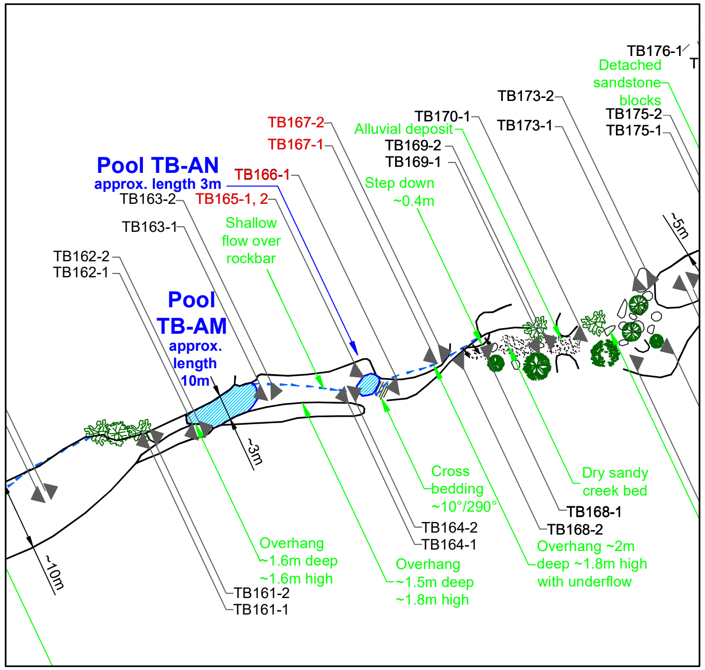
TB165-2 Overhang at Upstream end of Pool TB-AN

Notes (as at 15 December 2009)

- Pool TB-AN approximately 3m long, 2.5m wide and 0.2m deep
- Base of the pool is sandstone
- Flow over cross bedding planes downstream of the pool, then underflow beneath overhang on northern bank

TB166-1 Downstream end of Pool TB-AN looking Upstream

TB167-2 Downstream of Pool TB-AN looking Downstream



TB167-1 Downstream of Pool TB-AN looking Upstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB165-1	310228	6215150	235
TB165-2	310228	6215150	235
TB166-1	310232	6215148	260
TB167-1	310239	6215152	245
TB167-2	310239	6215152	75

TRIBUTARY B STREAM MAPPING SUMMARY

TB168-1 Overhang downstream of Pool TB-AN

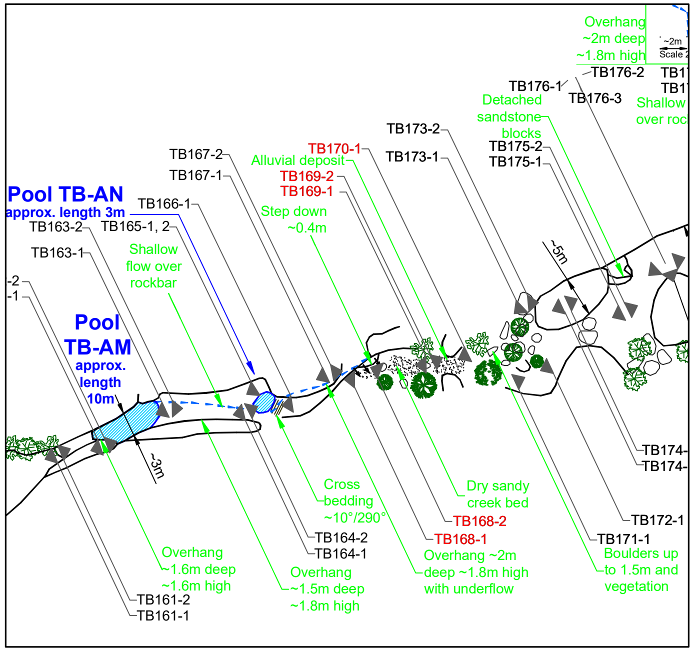
TB168-2 Downstream of Pool TB-AN looking Upstream

Notes (as at 15 December 2009)

- Overhang downstream of Pool TB-AN approximately 1.8m high and 2m deep with underflow
- Dry sandy creek bed with alluvial deposits downstream

TB169-1 Downstream of Pool TB-AN looking Upstream

TB169-2 Downstream of Pool TB-AN looking Downstream



TB170-1 Downstream of Pool TB-AN looking Upstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB168-1	310242	6215152	290
TB168-2	310242	6215152	270
TB169-1	310257	6215154	270
TB169-2	310257	6215154	65
TB170-1	310255	6215154	245

TRIBUTARY B STREAM MAPPING SUMMARY

TB171-1 Upstream of Pool P looking Downstream

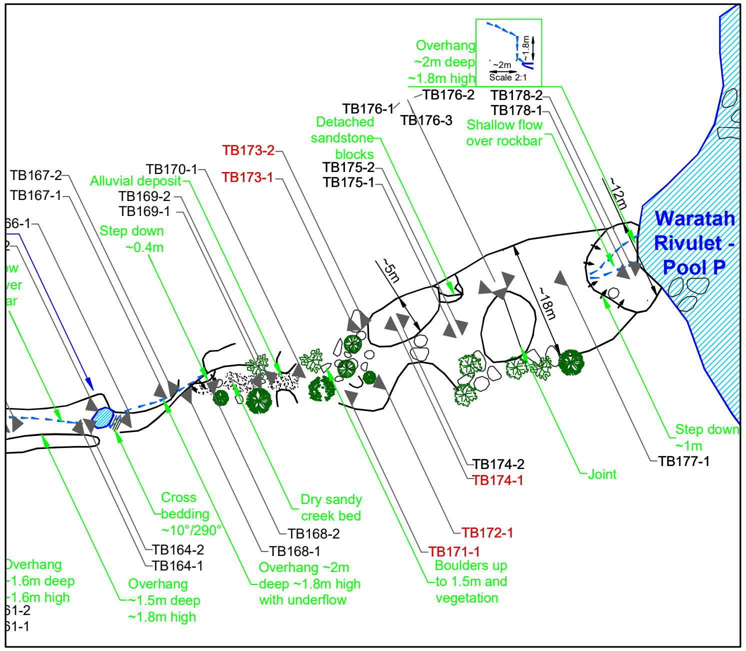
TB172-1 Upstream of Pool P looking Upstream

TB173-1 Upstream of Pool P looking Upstream

Notes (as at 15 December 2009)

- Alluvial deposits open to boulder field and vegetation, with boulders up to 1m
- No flow visible through boulder field
- Boulder field opens to wide rockbar at TB173

TB173-2 Upstream of Pool P looking Downstream



TB174-1 Upstream of Pool P looking Upstream

Photo Details

Photo ID	Easting	Northing	Bearing
TB171-1	310266	6215152	65
TB172-1	310271	6215151	245
TB173-1	310267	6215163	225
TB173-2	310267	6215163	85
TB174-1	310273	6215163	245

TRIBUTARY B STREAM MAPPING SUMMARY

TB174-2 Upstream of Pool P looking Downstream

TB175-1 Upstream of Pool P looking Upstream

TB175-2 Upstream of Pool P looking Downstream

Notes (as at 15 December 2009)

- Rockbar at TB175 approximately 12m wide
- No flow visible
- Scattered vegetation debris

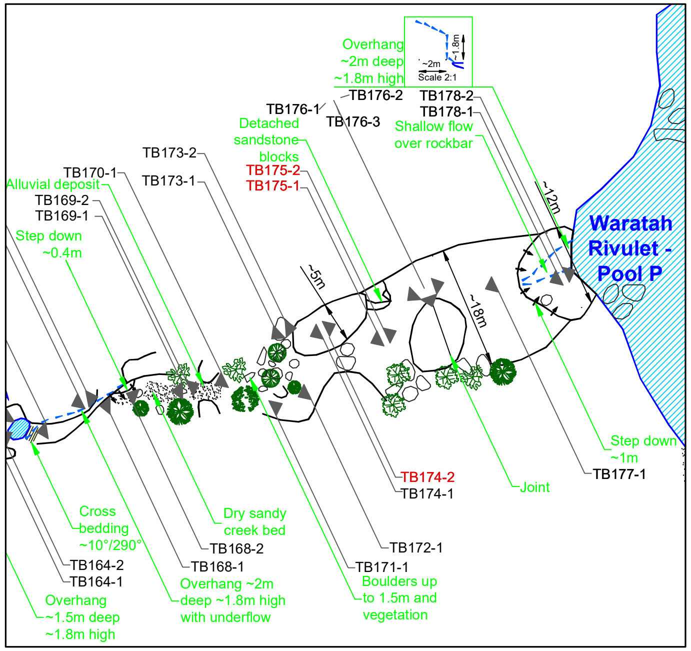


Photo Details

Photo ID	Easting	Northing	Bearing
TB174-2	310273	6215163	65
TB175-1	310283	6215162	245
TB175-2	310283	6215162	65

TRIBUTARY B STREAM MAPPING SUMMARY

TB176-1 Upstream of Pool P looking Upstream

TB176-2 Upstream of Pool P looking Downstream

TB176-3 Joint

Notes (as at 15 December 2009)

- Rockbar approximately 18m wide at TB176, with large detached sandstone blocks
- Large joint through rockshelf on southern bank

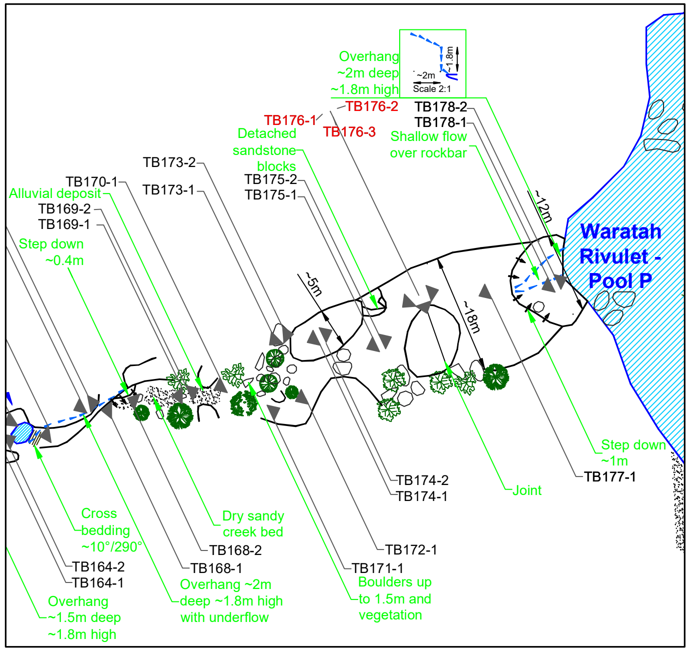


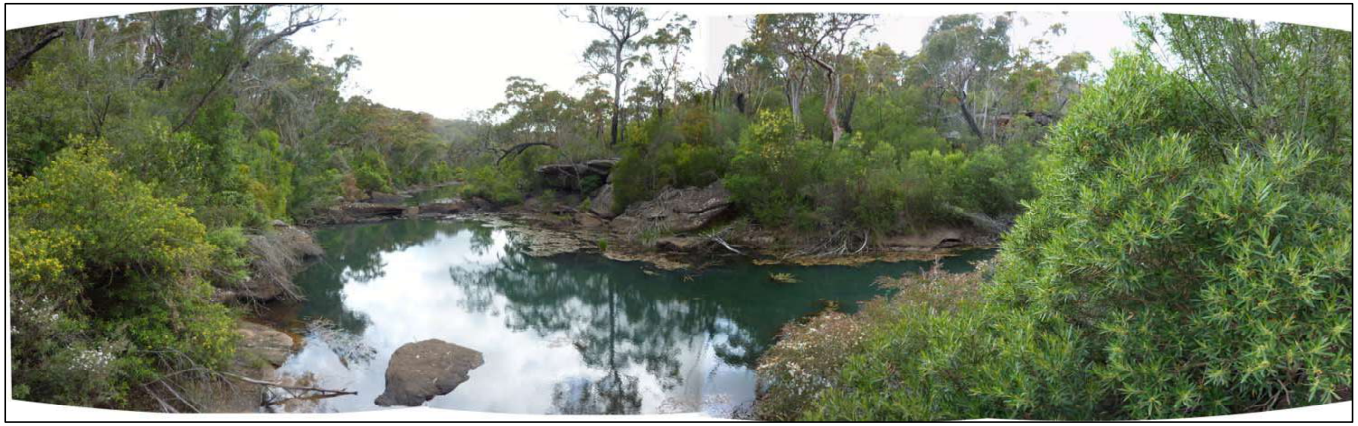
Photo Details

Photo ID	Easting	Northing	Bearing
TB176-1	310290	6215168	230
TB176-2	310290	6215168	70
TB176-3	310290	6215167	160

TRIBUTARY B STREAM MAPPING SUMMARY

TB177-1 Upstream of Pool P looking Upstream

TB178-1 Upstream of Pool P looking Upstream



TB178-2 Upstream of Pool P looking Downstream

Notes (as at 15 December 2009)

- Rockbar steps down approximately 1m at TB177 where flow emerges
- Shallow flow over rockbar downstream toward Waratah Rivulet
- Rockbar approximately 12m wide at the downstream end
- Overhang approximately 1.8m high and 2m deep

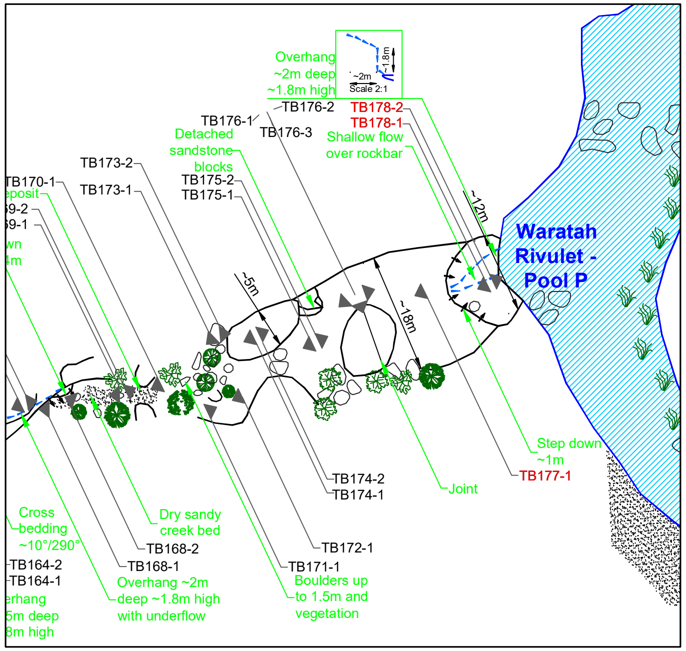


Photo Details

Photo ID	Easting	Northing	Bearing
TB177-1	310300	6215176	245
TB178-1	310312	6215174	245
TB178-2	310312	6215174	65

APPENDIX 5

VISUAL INSPECTION AND PHOTOGRAPHIC SURVEY OF STREAMS IN THE VICINITY OF LONGWALLS 304-310

3 July 2024

Visual Inspection and Photographic Survey of Streams in the Vicinity of Longwalls 304 to 310

1.0 INTRODUCTION

A visual inspection and photographic survey of streams in the vicinity of Longwalls 304-310 was conducted by Hydro Engineering and Consulting Pty Ltd (HEC) in April 2018 to characterise and document the baseline conditions and prominent features in surface water streams overlying or in the vicinity of Longwalls 304-310 and, on the basis of the field inspections, consider surface water flow, pool water level or surface water quality monitoring.

HEC undertook a similar inspection and photographic survey of streams in the 301 to 303 area in July 2015 during preparation of the Longwalls 301-303 Water Management Plan. This exercise for Longwalls 304-310 expands on the previous HEC (2016)[1] stream survey.

2.0 DESKTOP REVIEW

An east-west divide runs approximately north to south to the east of the Longwalls 304-310 study area, dividing drainages which flow into the Eastern Tributary and the Woronora Reservoir (on the western side) from areas which flow into Wilsons Creek and Cawleys Creek (on the eastern side) (Figure 1).

One metre contours were used to refine the mapping available from the Department of Lands in the vicinity of Longwalls 304-310. The one metre contour mapping generated by Geo-Spectrum (Australia) Pty Ltd[2] was the most detailed mapping available and provided greater accuracy in terms of stream location, alignment and stream network for the field survey. Sixteen streams overlying or in close proximity to Longwalls 304-310 were identified using the one metre contours, as shown on Figure 1 (streams A, B, C, D, E, F, H, I, J, K, L, P, Q, R, S-East and T).

[1] Hydro Engineering & Consulting (2016). *Visual Inspection and Photographic Survey of Streams in the Vicinity of Longwalls 301 to 303*.

[2] Geo-Spectrum (Australia) Pty Limited (2007). *Orthophotomap (1:7,500) of Helensburgh Coal Metropolitan Colliery*. October 2007 from 1:20,000 Scale. Aerial photography from 27 August 2007. Ground survey by Monaghan Surveyors Pty Ltd.

The locations of stream lines shown in this report (Figure 1) have been adjusted from the locations shown in HEC (2016) so as to be more closely aligned to the valley floor and to reflect the actual stream bed alignment as observed during the reconnaissance surveys. The differences reflect the limitations of mapping produced from aerial photography of densely forested canopy and the difficulties of identifying the location of small first order streams in the underlying complex sandstone morphology.

The main streams that were inspected are shown as solid blue lines in Figure 1. Where tributaries to the streams have been observed, their alignments have been interpreted based on the 1 metre contours and are shown as dashed blue lines on Figure 1.

Streams A, B, C, H, I, J, K and L were considered and inspected as part of HEC's 2015 survey (Table 1).

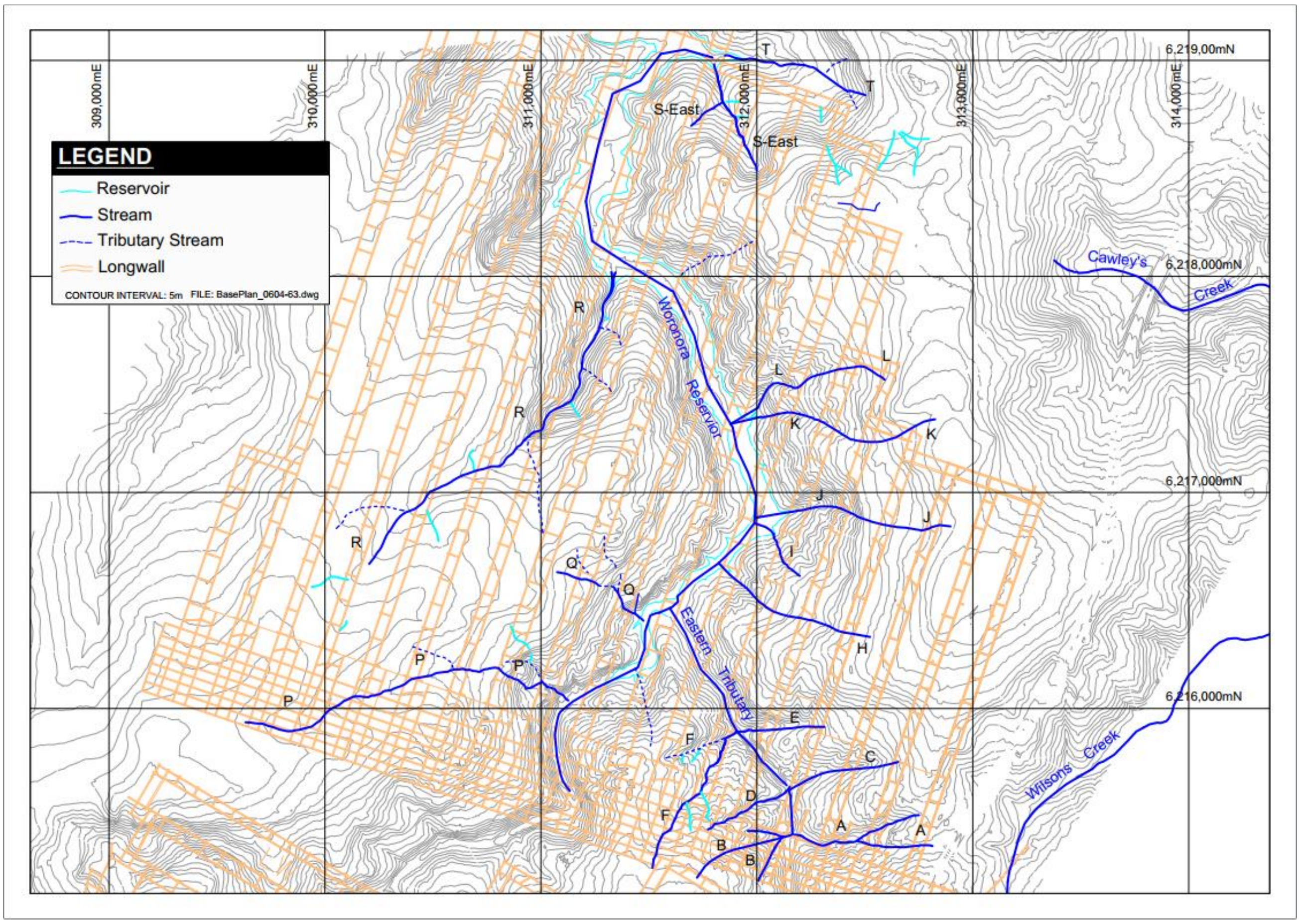


Figure 1 Streams Overlying or Near to Proposed Longwalls 304 to 310[3]

3 Streams J and L shown in Figure 1 were referred to as Streams I and K, respectively, in an earlier draft of the Longwalls 301-303 reconnaissance report. Streamflow monitoring stations have been installed on these streams as a component of the Woronora Reservoir Impact Strategy.

Details of the streams overlying or near to Longwalls 304-310 are summarised in Table 1 below.

Table 1 Stream Reconnaissance Summary

Stream Label	Stream Order*	Comments
A	2	Previously inspected (HEC, 2016)
B	2	Previously inspected (HEC, 2016)
C	1	Previously inspected (HEC, 2016)
D	1	Inspected April 2018
E	1	Previously inspected (HEC, 2016)
F	2	Inspected April 2018
H	1	Previously inspected (HEC, 2016)
I	1	Previously inspected (HEC, 2016)
J	1	Previously inspected (HEC, 2016)
K	1	Previously inspected (HEC, 2016)
L	1	Previously inspected (HEC, 2016)
P	2	Inspected April 2018
Q	2	Inspected April 2018
R	2	Inspected April 2018
S-East	2	Inspected April 2018
T	2	Inspected April 2018

2.0 FIELD CONDITIONS

The stream reconnaissance was conducted between the 9th and 13th of April 2018. The weather was fine during the course of the reconnaissance. The period leading up to the reconnaissance had relatively low rainfall (refer Figure 2). January and early February experienced unusually low rainfall with only minor falls being recorded through to late February. Two moderate rainfall events on the 20th and 26th of February (44 and 47.5 mm respectively) were recorded at Metropolitan Coal's pluviometer PV7. Following these events there was no significant rainfall recorded until the 21st of March when a total of 96.5 mm was recorded between the 21st and 23rd of March. There was no significant rainfall recorded between the 23rd of March and the reconnaissance survey – indicated by the red lines on Figure 2. Flow in the surface catchments would therefore have been in recession from the 21st to the 23rd March rainfall event.

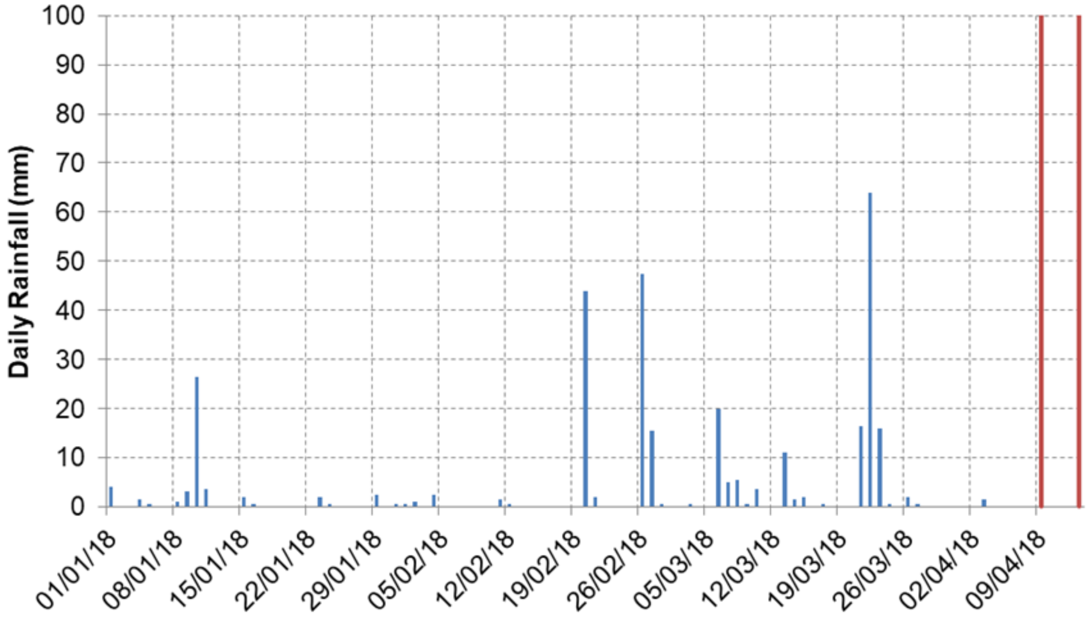


Figure 2 Rainfall Recorded at PV7 January to April 2018

Groundwater-fed baseflow in streams responds to dominant wetting (aquifer recharging) and drying (aquifer discharging) cycles. These cycles are typically evident in rainfall residual plots which can be correlated to periods when aquifers are predominantly recharging when groundwater levels are rising; and periods when aquifers are discharging and groundwater levels are declining. Figure 3 shows the rainfall residual for the period 1st January 2000 to 31st April 2018 derived from the rainfall record from the Bureau of Meteorology rain gauge at Darkes Forest – Station 68024. Periods where the residual rainfall curve is trending upward correspond to above average rainfall. Periods where the residual rainfall line decreases (slopes downward) reflect below average rainfall. The reconnaissance, shown by the vertical red line, was conducted during a pronounced drying period. The steep downward trend in the rainfall from mid-2017 indicates drying catchment conditions with declining groundwater outflows to streams (compared to the average) in the lead-up to the survey. The rainfall residual over this period is sloping unusually steeply downward for a prolonged period indicating likely low groundwater outflows to streams from groundwater sources.

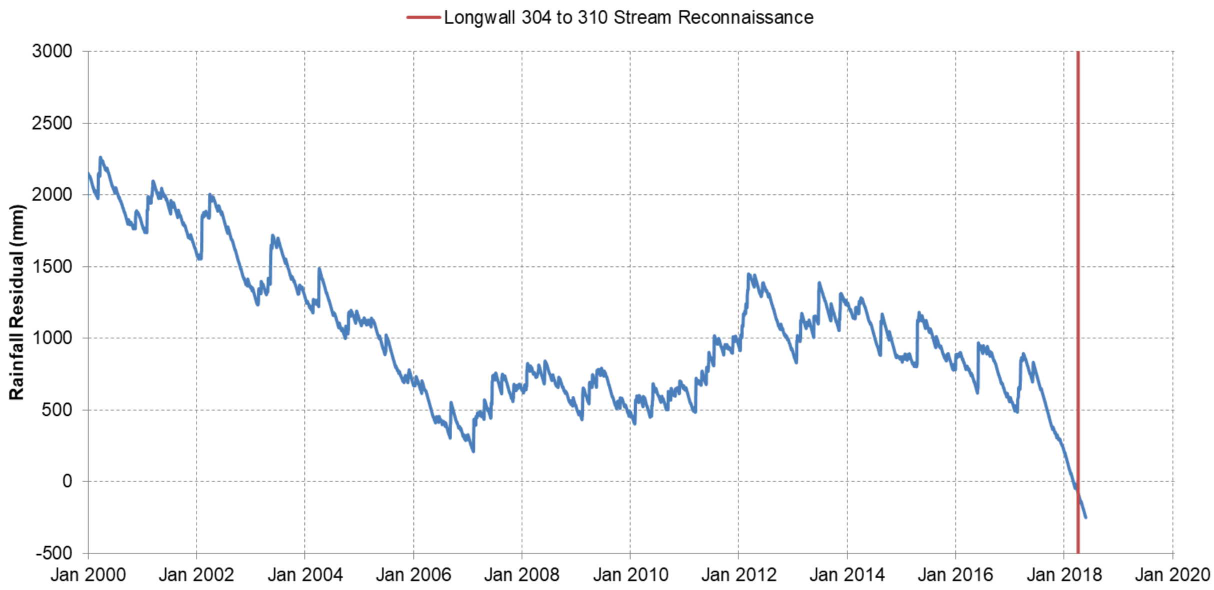


Figure 3 Darkes Forest Rainfall Residual Plot, January 2000 to May 2018

The water level in the Woronora Reservoir was about 5.4 m below the full supply level during the survey.

3.0 METHODOLOGY

Reconnaissance of the streams involved walking along the accessible length of the streams, mapping the geomorphic characteristics and features of the streams and compiling a photographic record. The observed features and mapping of each stream are shown and described in Section 4 and photographs of the features are provided in Attachment A.

Stream features have been mapped using the following alphabetic symbols:

(US) Upland swamp

(WF) Waterfall of at least 2 m near vertical drop.

(BC) Boulder cascade comprising a steep chute of boulders. Water would be highly aerated by rapid flow over and through spaces between the boulders.

(BF) Boulder field comprising an extended section of boulders with low flows passing through the interstices between the boulders and which acts to control upstream water level

(RS) Rock shelf comprising a hard and relatively smooth rock outcrop often containing shallow depression(s).

(RC) Rock cascade a steep chute of predominately cobbles and gravel sized bed sediment.

(P_s) Small pool between 1 m and 3 m long and less than 0.3 m deep. These features would likely be transient but persist for some time following cessation of flow.

(P_m) Medium sized pool larger than a small pool and typically 3 m to 5 m long and around 0.5 m deep. The largest pool observed was estimated to be less than 5 m long and less than 1 m deep at its deepest. These pools would be expected to retain ponded water under most climatic conditions.

(P_l) Large pool longer than 5 m and greater than 0.5m deep.

4.0 RESULTS OF STREAM RECONNAISSANCE

4.1 Stream D

Stream D comprised a small first order stream which drained into Eastern Tributary (Figure 4) adjacent to the flow monitoring flume at Pool ETAU.

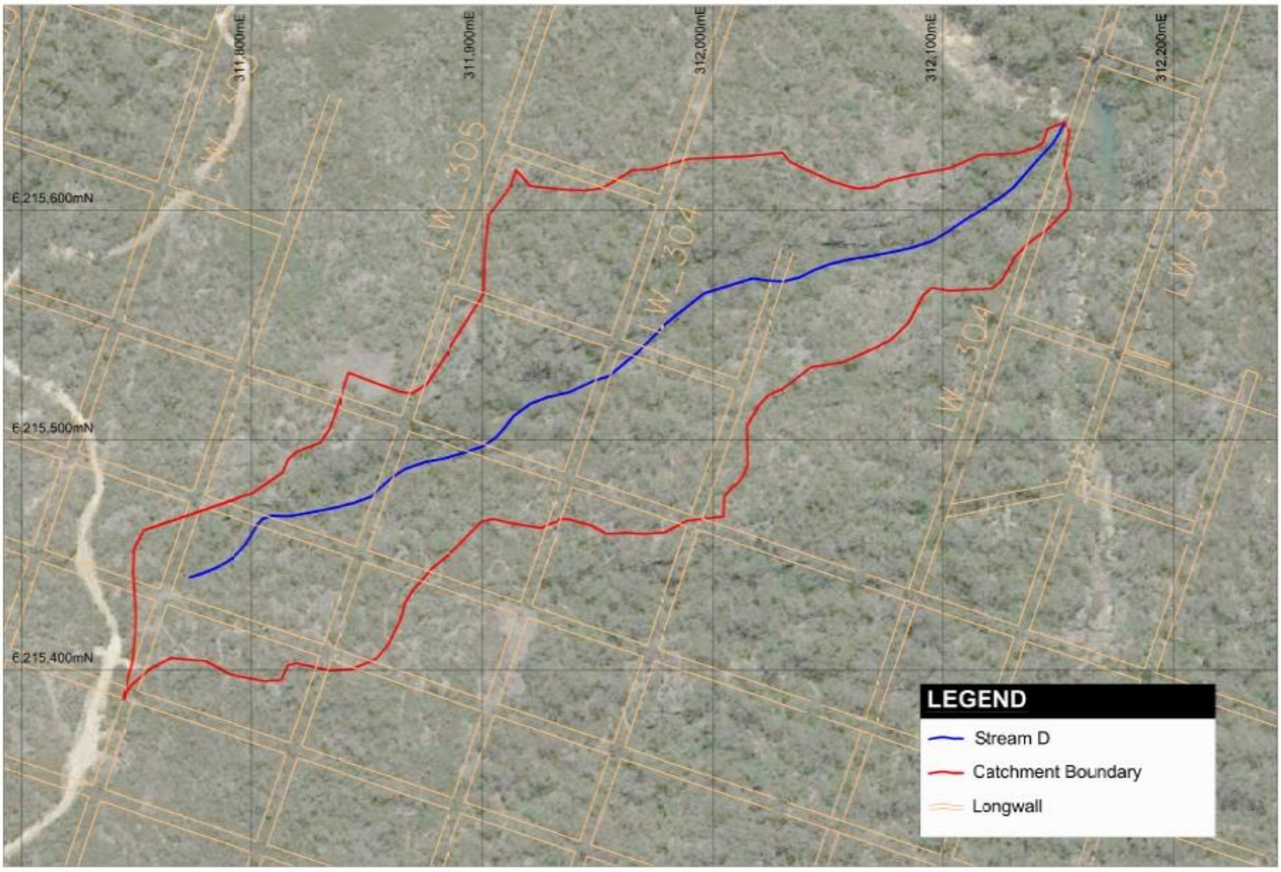


Figure 4 Stream D Catchment

There was no flow or significant water observed within the stream at the time of the reconnaissance. The upper sections comprised small localized and discontinuous drainage lines and depressions. The middle and lower sections of the stream comprised a steep incised channel with boulder cascades interspaced with rock shelves and shallow depressions – refer Figure 5. A summary of the catchment characteristics is provided in Table 2 below.

Table 2 Catchment Characteristics Stream D

Feature	Value
Stream order	1st
Catchment area (km^2)	0.04
Stream length (km)	0.45
Average gradient (%)	13.5

The observed features in Stream D are shown on Figure 5.

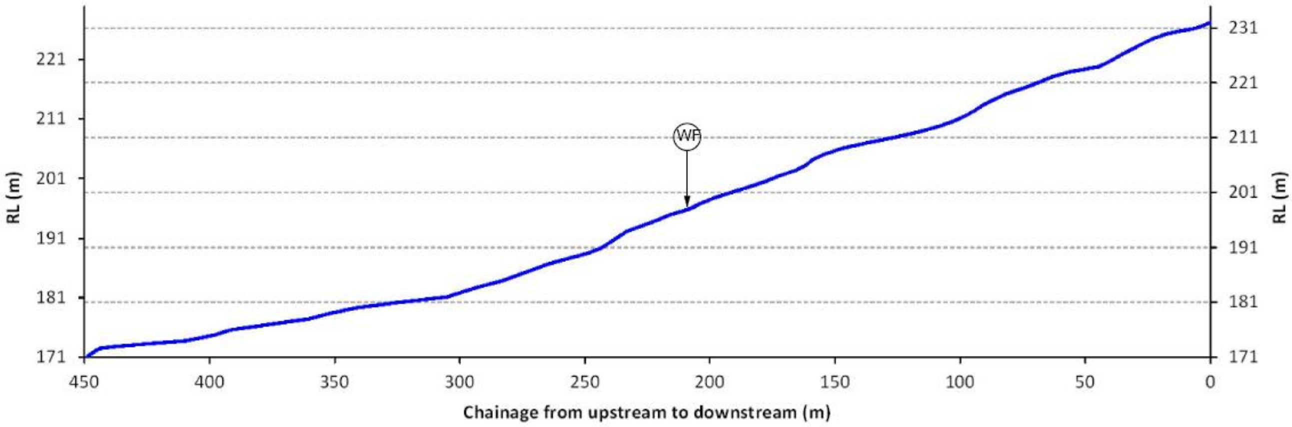


Figure 5 Features in Stream D

4.2 Stream F

Stream F is a longer stream which is joined by a one shorter stream near the inflow to the reservoir. The upper sections on the longer stream comprised a densely vegetated upland swamp – refer Figure 6 and 7. The only surface drainage features observed with in the swamp comprised discontinuous depressions in the topographic "low" points of the swamp. The swamp terminated at an extensive rock bar. There was a trickle of water overflow on one section of the rock bar. Moss and stain markings on the rock bar however suggested that larger overflows would have occurred frequently in the past.

The reach downstream of the swamp comprised a series of rock cascades, small waterfalls, instream pools, rock shelves and sections of straight incised channel. Small semi-continuous flow was observed along the downstream reach. The instream pools became larger and more dominant in the lower sections of the stream.

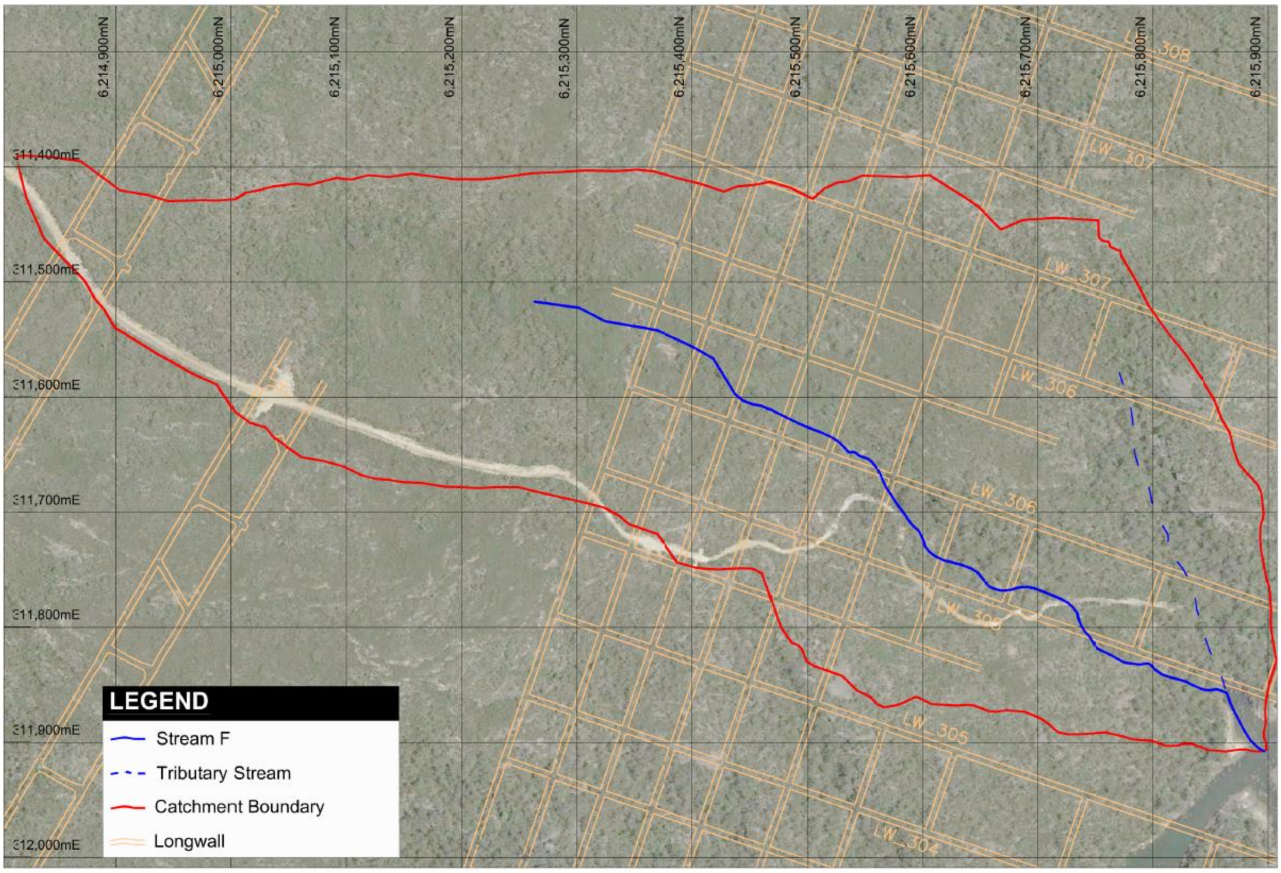


Figure 6 Stream F Catchment

The observed features in Stream F are shown in Figure 7.

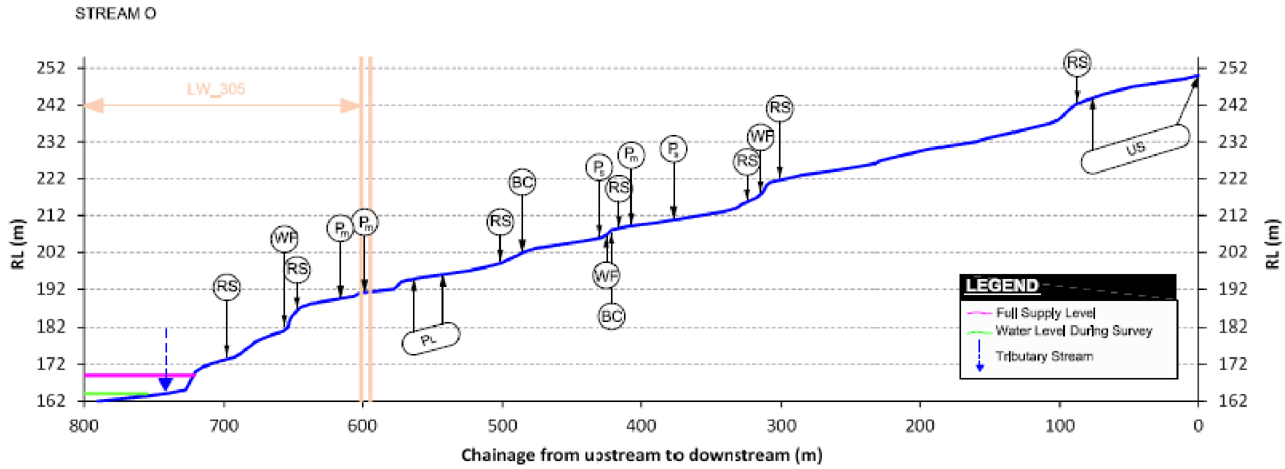


Figure 7 Features in Stream F

A summary of the catchment characteristics is provided in Table 3 below.

Table 3 Catchment Characteristics Stream F

Feature	Value
Stream order	2nd
Catchment area (km^2)	0.324
Stream length (km)	0.80
Average gradient of upland swamp (%)	8.2
Average gradient downstream of swamp (%)	7.6

4.3 Stream P

Stream P comprised a long stream with shorter tributary streams which flowed into the stream near the reservoir – refer Figure 8. The upper sections of the main (longer) arm comprised a densely vegetated upland swamp. The only surface drainage features observed with in the swamp comprised discontinuous depressions in the topographic "low" points of the swamp. The swamp terminated at an extensive rock bar. There was no overflow evident on the rock bar. Desiccated moss and staining markings on the rock bar suggested that overflows would have occurred frequently in the past and that the swamp would contribute flow to downstream reaches.

The reach on the main arm downstream of the swamp comprised a series of rock and boulder cascades, small waterfalls, instream pools, rock shelves and sections of straight incised channel. Small semi-continuous flow[4] was observed along the downstream reach. The instream pools became larger and more dominant in the lower sections of the stream. The lower reach of shorter arm was also inspected. It comprised a series of dry boulder cascades and rock chutes – refer Figure 9.

[4] Flow disappeared from view in the boulder cascades where it flowed along the base of the loose boulder field. Flow also disappeared from view in the sandy delta which had formed where the stream flowed into the reservoir.

Figure 8 Stream P Catchment

The observed features in Stream P are shown in Figure 9.

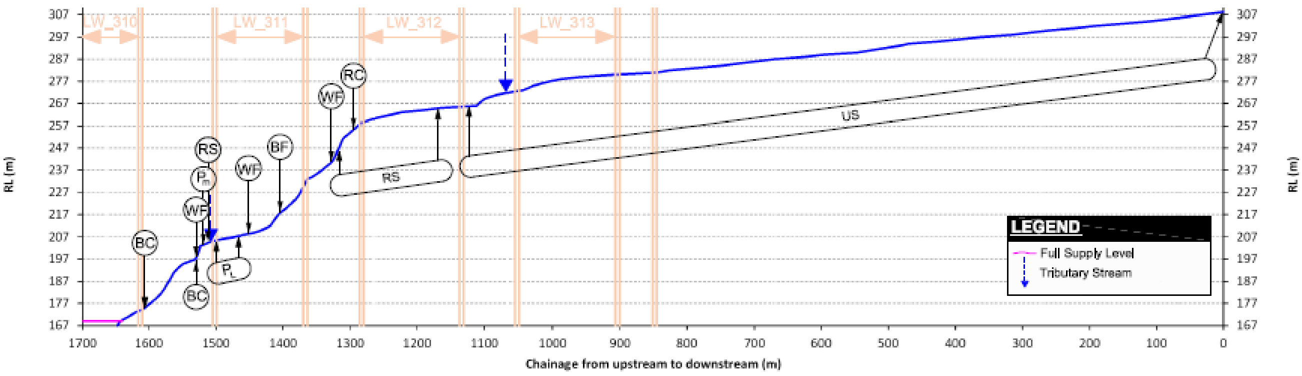


Figure 9 Features in Stream P

A summary of the catchment characteristics is provided in Table 4 below.

Table 4 Catchment Characteristics Stream P

Feature	Value
Stream order	2nd
Catchment area (km²)	0.864
Stream length main arm (km)	1.65
Stream length shorter arm (km)	1.62
Average gradient of upland swamp (%)	3.7
Average gradient downstream of swamp (%)	8.8

4.4 Stream Q

Stream Q comprised a small semi-continuous stream with small tributaries joining in three locations – refer Figure 10. The upper reaches comprised an ill-defined drainage path in a moderately steep gully. There was no water observed upstream of a significant waterfall which was partially obscured by dense vegetation. Access to the lower reaches of the stream was deemed too dangerous and completion of the planned reconnaissance of the lower sections of the creek was abandoned due to safety concern with very dense vegetation potentially obscuring steep drops.

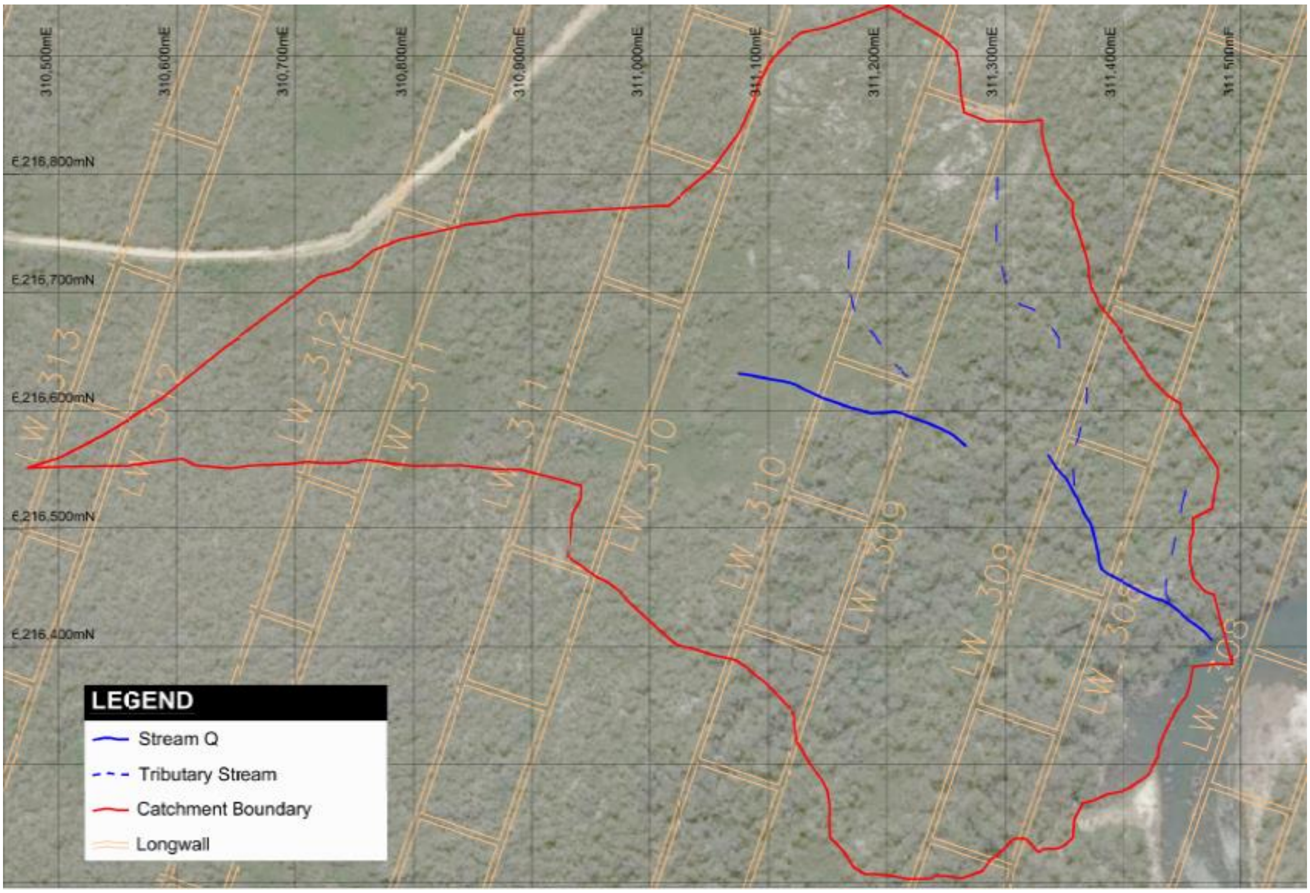


Figure 10 Stream Q Catchment

The observed features in Stream Q are shown in Figure 11.

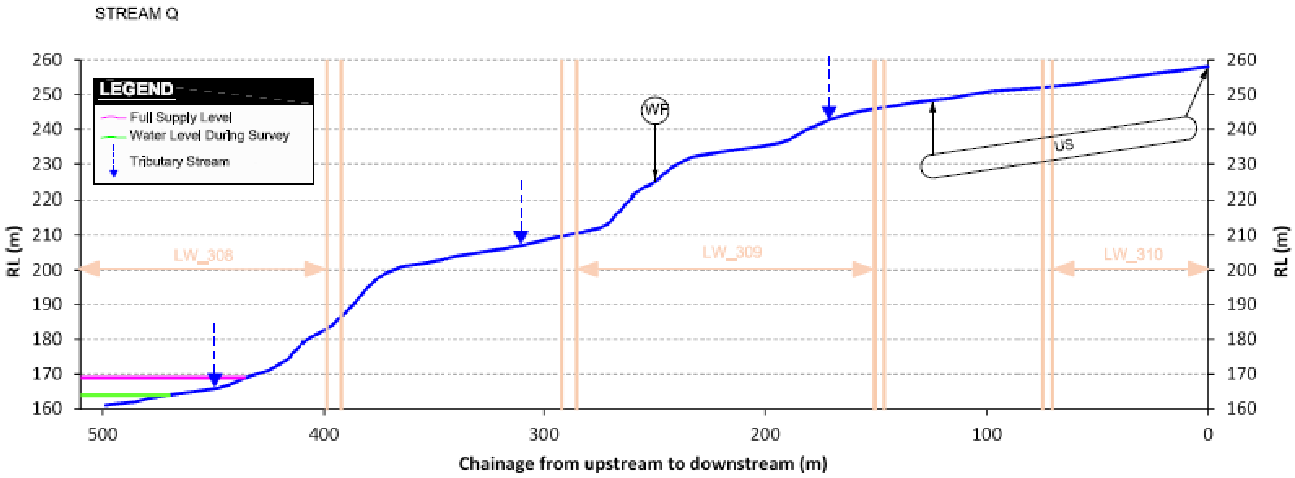


Figure 11 Stream Q Features

A summary of the catchment characteristics is provided in Table 5 below.

Table 5 Catchment Characteristics Stream Q

Feature	Value
Stream order	2nd
Catchment area (km²)	0.329
Stream length (km)	0.50
Average gradient (%)	19.1

4.5 Stream R

Stream R originates in an upland swamp and becomes a second order stream following inflow of a smaller stream line some 300m upstream of its outlet into the Woronora Reservoir – refer Figures 12 and 13.

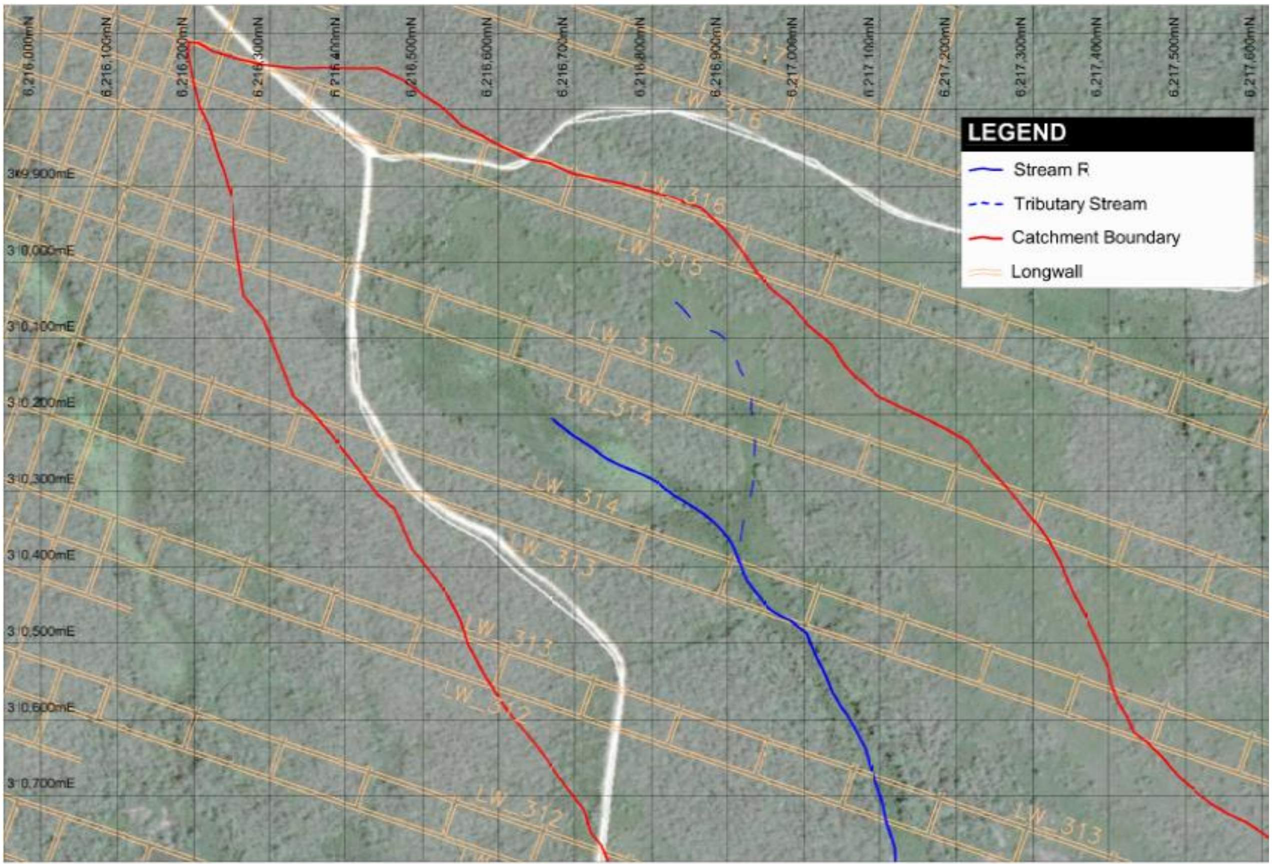


Figure 12 Stream R Upper Catchment

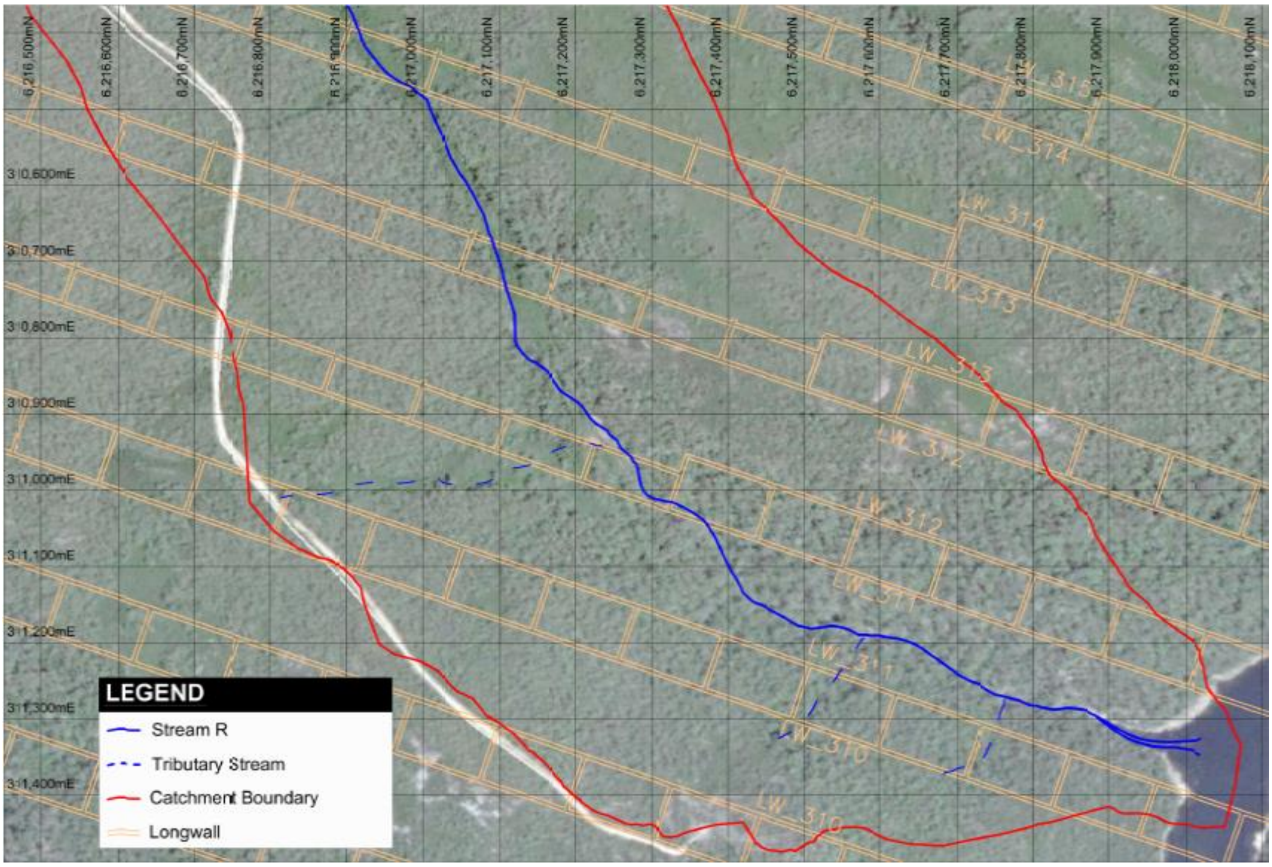


Figure 13 Stream R Lower Catchment

The upper reach comprised a large upland swamp. Swamp vegetation was very dense and inhibited access. The sections of the swamp accessed during the survey indicate it was similar to the swamps in the upstream reaches of Streams O and P with an ill-defined and discontinuous flow path. The swamp terminated at a large rock bar. There was no discernible flow over the rock bar however as with the other swamps it was apparent that there would be surface water flowing out of the swamp during wet periods. Downstream of the swamp the stream gradient changed with the stream morphology becoming more incised and comprising a series of rock and boulder cascades and waterfalls interspersed by pools and rock shelves. A continuous flow was observed in the lower reaches where relatively closely spaced pools become the dominant feature.

The tributary stream which flowed into the main arm some 250 m upstream of the outfall into Woronora Reservoir was dry. The largest pools downstream of this confluence were up to 25 m long which formed in depressions between low rock bars. The observed features in Stream R are shown in Figure 14.

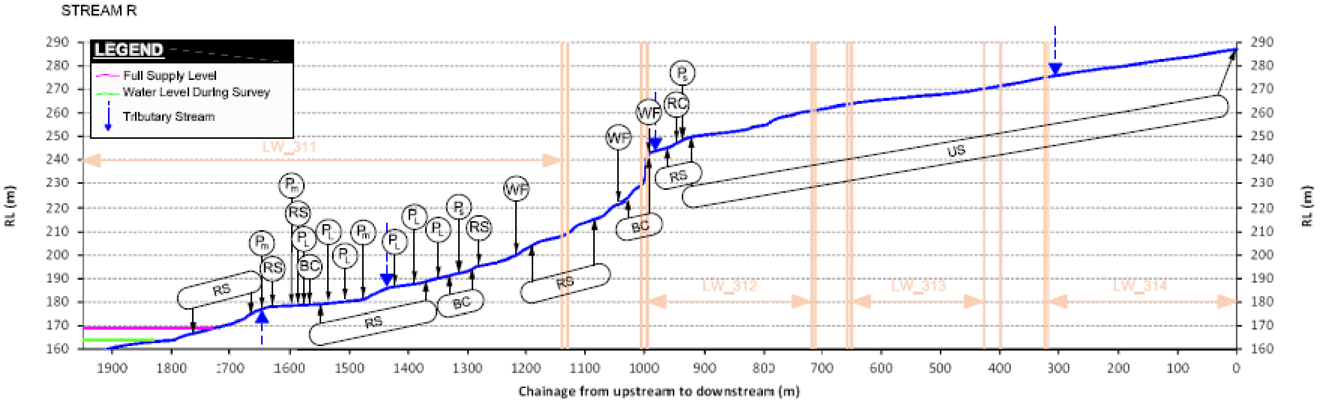


Figure 14 Stream R Features

A summary of the catchment characteristics is provided in Table 6 below.

Table 6 Catchment Characteristics Stream R

Feature	Value
Stream order	2nd
Catchment area (km²)	1.401
Stream length (km)	1.90
Average gradient (%)	6.7

4.6 Stream S-East

Stream S-East is joined by a small stream which flowed through a confined valley – refer Figure 15. The upper sections comprised a steep, gully form with ill-defined drainage channels and boulder cascades. Several pools were observed in the lower reaches with two medium pools near the confluence of the two arms of the stream. There was no significant flow observed and no visible flow at either the stream confluence or at the outflow to the Woronora Reservoir.

Figure 15 Stream S-East Catchment

The observed features in Stream S-East are shown in Figure 16.

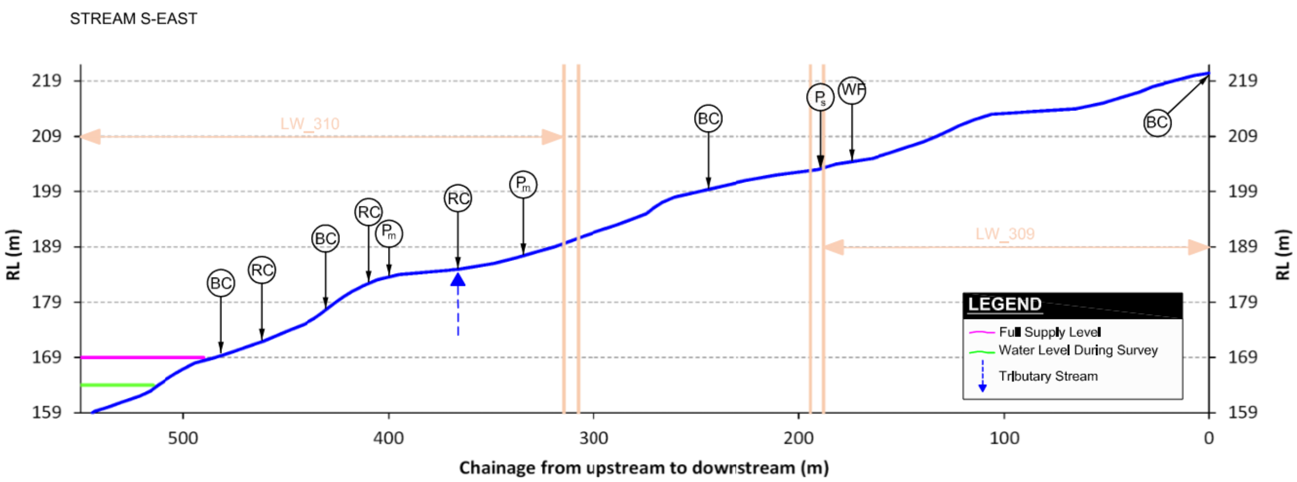


Figure 16 Stream S-East Features

A summary of the catchment characteristics is provided in Table 7 below.

Table 7 Catchment Characteristics Stream S-East

Feature	Value
Stream order	2nd
Catchment area (km²)	0.224
Stream length (km)	0.55
Average gradient (%)	11.3

4.7 Stream T

Stream T is a small second order stream – refer Figure 17. The stream morphology is similar to Stream S-East. There was a small continuous flow in the lower reaches of the stream which carried through to the Woronora Reservoir. The medium and larger pools mapped were larger than those observed in Stream S-East.

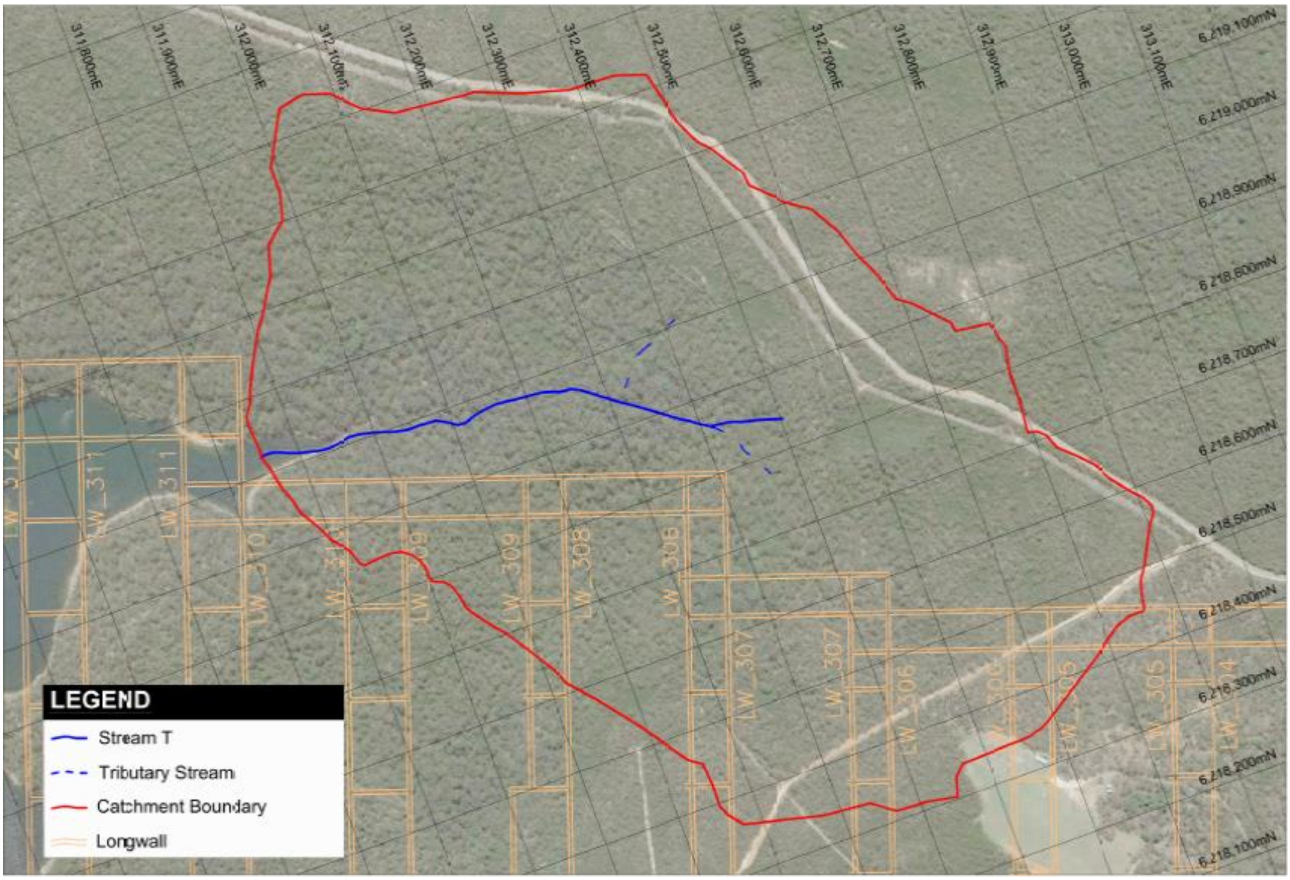


Figure 17 Stream T Catchment

The observed features in Stream T are shown in Figure 18.

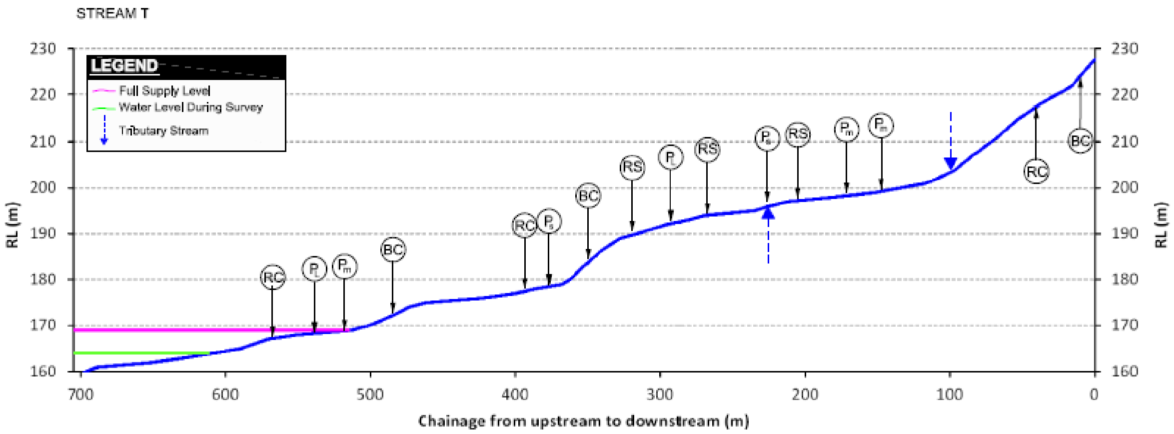


Figure 18 Stream T Features

A summary of the catchment characteristics is provided in Table 8 below.

Table 8 Catchment Characteristics Stream T

Feature	Value
Stream order	2nd
Catchment area (km²)	0.716
Stream length (km)	0.71
Average gradient (%)	9.8

5.0 RECOMMENDATIONS FOR MONITORING

The inspected streams are all small 1st and 2nd order streams. Based on observation of the effects of subsidence and non-conventional subsidence impacts on similar streams, including Forest Gully and Tributary B and D, it is expected that longwall mining will result in fracturing of bed rock and underflow and loss of function of some of what are currently a mixture of both intermittent and permanent pools.

It is recommended that, subject to access constraints, Metropolitan Coal investigate the potential to install:

- a pool water level meter in the large pool mapped on Stream P (Figure 9);
- a pool water level meter in two large pools in the lower reaches of Stream R (Figure 14);
- a small flow measuring flume immediately downstream of the upland swamp associated with Streams P (Figure 9) (no pool has been mapped at this location, however there may be potential to direct flow from the upland swamp toward a flume); and
- a small flow measuring flume in the vicinity of the first small pool mapped on Stream R to provide data on outflows from the swamp in the headwaters of this catchment (Figure 14).

Yours sincerely

Lindsay Gilbert
Principal Water Resources Engineer

ATTACHMENT A

Stream Reconnaissance Photographs

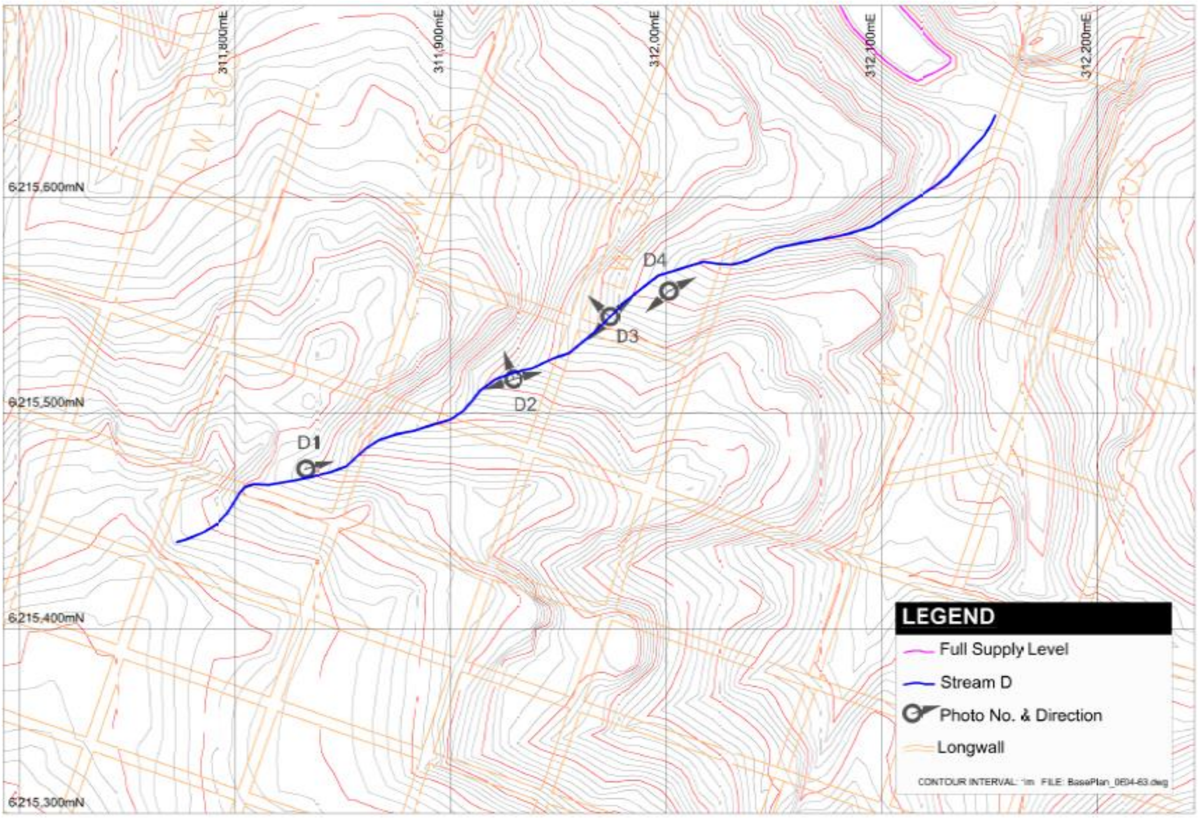


Photo D1 (Downstream)

Photo D2 (Downstream)

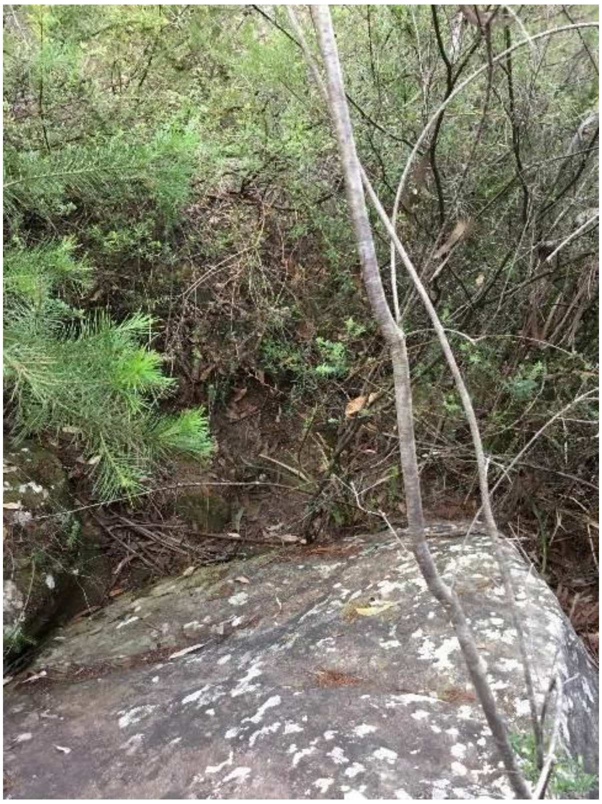


Photo D2 (Left Bank)

Photo D2 (Upstream)

Photo D3 (Downstream)

Photo D3 (Left Bank)

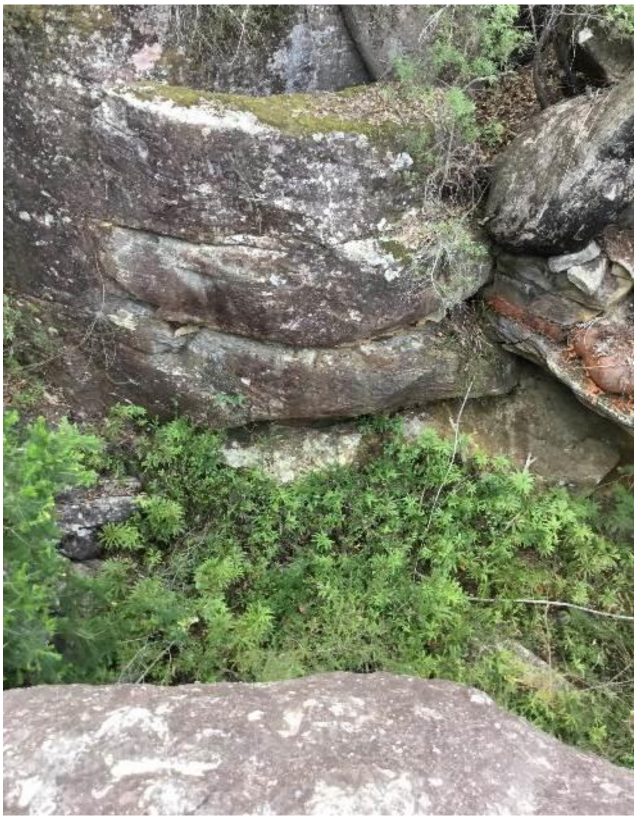


Photo D3 (Upstream)

Photo D4 (Downstream)

Photo D4 (Upstream)

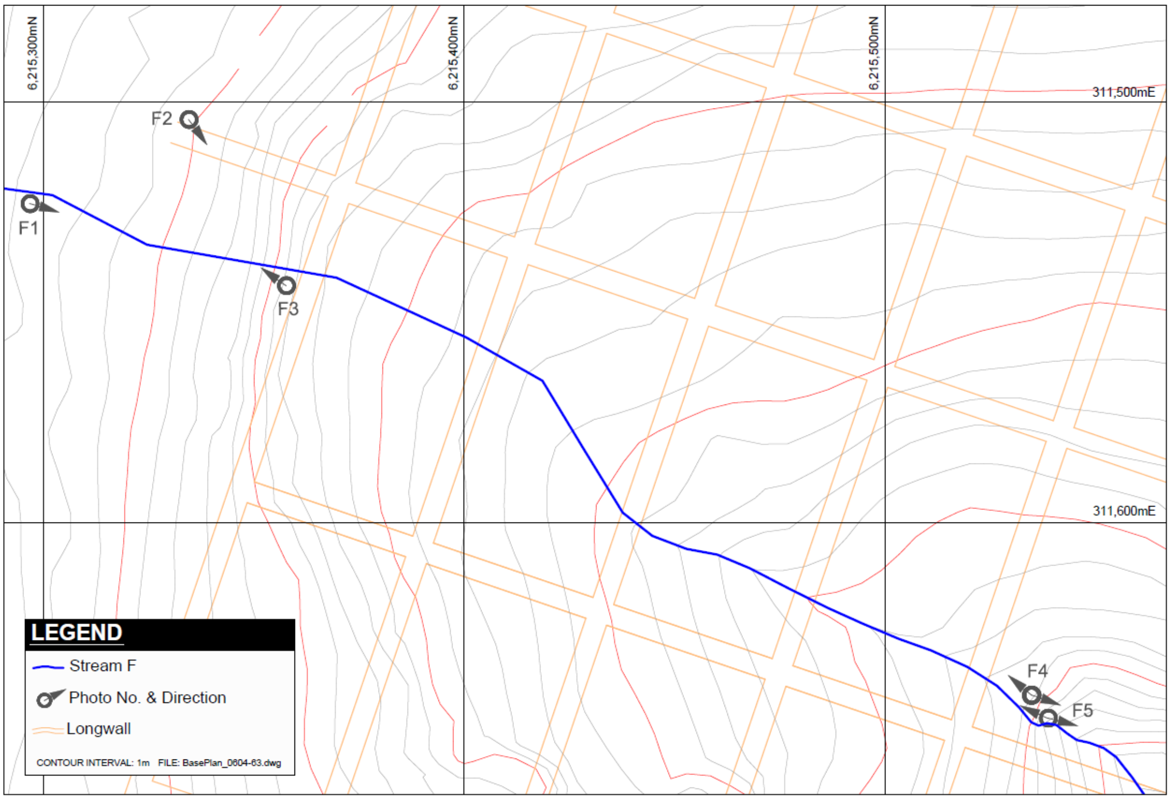


Photo F1 (Downstream)

Photo F2 (Downstream)

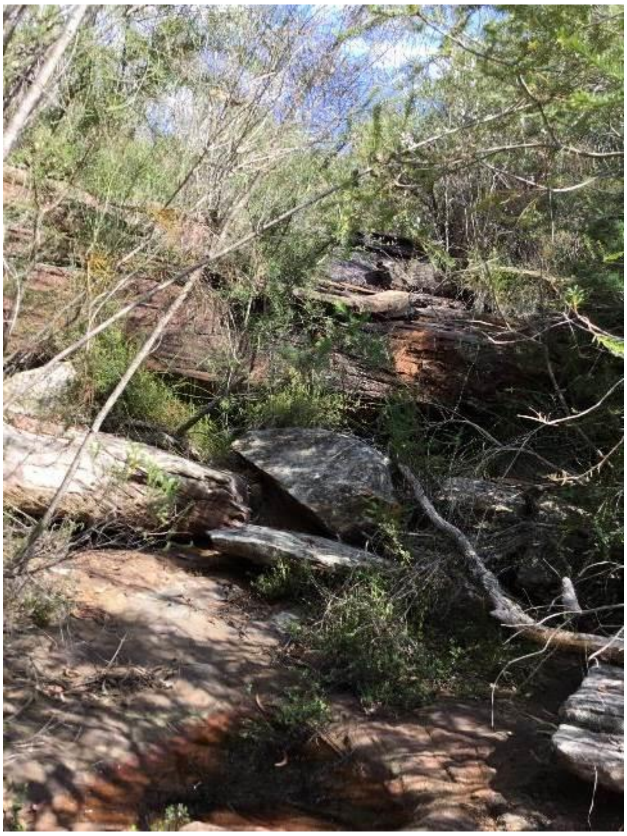
Photo F3 (Upstream)

Photo F4 (Downstream)

Photo F4 (Upstream)

Photo F5 (Downstream)

Photo F5 (Upstream)



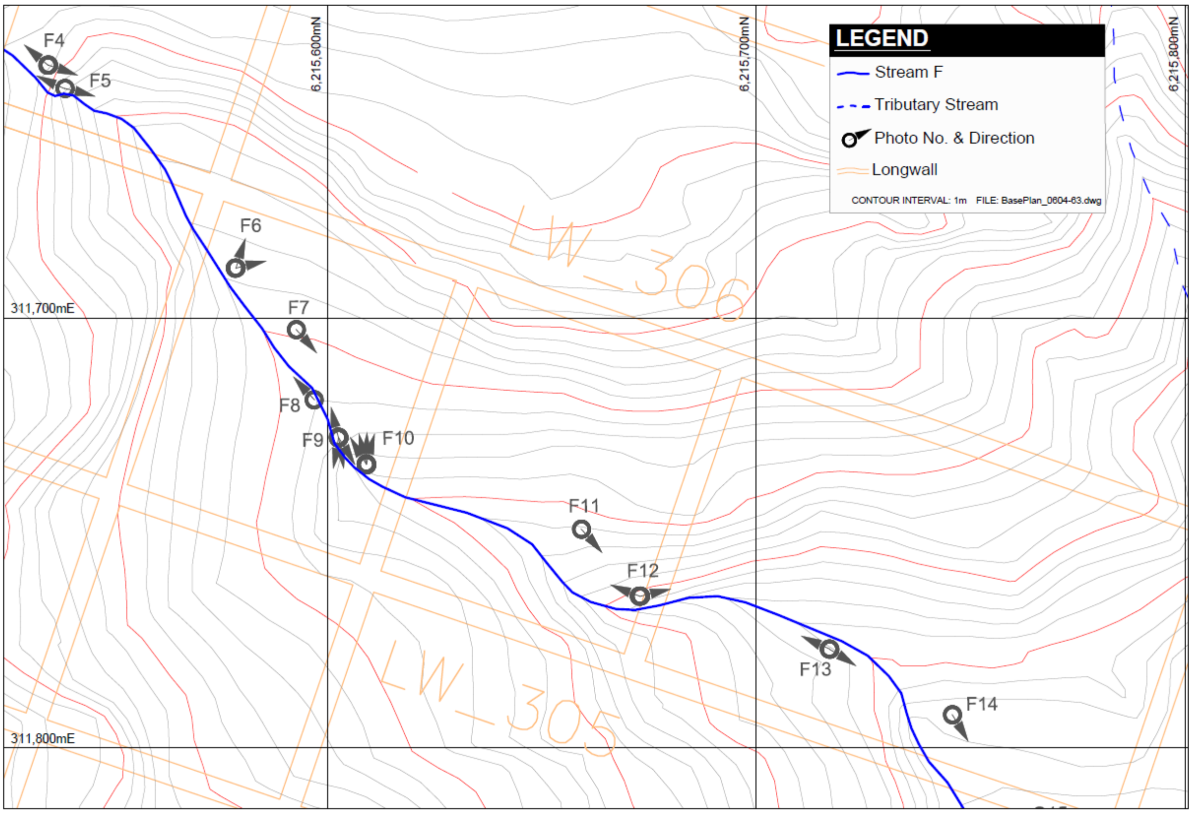


Photo F6 (Left Bank 1)

Photo F6 (Left Bank 2)

Photo F7 (Downstream)

Photo F8 (Upstream)

Photo F8 (Downstream 1)

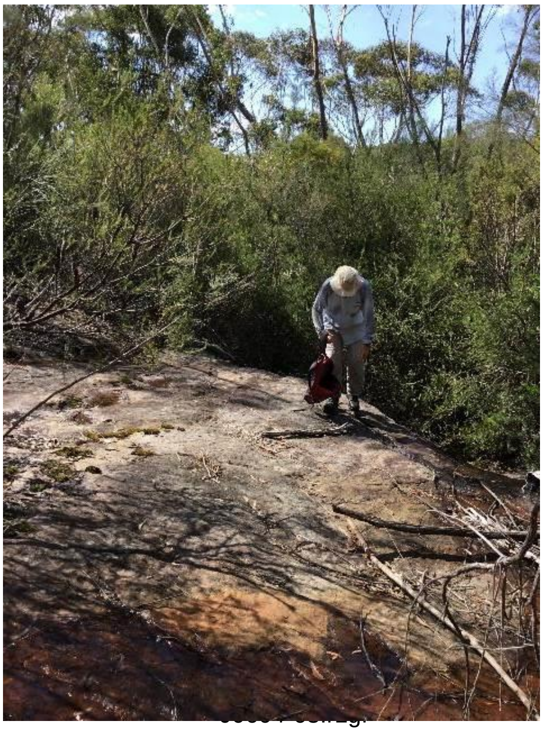


Photo F8 (Downstream 2)

Photo F8 (Downstream 3)

Photo F9 (Upstream 1)

Photo F9 (Upstream 2)

Photo F10 (Upstream 1)

Photo F10 (Upstream 2)

Photo F10 (Upstream 3)

Photo F10 (Upstream 4)

Photo F11 (Downstream)

Photo F12 (Downstream)

Photo F12 (Upstream)

Photo F13 (Downstream)

Photo F13 (Upstream)

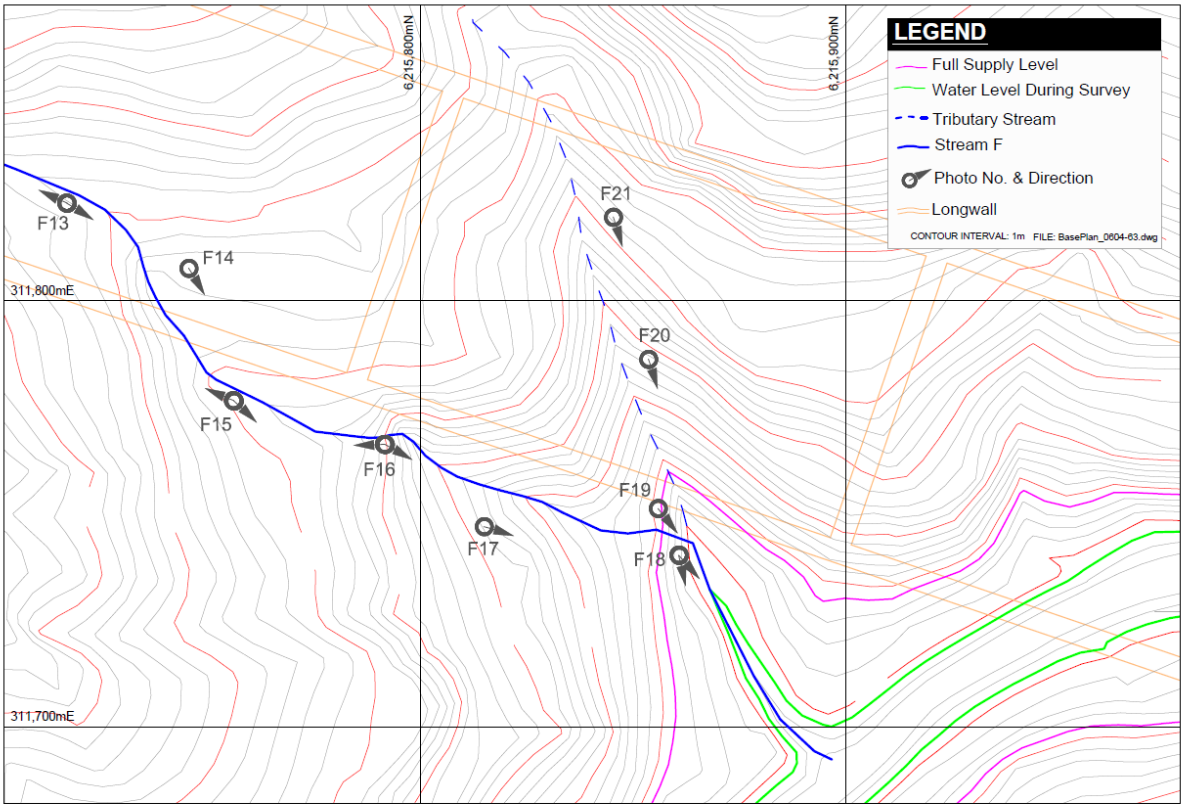


Photo F14 (Downstream)

Photo F15 (Downstream)

Photo F15 (Upstream)

Photo F16 (Downstream)

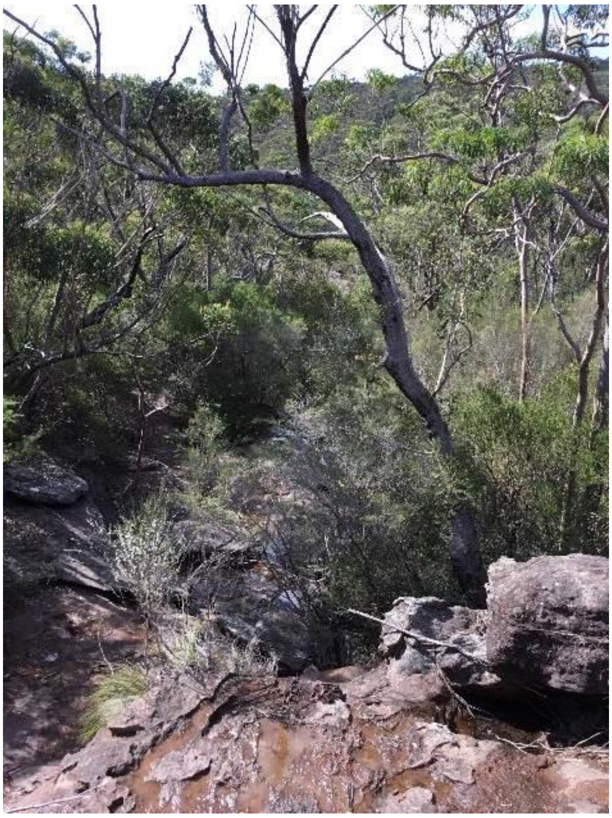


Photo F16 (Upstream)

Photo F17 (Downstream)

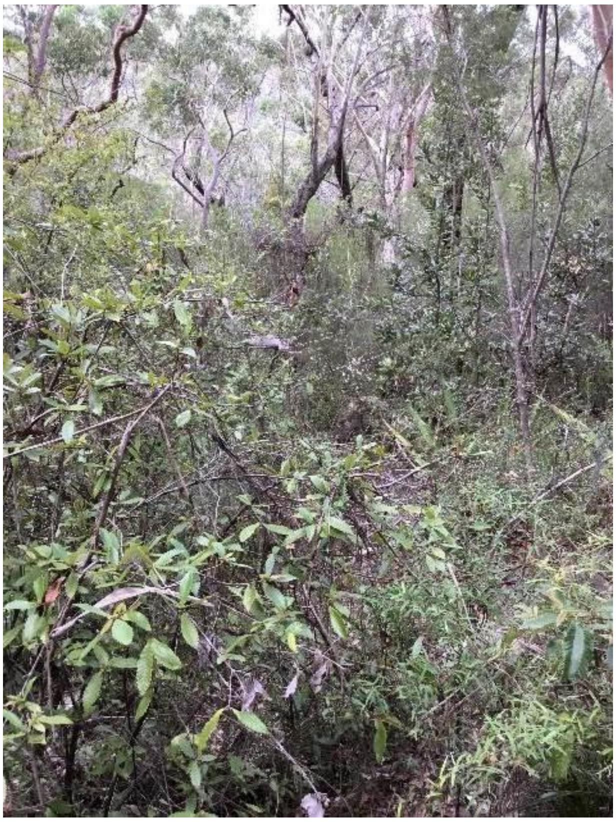
Photo F18 (Downstream 1)

Photo F18 (Downstream 2)

Photo F19 (Downstream)

Photo F20 (Downstream)

Photo F21 (Downstream)



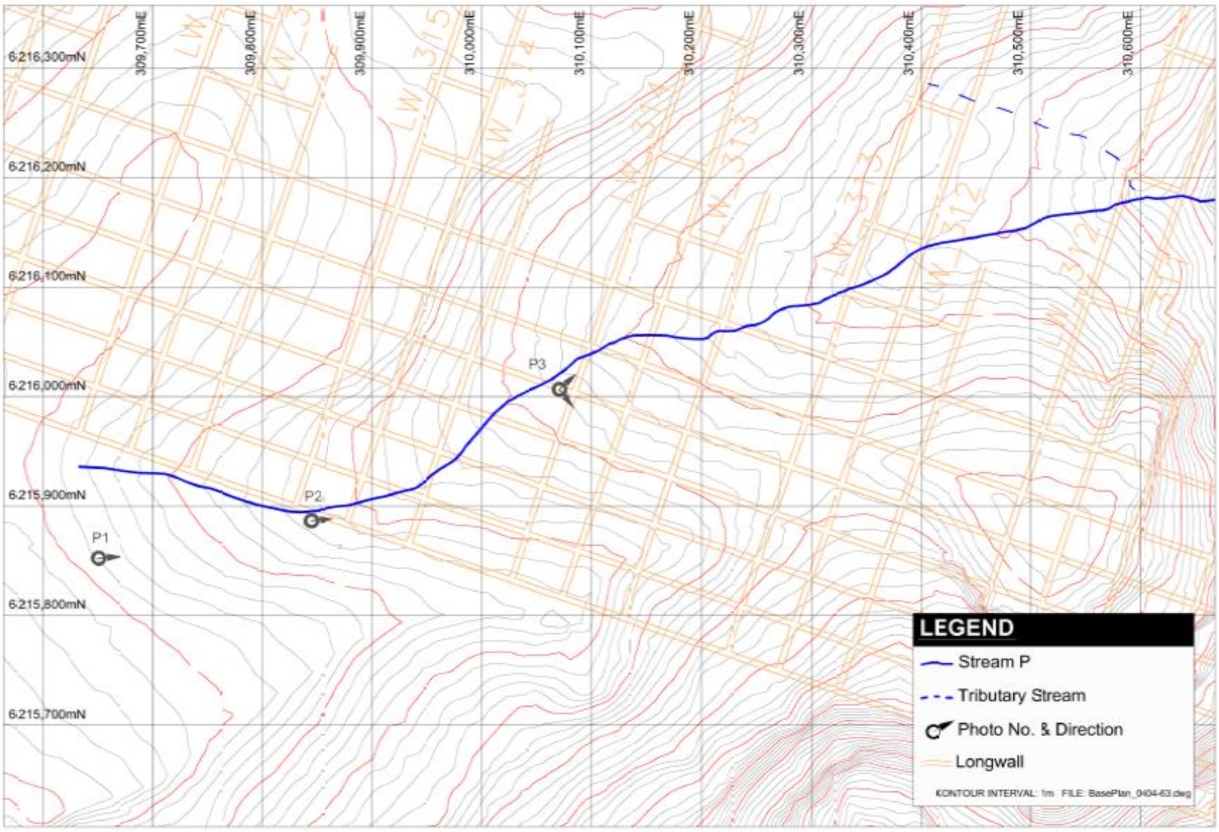


Photo P1 (Downstream)

Photo P2 (Downstream)

Photo P3 (Right Bank Bore)

Photo P3 (Downstream)

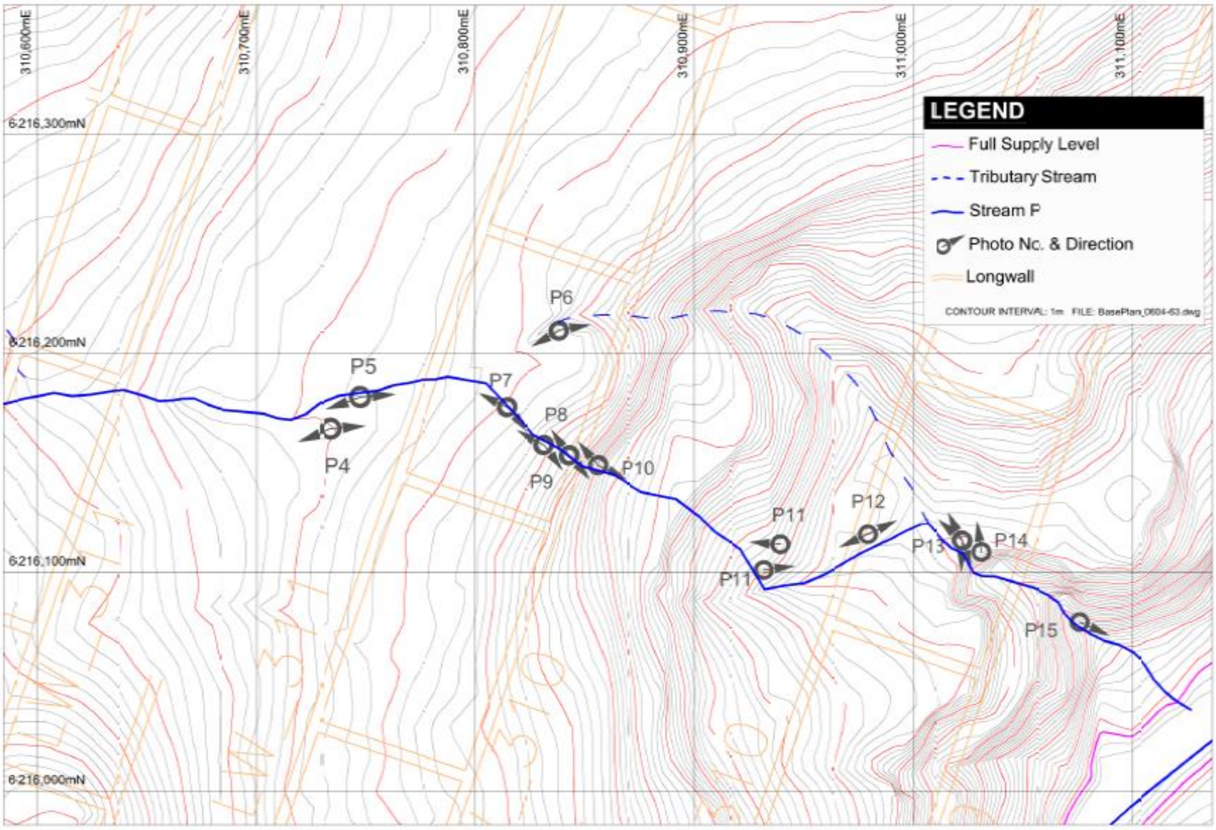


Photo P4 (Downstream)

Photo P4 (Upstream)

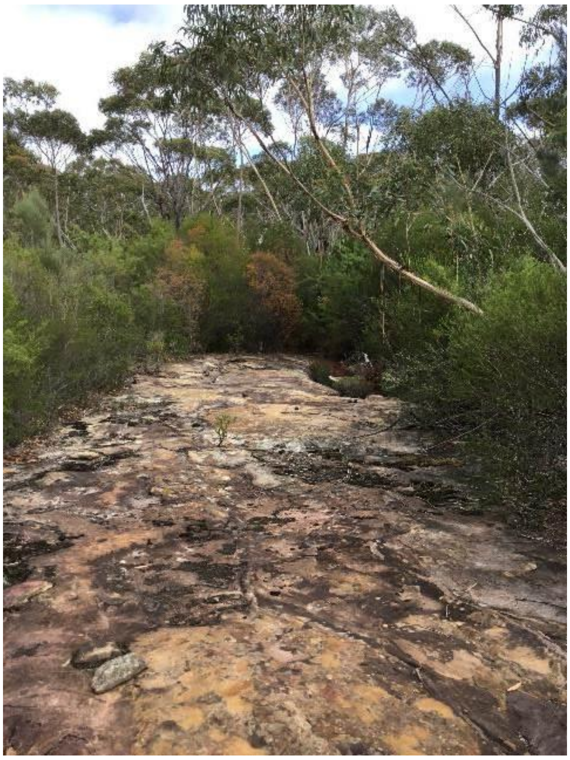


Photo P5 (Downstream)

Photo P5 (Upstream)

Photo P6 (Downstream)

Photo P6 (Upstream)

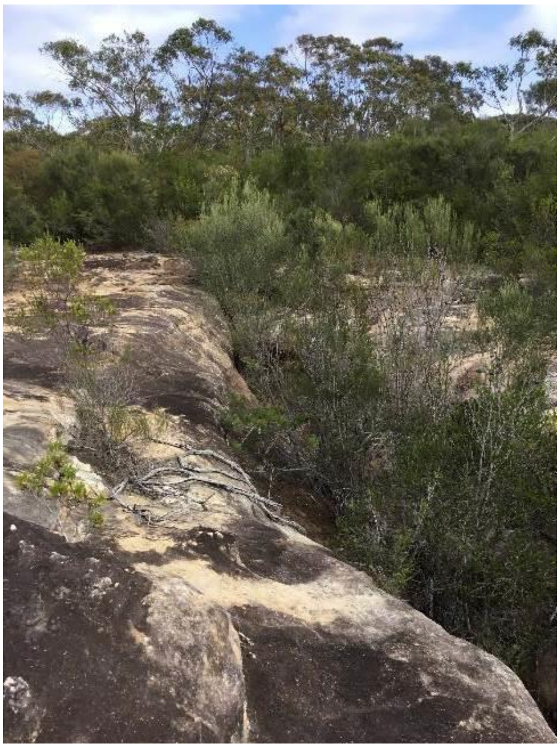


Photo P7 (Downstream)

Photo P7 (Upstream)

Photo P8 (Downstream)

Photo P8 (Upstream)

Photo P9 (Downstream)

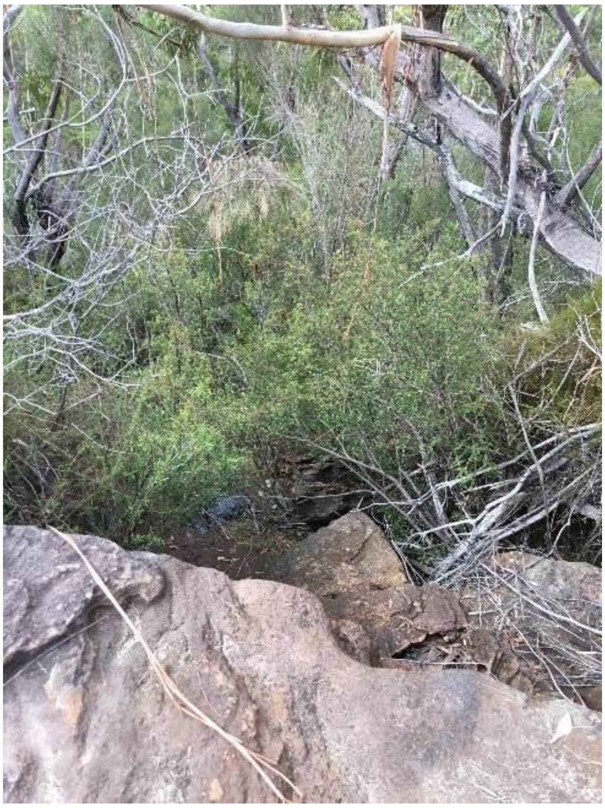


Photo P9 (Upstream)

Photo P10 (Downstream)

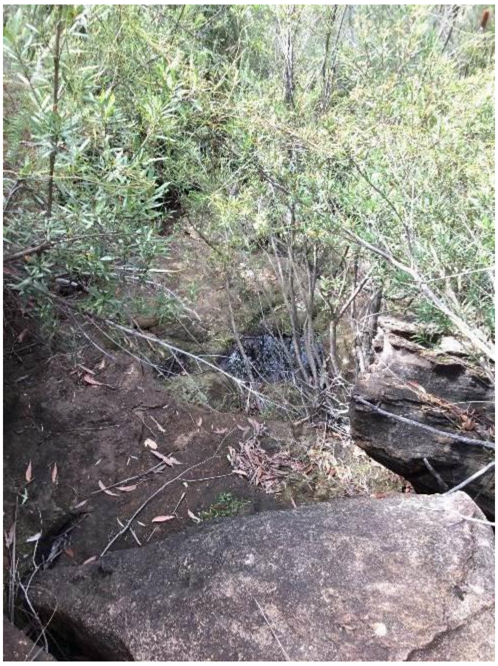


Photo P10 (Upstream)

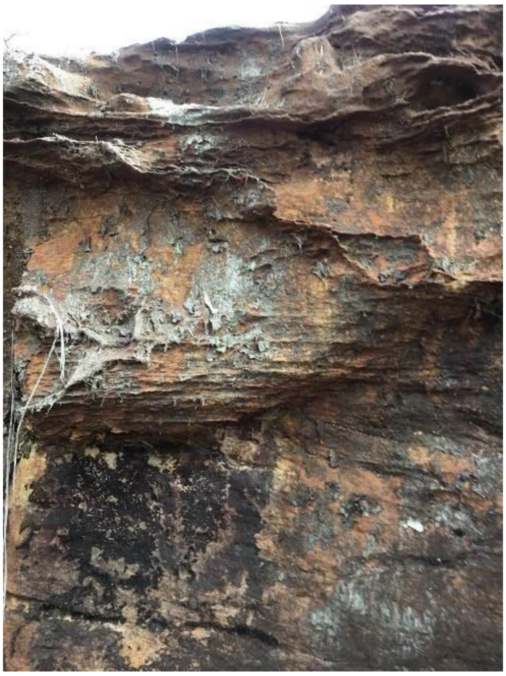


Photo P11 (Downstream)

Photo P11 (Upstream)

Photo P12 (Downstream)

Photo P12 (Upstream)

Photo P13 (Downstream 1)

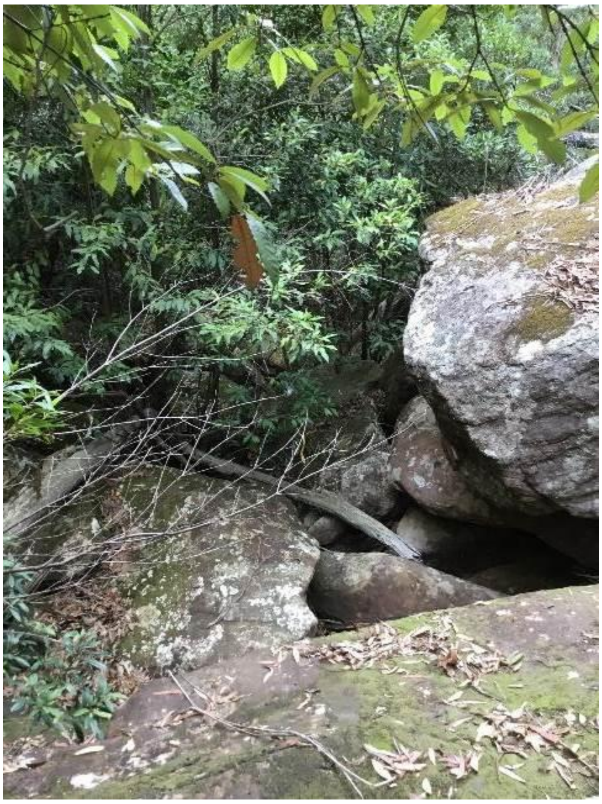
Photo P13 (Downstream 2)

Photo P13 (Upstream 1)

Photo P13 (Upstream 2)

Photo P14 (Upstream)

Photo P15 (Downstream)



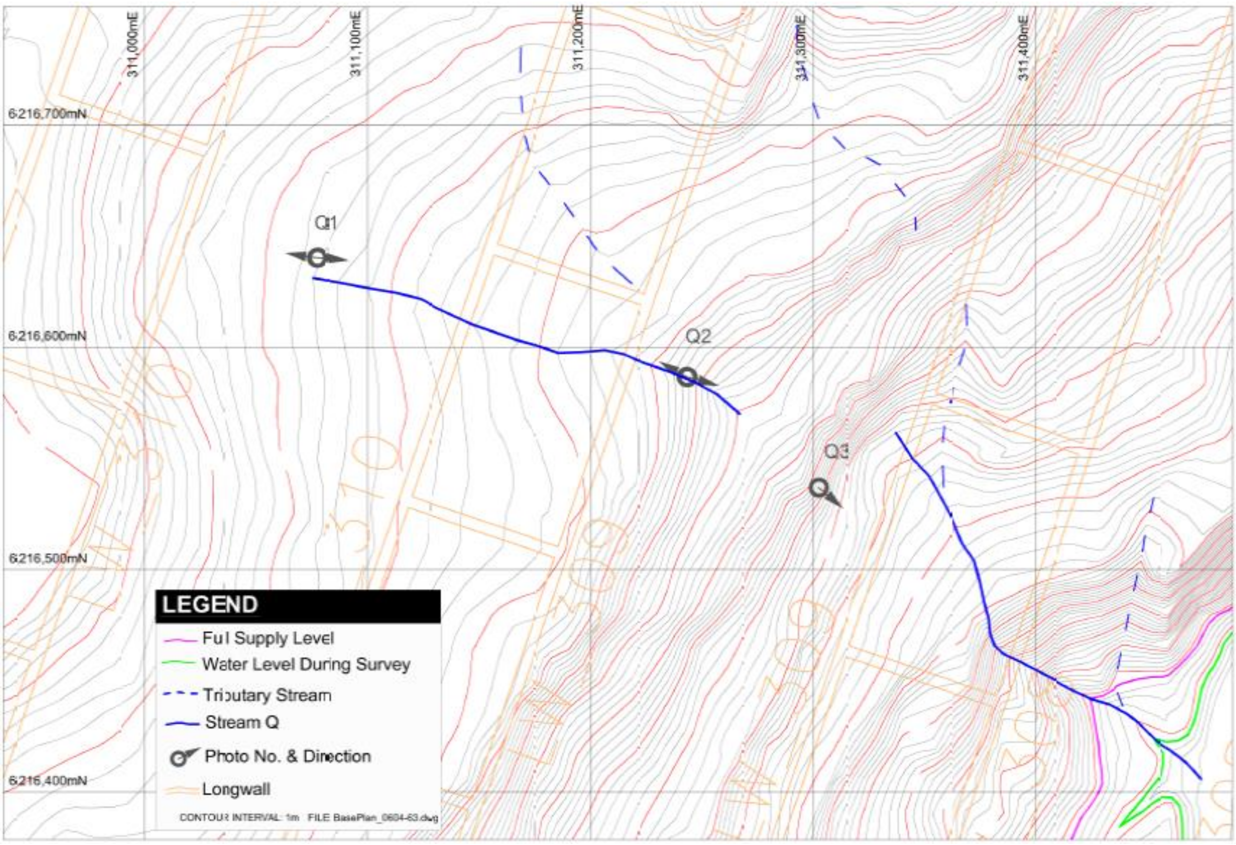


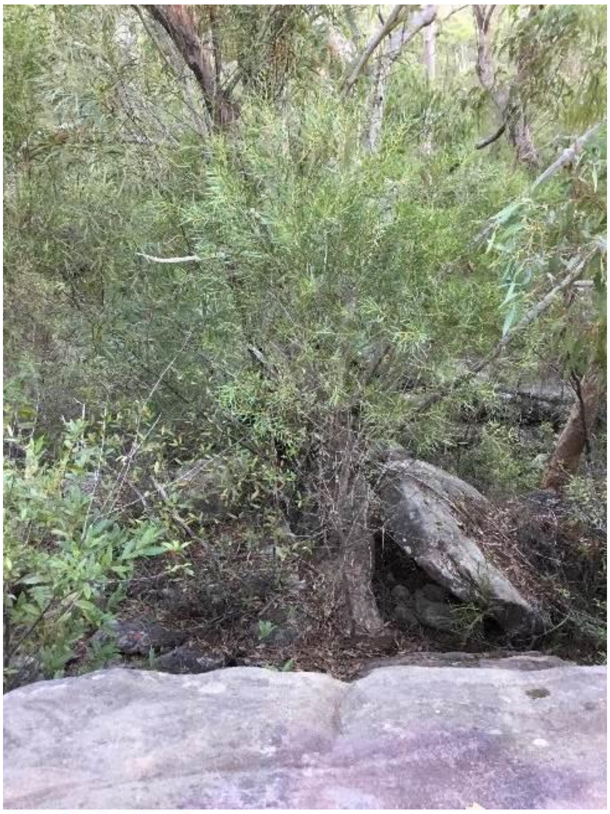
Photo Q1 (Downstream)

Photo Q1 (Upstream)

Photo Q2 (Downstream)

Photo Q2 (Upstream)

Photo Q3 (Downstream)



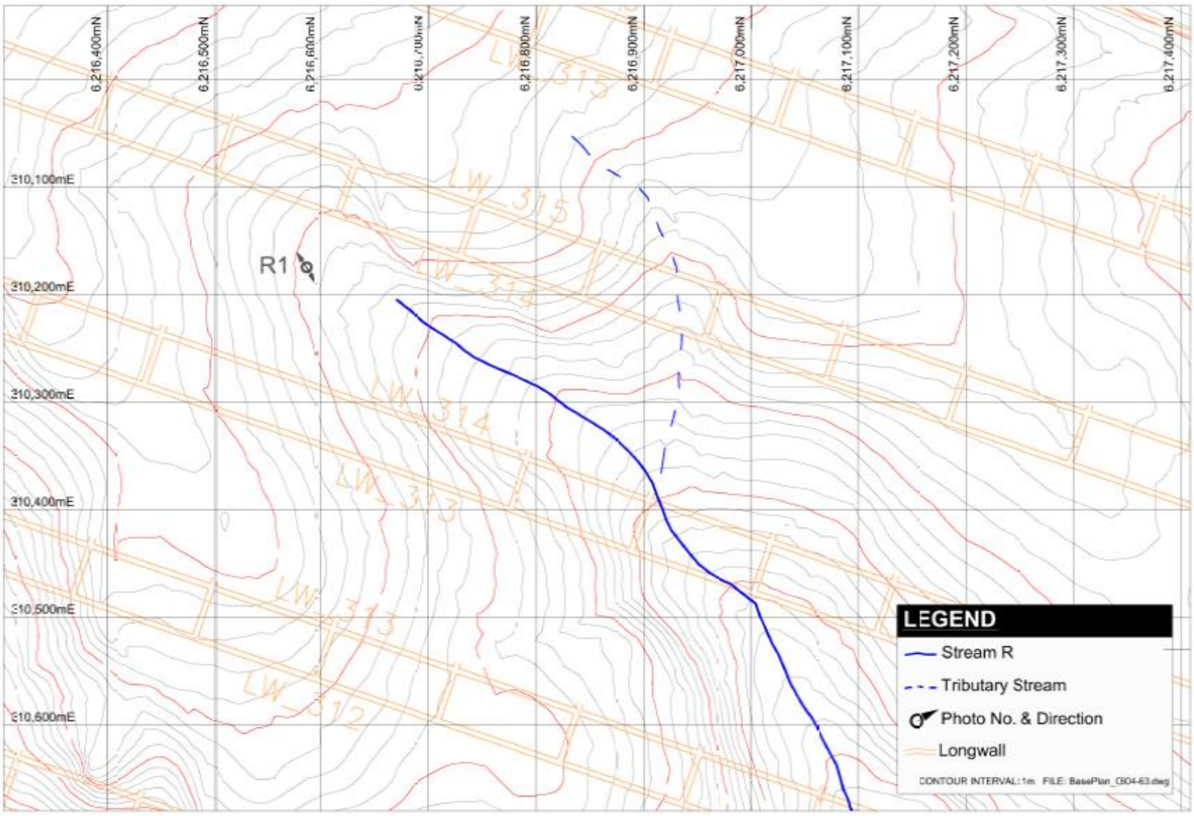


Photo R1 (Downstream)

Photo R1 (Upstream)

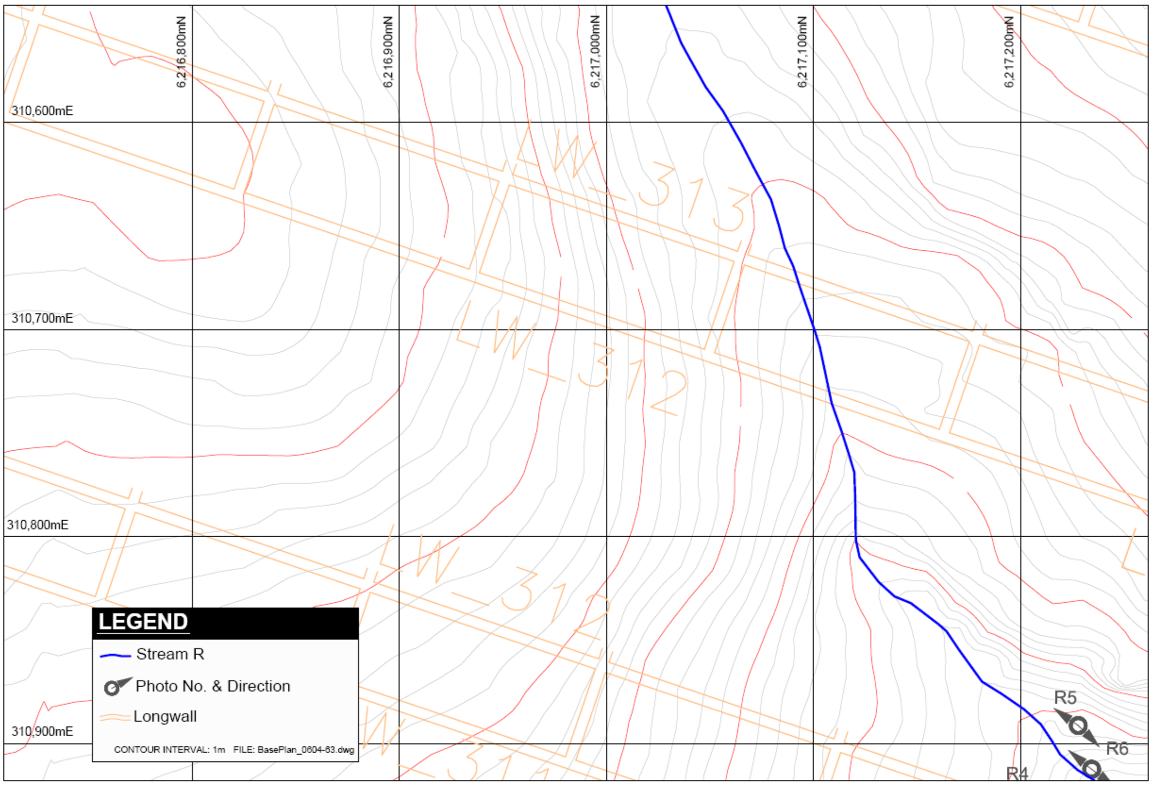


Photo R5 (Downstream)

Photo R5 (Upstream)

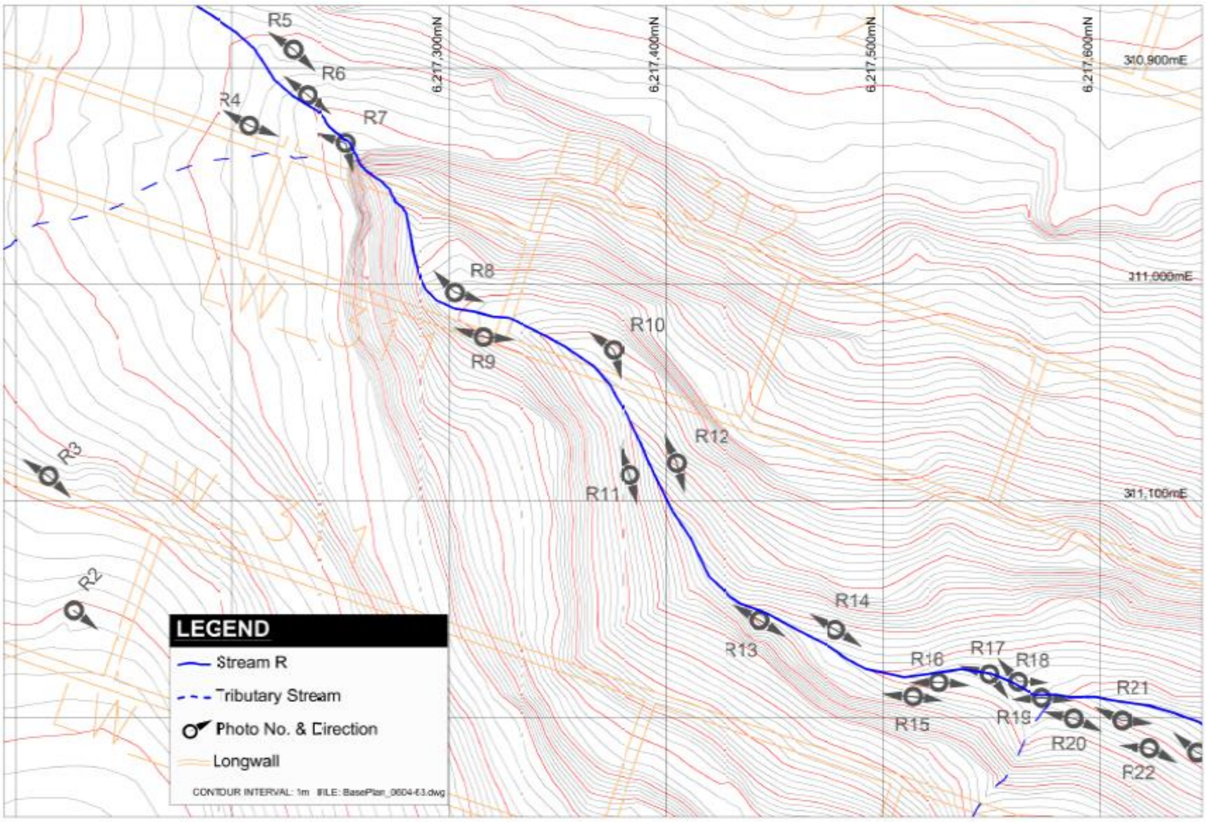


Photo R2 (Downstream)

Photo R3 (Downstream)

Photo R3 (Upstream)

Photo R4 (Downstream)

Photo R4 (Upstream)

Photo R6 (Downstream)

Photo R6 (Upstream)

Photo R7 (Downstream)

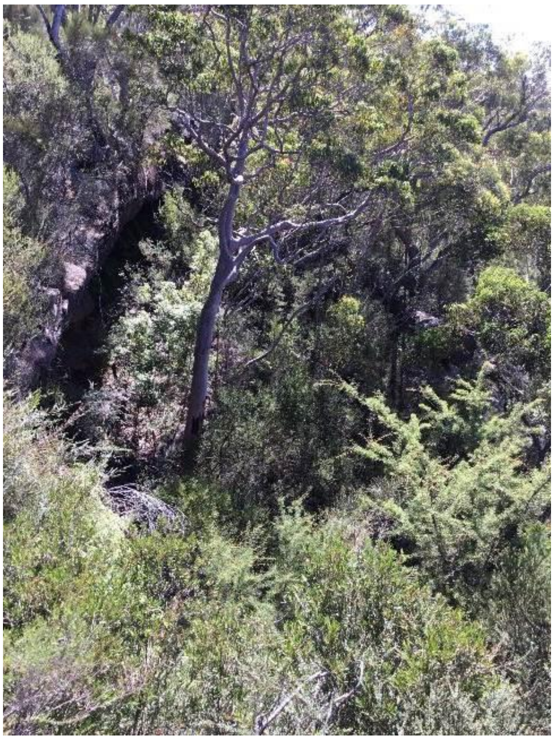


Photo R7 (Upstream)

Photo R8 (Downstream)

Photo R8 (Upstream)

Photo R9 (Downstream)

Photo R9 (Upstream)

Photo R10 (Downstream)

Photo R10 (Upstream)

Photo R11 (Downstream)

Photo R11 (Upstream)

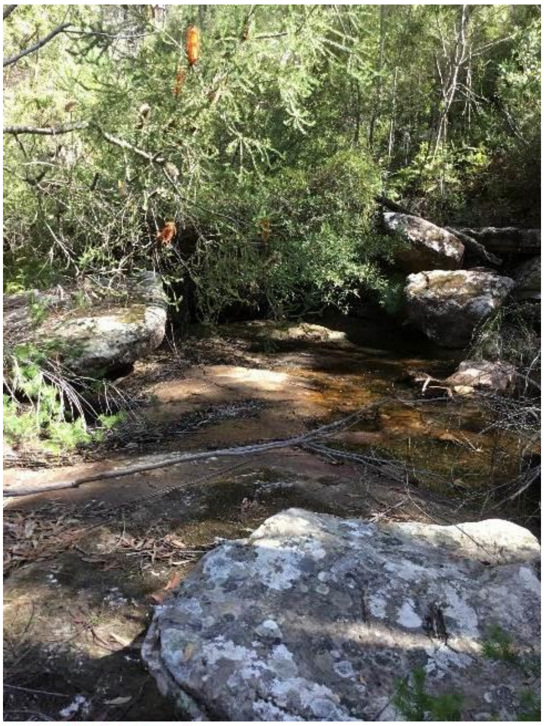


Photo R12 (Downstream)

Photo R12 (Upstream)

Photo R13 (Downstream)

Photo R13 (Upstream)

Photo R14 (Downstream)

Photo R14 (Upstream)

Photo R15 (Downstream)

Photo R15 (Upstream)

Photo R16 (Downstream)

Photo R16 (Upstream)

Photo R17 (Downstream)

Photo R17 (Upstream)

Photo R18 (Downstream)

Photo R18 (Upstream)

Photo R19 (Downstream)

Photo R19 (Upstream)

Photo R20 (Downstream)

Photo R20 (Upstream)

Photo R21 (Downstream)

Photo R21 (Upstream)

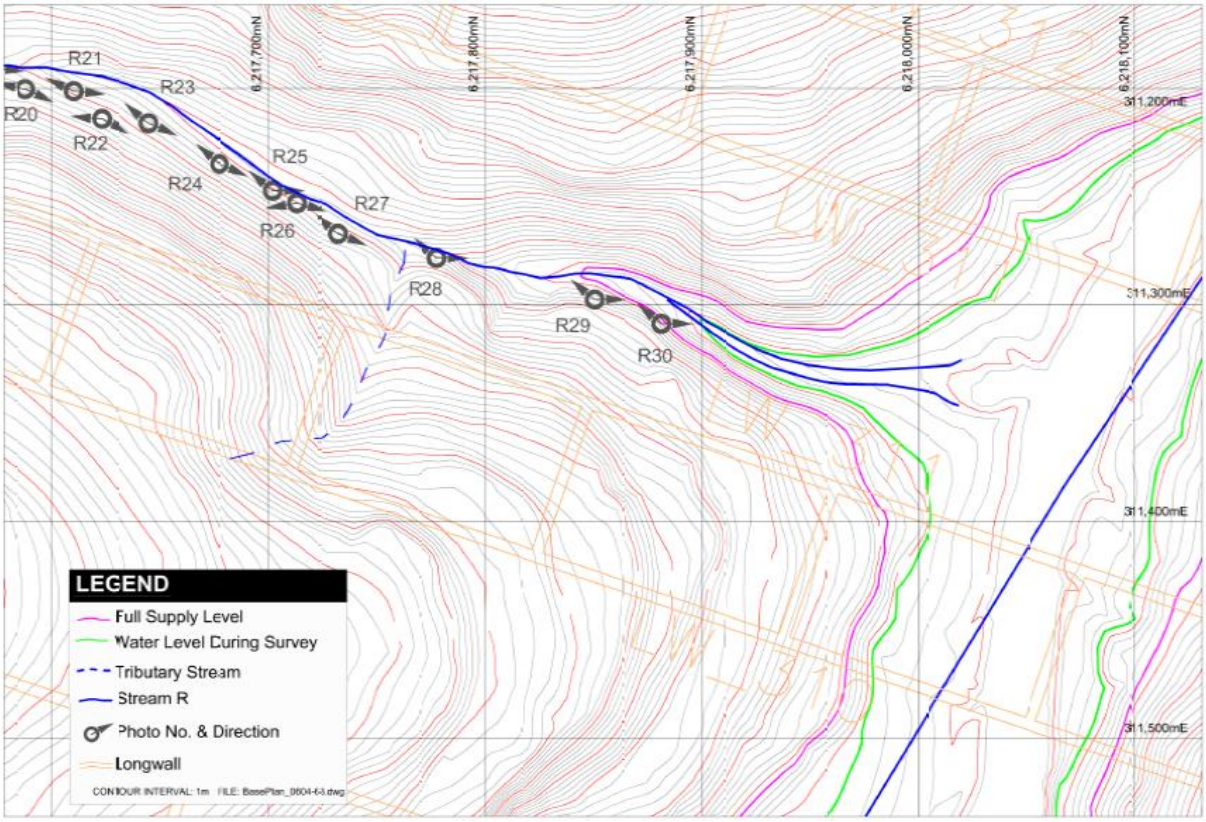


Photo R22 (Downstream)

Photo R22 (Upstream)

Photo R23 (Downstream)

Photo R23 (Upstream)

Photo R24 (Downstream)

Photo R24 (Upstream)

Photo R25 (Downstream)

Photo R25 (Upstream)

Photo R26 (Downstream)

Photo R26 (Upstream)

Photo R27 (Downstream)

Photo R27 (Upstream)

Photo R28 (Downstream)

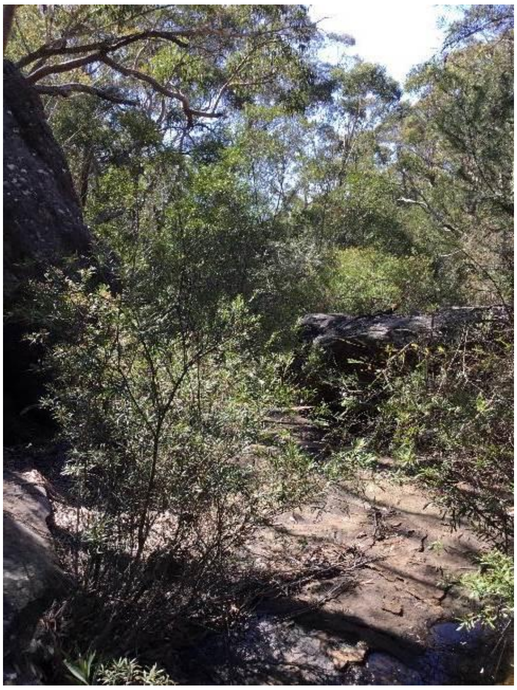


Photo R28 (Upstream)

Photo R29 (Downstream)

Photo R29 (Upstream)

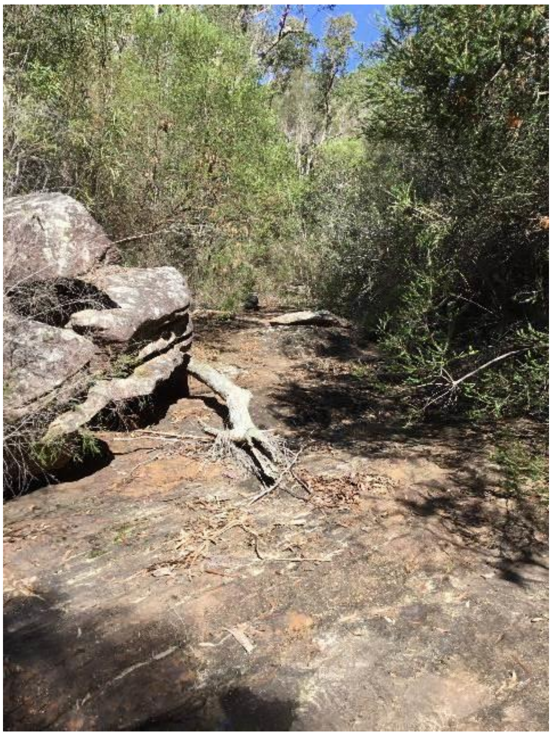


Photo R30 (Downstream)

Photo R30 (Upstream)

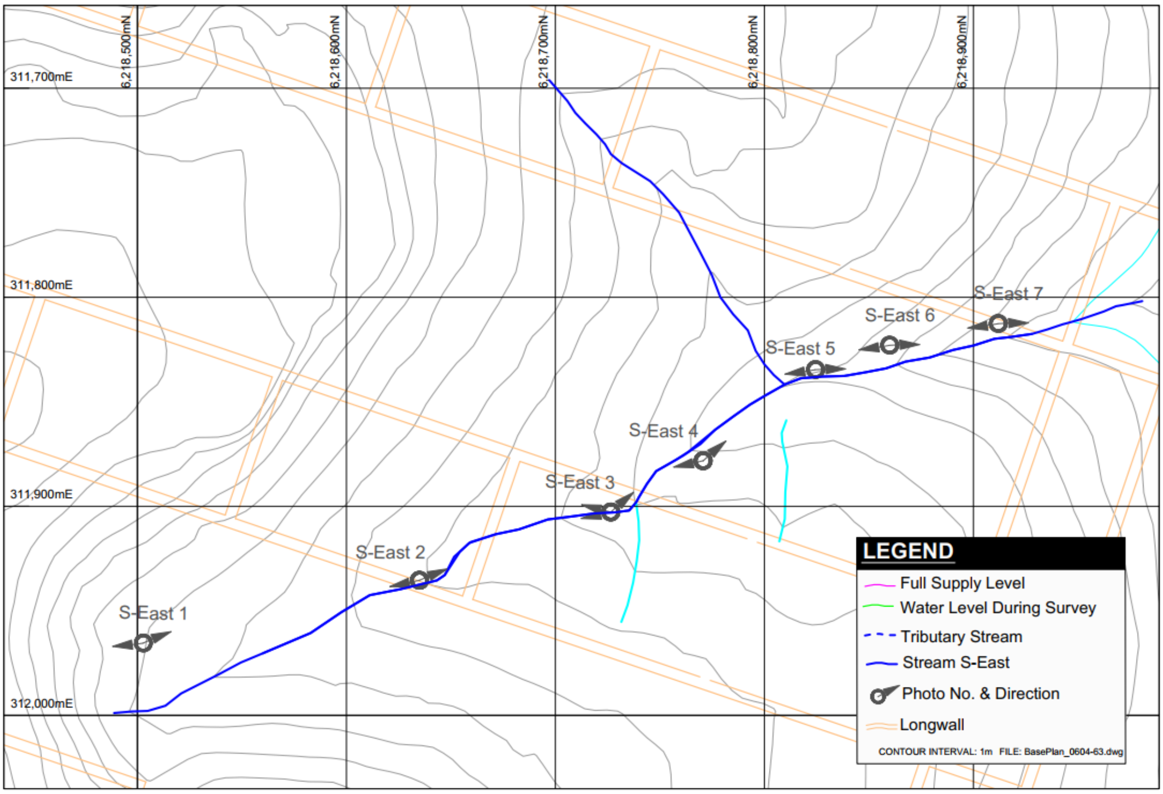


Photo S-East 1 (Downstream)

Photo S-East 1 (Upstream)

Photo S-East 2 (Downstream)

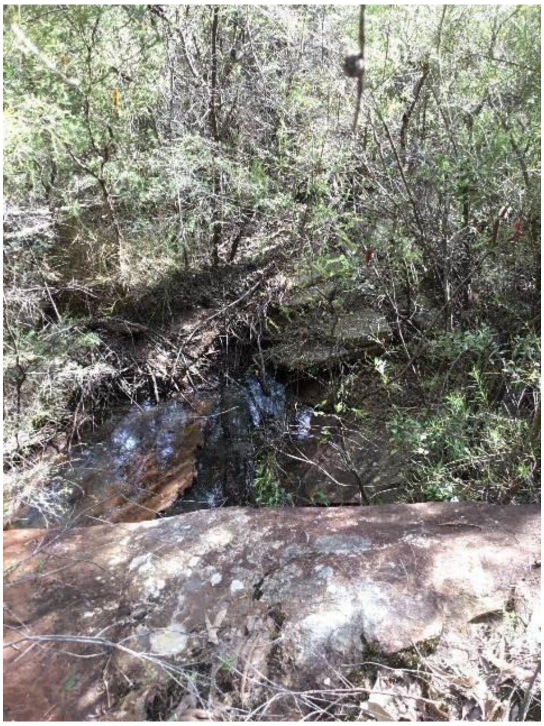


Photo S-East 2 (Upstream)

Photo S-East 3 (Downstream)

Photo S-East 3 (Upstream 1)

Photo S-East 3 (Upstream 2)

Photo S-East 4 (Downstream)

Photo S-East 4 (Upstream)

Photo S-East 5 (Downstream)

Photo S-East 5 (Upstream)

Photo S-East 6 (Downstream)

Photo S-East 6 (Upstream)

Photo S-East 7 (Downstream)

Photo S-East 7 (Upstream)

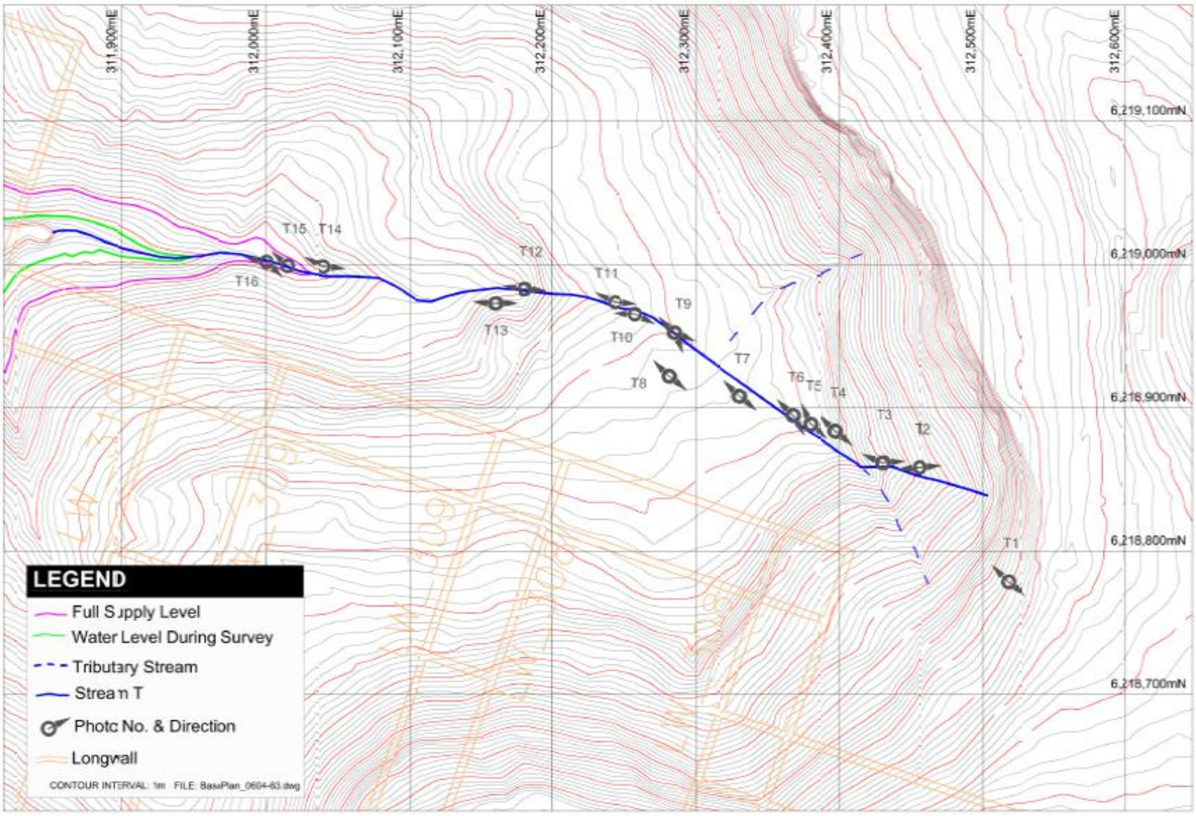


Photo T1 (Downstream)

Photo T1 (Upstream)

Photo T2 (Downstream)

Photo T2 (Upstream)

Photo T3 (Downstream)

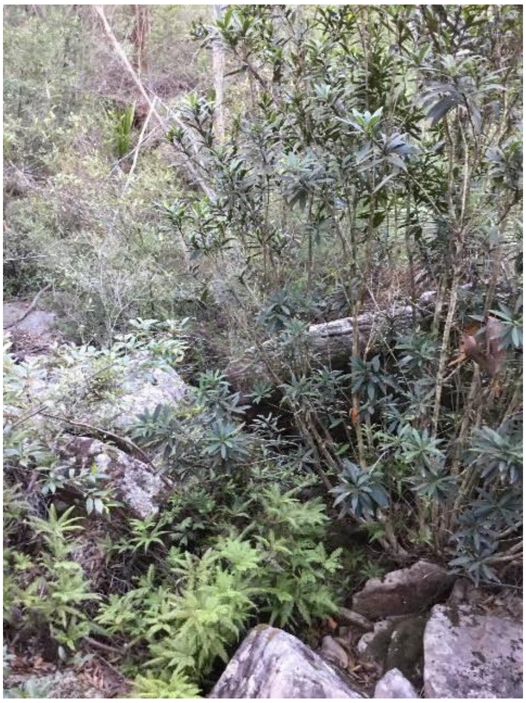


Photo T3 (Upstream)

Photo T4 (Downstream)

Photo T4 (Upstream)

Photo T5 (Downstream)

Photo T5 (Upstream)

Photo T6 (Downstream)

Photo T6 (Upstream)

Photo T7 (Downstream)

Photo T7 (Upstream)

Photo T8 (Downstream)

Photo T8 (Upstream)

Photo T9 (Downstream)

Photo T9 (Upstream 1)

Photo T9 (Upstream 2)

Photo T10 (Downstream)

Photo T10 (Upstream)

Photo T11 (Downstream)

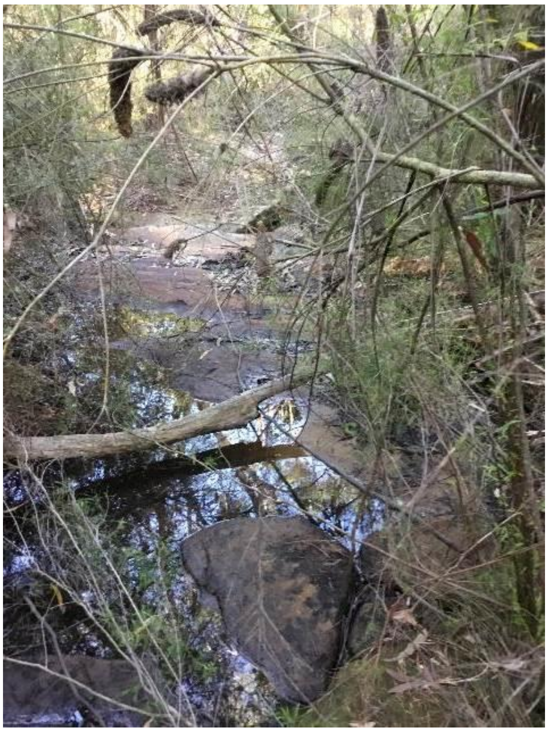


Photo T11 (Upstream)

Photo T12 (Downstream)

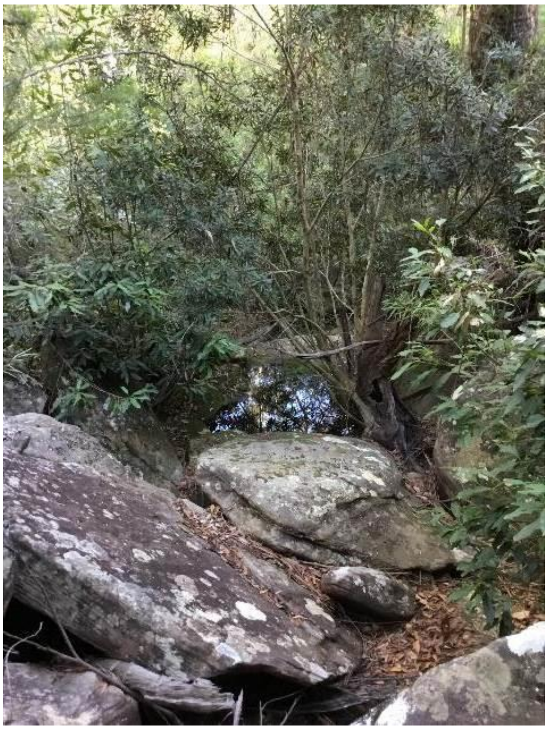


Photo T12 (Upstream)

Photo T13 (Downstream)

Photo T13 (Upstream)

Photo T14 (Downstream)

Photo T14 (Upstream)

Photo T15 (Downstream)

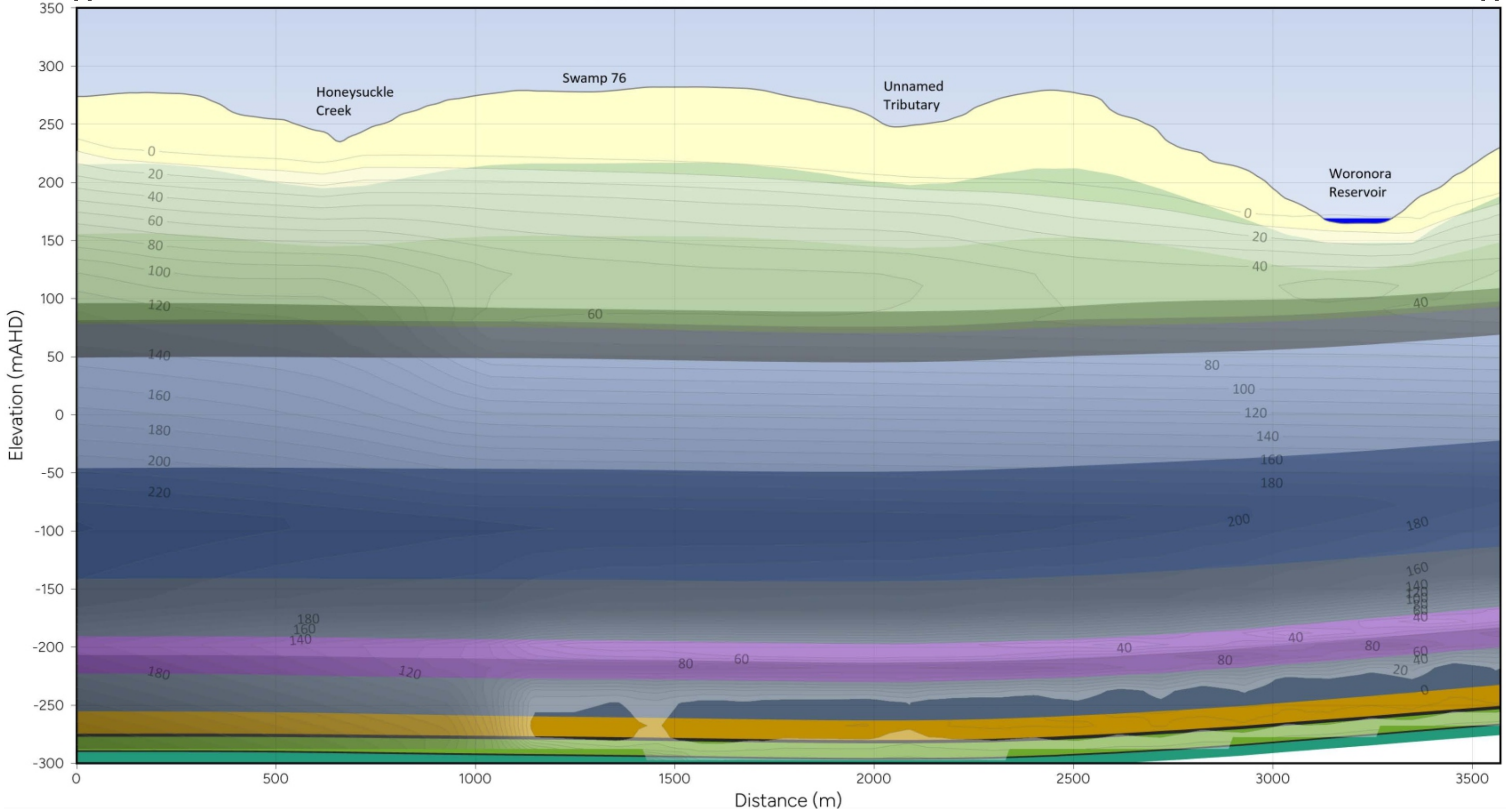
Photo T16 (Downstream)

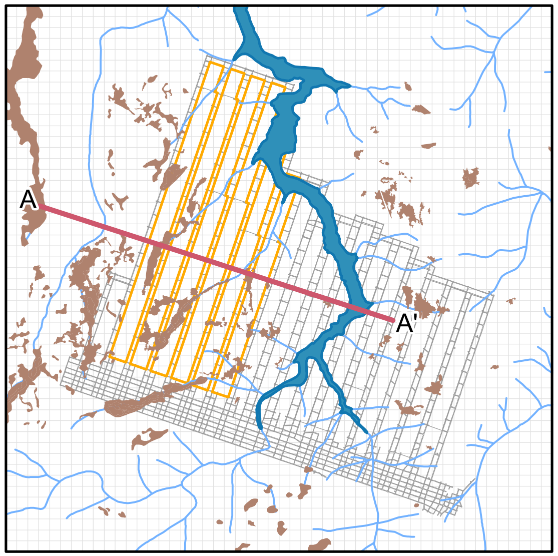
Photo T16 (Upstream)

APPENDIX 6

REPRESENTATIVE NORTH-SOUTH AND EAST-WEST CROSS SECTIONS FOR LONGWALLS 311-316

A — Cross Section A-A' Pore Pressure Profile — A'





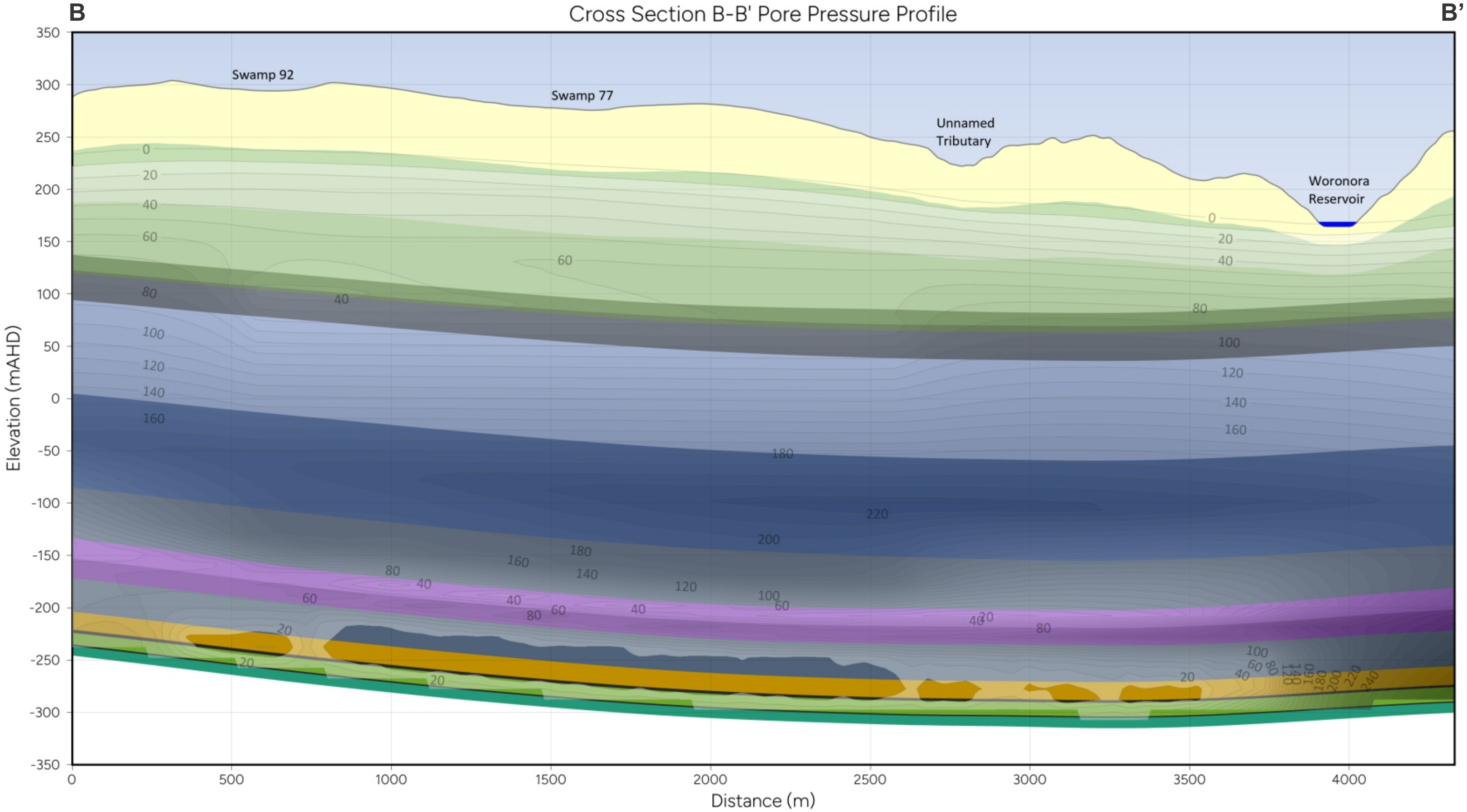
Left E308963:N6217849 GDA94 Z56
Right E312361:N6216749 GDA94 Z56
Vertical Exaggeration 1:2.9

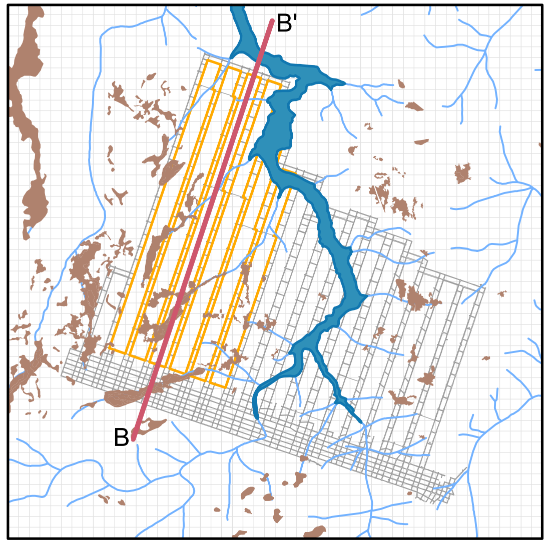
LEGEND

- Superficial Aquifer
- Upper Hawkesbury Sandstone
- Mid-Upper Hawkesbury Sandstone
- Mid-Lower Hawkesbury Sandstone
- Lower Hawkesbury Sandstone
- Bald Hill Claystone
- Upper Bulgo Sandstone
- Lower Bulgo Sandstone
- Stanwell Park Claystone
- Upper Scarborough Sandstone
- Lower Scarborough Sandstone
- Wombarra Claystone
- Coal Cliff Sandstone
- Bulli Coal Seam
- Loddon Sandstone
- Balgownie Coal Seam
- Lawrence Sandstone
- Pore Pressure Contours (m)

Peabody
METROPOLITAN COAL
Pore Pressure Cross Section East-West

Cross Section B-B' Pore Pressure Profile





Left E309865:N6215505 GDA94 Z56
Right E311235:N6219620 GDA94 Z56
Vertical Exaggeration 1:3.3

LEGEND

- Superficial Aquifer
- Upper Hawkesbury Sandstone
- Mid-Upper Hawkesbury Sandstone
- Mid-Lower Hawkesbury Sandstone
- Lower Hawkesbury Sandstone
- Bald Hill Claystone
- Upper Bulgo Sandstone
- Lower Bulgo Sandstone
- Stanwell Park Claystone
- Upper Scarborough Sandstone
- Lower Scarborough Sandstone
- Wombarra Claystone
- Coal Cliff Sandstone
- Bulli Coal Seam
- Loddon Sandstone
- Balgownie Coal Seam
- Lawrence Sandstone
- Pore Pressure Contours (m)

Peabody
METROPOLITAN COAL
Pore Pressure Cross Section North-South

APPENDIX 7

METROPOLITAN COAL STREAM REMEDIATION PLAN

METROPOLITAN COAL

STREAM REMEDIATION PLAN




Peabody

METROPOLITAN COAL

STREAM REMEDIATION PLAN

Revision Status Register

Section/Page/ Annexure	Revision Number	Amendment/ Addition	Distribution	DPIE Approval Date
All	SRP-R01-A	Original – Draft for Consultation	DP&E, DRG, WaterNSW, OEH, Department of Industry – Water, DPI – Fishing	-
All	SRP-R01-B	Revisions to address WaterNSW and OEH comments	DP&E, DRG, WaterNSW, OEH, Department of Industry – Water, DPI – Fishing	-
All	SRP-R01-C	Revisions to address WaterNSW, BCD and DRG comments	DPIE, DRG, WaterNSW, BCD, DPIE – Water, DPI – Fisheries	-
All	SRP-R01-D	Revisions to address DPIE comments	DPIE, DRG, WaterNSW, BCD, DPIE – Water, DPI – Fisheries	1 November 2019
All	SRP-R01-E	Revision to the remediation activities description	DPIE, Resources Regulator, WaterNSW, BCD, DPIE – Water, DPI - Fisheries	12 August 2021

JUNE 2021

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS (continued)

LIST OF FIGURES (Continued)

LIST OF ATTACHMENTS

1 INTRODUCTION

Metropolitan Coal is a wholly owned subsidiary of Peabody Energy Australia Pty Ltd (Peabody). Metropolitan Coal was granted approval for the Metropolitan Coal Project (the Project) under Section 75J of the New South Wales *Environmental Planning and Assessment Act, 1979* on 22 June 2009. A copy of the Project Approval is available on the Peabody website (http://www.peabodyenergy.com).

The Project comprises the continuation, upgrade and extension of underground coal mining operations and surface facilities at Metropolitan Coal. The current underground mining longwall layout is shown on Figure 1.

1.1 PURPOSE AND SCOPE

This Stream Remediation Plan has been prepared as a component of the Metropolitan Coal Water Management Plan in accordance with Condition 6, Schedule 3 of the Project Approval, and Condition 4, Schedule 6 of the Project Approval to manage the stream remediation activities that are required to achieve the rehabilitation objective for the Waratah Rivulet and Eastern Tributary.

The rehabilitation objective for the Waratah Rivulet and Eastern Tributary is specified in Table 11 of Condition 1, Schedule 6 of the Project Approval.

Table 11: Rehabilitation Objectives

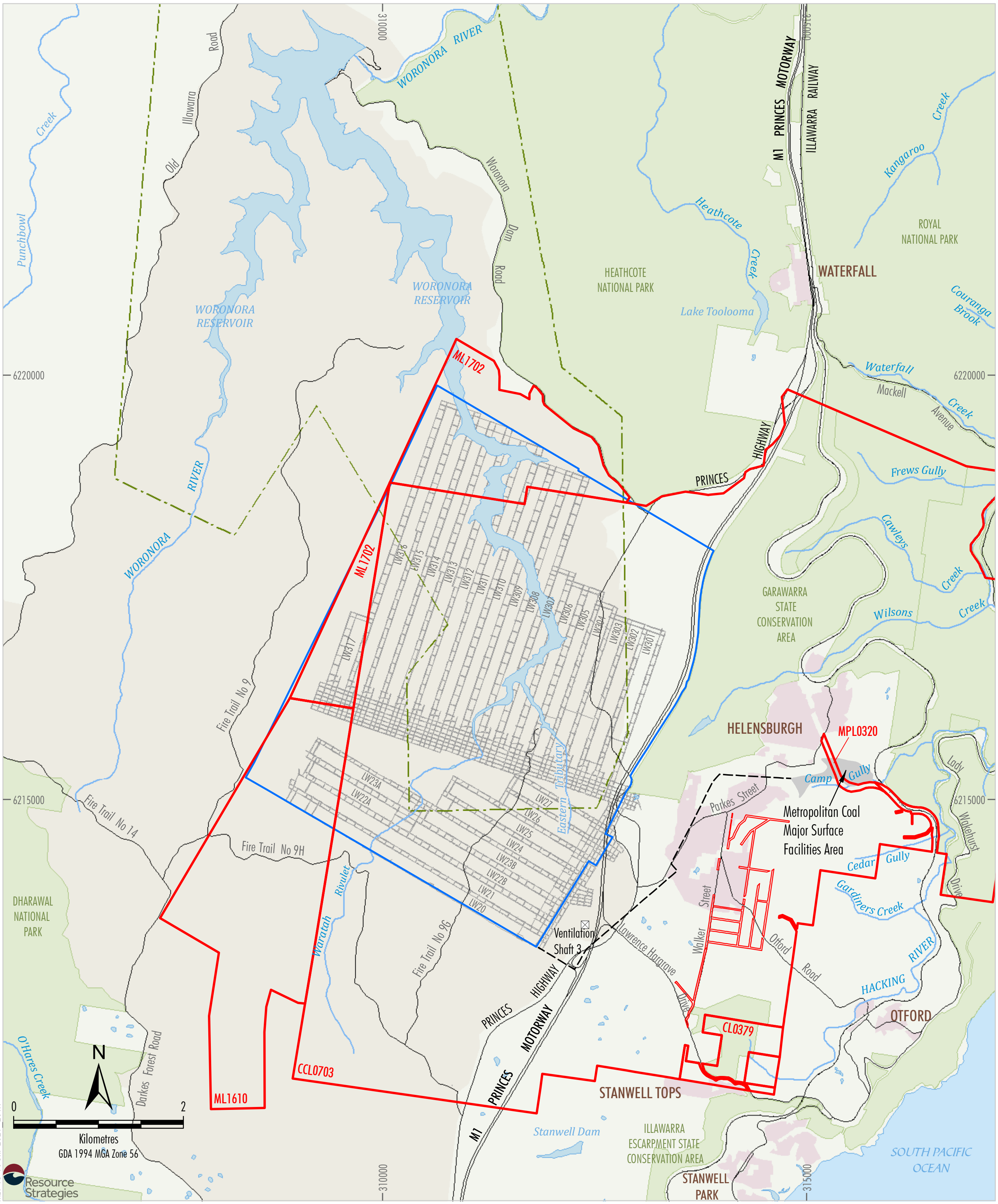
Domain	***Rehabilitation objective***
Waratah Rivulet, between the downstream edge of Flat Rock Swamp and the full supply level of the Woronora Reservoir *Eastern Tributary, between the maingate of Longwall 26 and the full supply level of the Woronora Reservoir*	*Restore surface flow and pool holding capacity as soon as reasonably practicable*

The Project Approval defines rehabilitation and remediation as follows:

Rehabilitation: *The treatment or management of land disturbed by the project for the purpose of establishing a safe, stable and non-polluting environment.*

Remediation: *Activities associated with partially or fully repairing or rehabilitating the impacts of the project or controlling the environmental consequences of this impact.*

The relationship of the Metropolitan Coal Water Management Plan to the Metropolitan Coal Environmental Management Structure is shown on Figure 2. Of particular relevance, a Rehabilitation Management Plan has been prepared for Project rehabilitation and remediation works in accordance with Condition 4, Schedule 6 of the Project Approval. Condition 4, Schedule 6 notes that some of the proposed remediation or rehabilitation measures may be included in the detailed management plans that form part of the Extraction Plan (Figure 2).



LEGEND

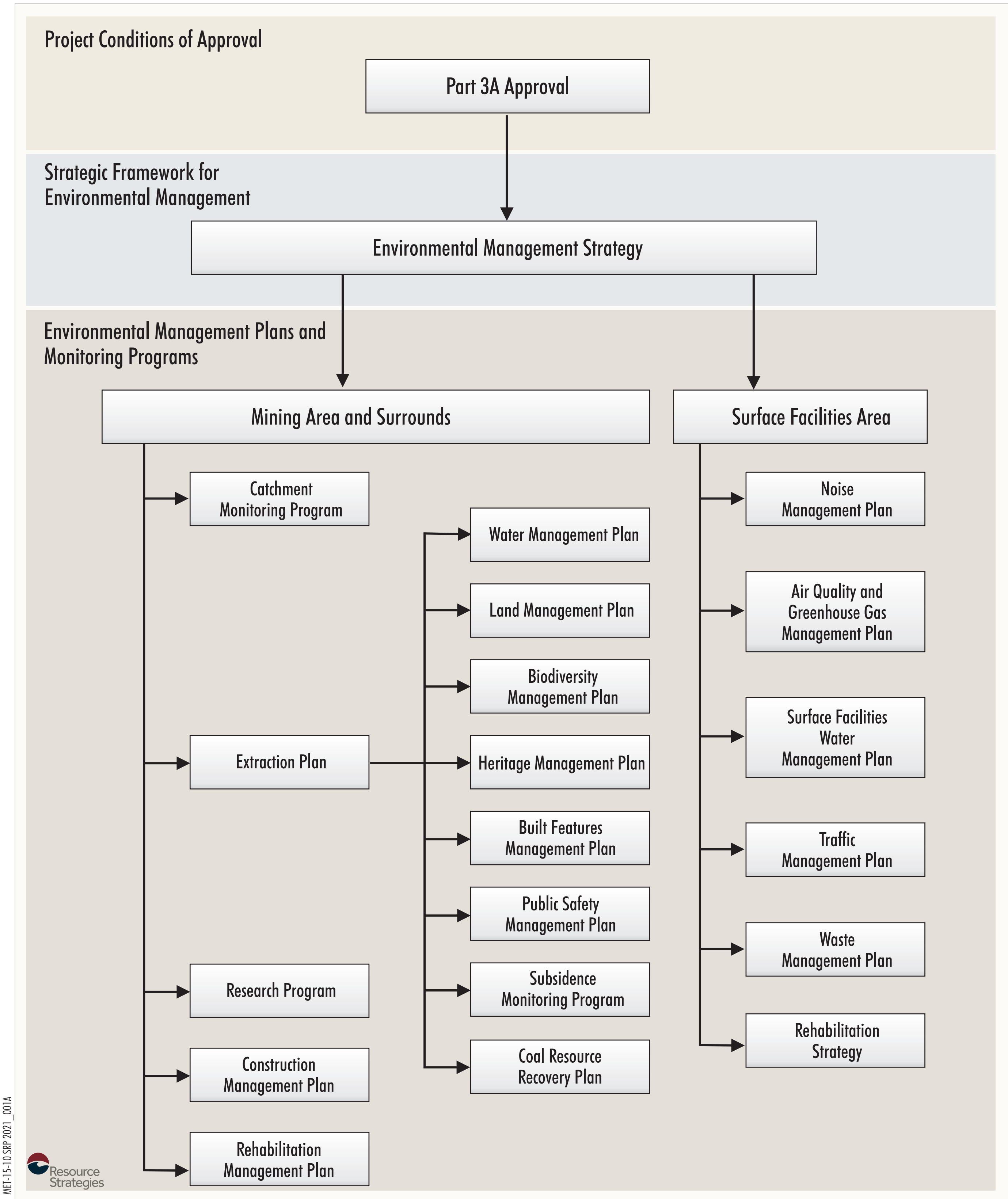
- Mining Lease Boundary
- Woronora Special Area
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Woronora Notification Area
- Existing Underground Access Drive (Main Drift)

Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2019)

Peabody
METROPOLITAN COAL

Project Longwalls 20-27 and Longwalls 301-317 Layout

Figure 1



Peabody

METROPOLITAN COAL

Environmental Management Structure

Figure 2

1.2 STRUCTURE OF THE STREAM REMEDIATION PLAN

The remainder of the Stream Remediation Plan is structured as follows:

Section 2: Describes the areas requiring stream remediation activities.

Section 3: Details the baseline data relevant to areas requiring stream remediation activities.

Section 4: Describes the stream remediation measures.

Section 5: Details the monitoring to be conducted in relation to the stream remediation activities.

Section 6: Describes the assessment of stream remediation progress against stream remediation performance indicators.

Section 7: Describes the assessment of the Waratah Rivulet and Eastern Tributary watercourse rehabilitation objective.

Section 8: Details the offset requirements if the stream remediation activities fail to remediate the impacts on the Eastern Tributary between the full supply level of the Woronora Reservoir and the Longwall 26 maingate.

Section 9: Lists the references cited.

2 AREAS REQUIRING STREAM REMEDIATION MEASURES

Metropolitan Coal is required to achieve the rehabilitation objective specified in Table 11 of Condition 1, Schedule 6 of the Project Approval for the Waratah Rivulet and the Eastern Tributary watercourses.

Table 11: Rehabilitation Objectives

Domain	***Rehabilitation Objective***
Waratah Rivulet, between the downstream edge of Flat Rock Swamp and the full supply level of the Woronora Reservoir *Eastern Tributary, between the maingate of Longwall 26 and the full supply level of the Woronora Reservoir*	*Restore surface flow and pool holding capacity as soon as reasonably practicable*

Metropolitan Coal is also required to achieve the subsidence impact performance measures specified in Table 1 of Condition 1, Schedule 3 of the Project Approval in relation to the Waratah Rivulet and Eastern Tributary watercourses.

Table 1: Subsidence Impact Performance Measures

Watercourses	
Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P)	*Negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases)*
Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26	*Negligible environmental consequences over at least 70% of the stream length (that is no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining and minimal gas releases)*

The stream remediation process for the Waratah Rivulet and Eastern Tributary is summarised in Figure 3. Metropolitan Coal monitors pools applicable to the Waratah Rivulet and Eastern Tributary rehabilitation objective. The stream remediation process is triggered for a pool if monitoring indicates mine subsidence has resulted in the diversion of flow and/or change in the natural drainage behaviour. The relevant agencies are notified that the stream remediation process has been triggered and stream remediation activities are conducted in accordance with this Stream Remediation Plan (Figure 3).

The current status of pools in relation to the stream remediation process is described in Section 2.1 and Section 2.2 for the Waratah Rivulet and Eastern Tributary, respectively.

2.1 WARATAH RIVULET STREAM POOL/ROCK BAR REMEDIATION

The location of pools/rock bars along the Waratah Rivulet are shown on Figure 4 and on the detailed mapping in Appendix 1 of the Longwalls 305-307 Water Management Plan.

As described in Section 2, Metropolitan Coal is required to restore surface flow and pool holding capacity on the Waratah Rivulet between the downstream edge of Flat Rock Swamp and the full supply level of the Woronora Reservoir (i.e. Pools A to W). Metropolitan Coal is also required not to exceed the Waratah Rivulet watercourse subsidence impact performance measure, which is applicable to Pools P to W.

Sections 2.1.1 to 2.1.3 describe the status of the Waratah Rivulet pools/rock bars in relation to the triggering of stream remediation overlying the Longwalls 1-13 mining area, downstream of the Longwalls 1-13 mining area to the Longwall 23 maingate, and downstream of the Longwall 23 maingate to the full supply level of the Woronora Reservoir, respectively.

2.1.1 Longwalls 1-13 Mining Area (Downstream of Flat Rock Swamp to Longwall 20 Tailgate)

Pools A, B, C, E, F, G, G1, H and I on the Waratah Rivulet are situated in the completed mining area overlying Longwalls 1 to 13 between Flat Rock Swamp and the tailgate of Longwall 20 (Figure 4).

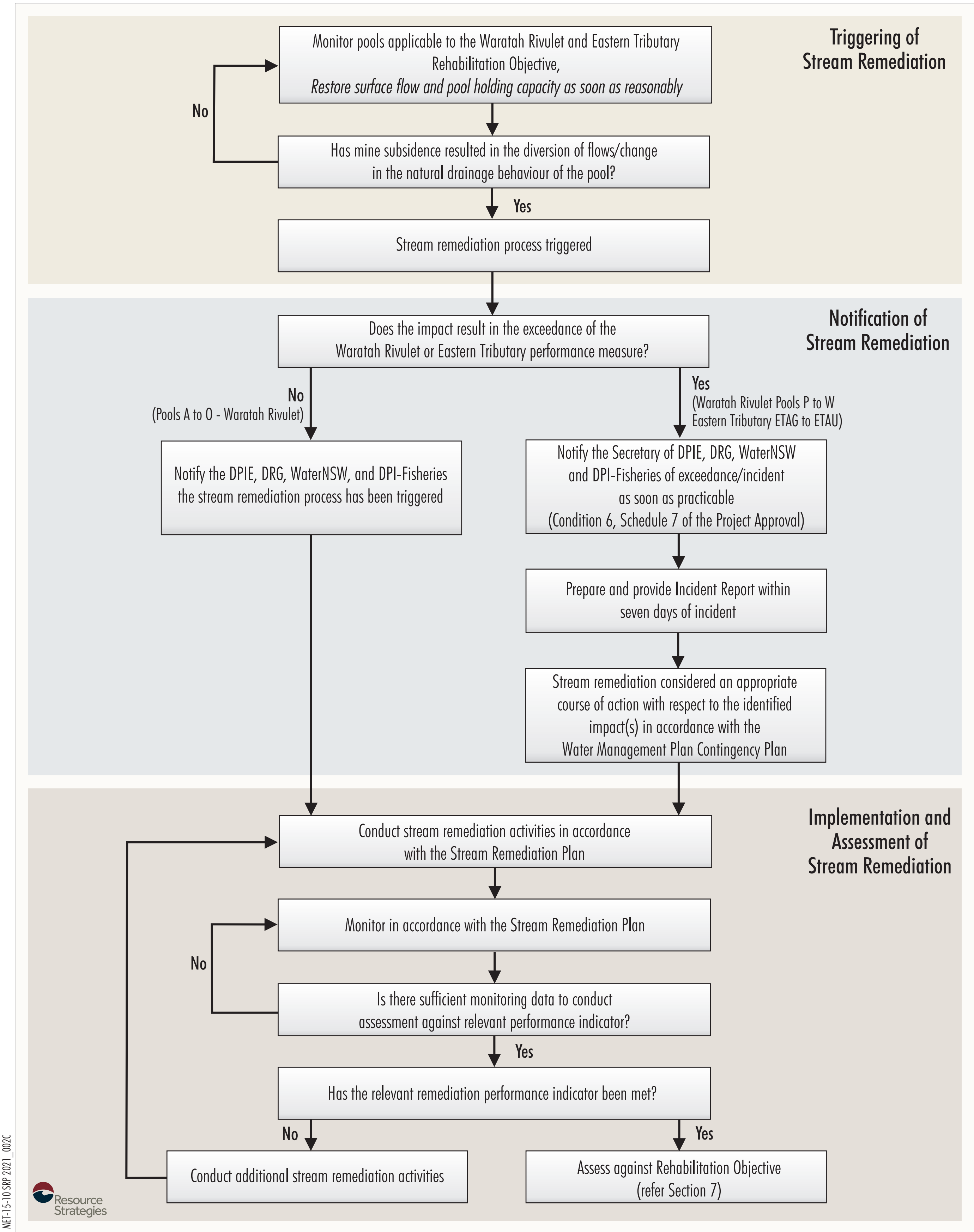
As a result of previous mining, the water levels in pools upstream of Flat Rock Crossing (i.e. Pools A to G) and immediately downstream of Flat Rock Crossing (Pool G1) have been impacted by mine subsidence. Stream remediation activities have been conducted at Pools A, F and G. The rock bars at Pools A and F are considered to largely control the pools located upstream of these rock bars. As a result, Metropolitan Coal anticipated that the restoration of surface flow and pool holding capacity at Pools A and F would restore the surface flow and pool holding capacity of pools between Flat Rock Swamp and Pool F.

Stream remediation (sand injection) was conducted at Pool A in 2005 and 2006. Stream remediation trials using polyurethane were conducted at the Pool F rock bar (also known as WRS4) from 17-23 March 2008 and 3 April to 19 May 2008. The remediation trials demonstrated that the hydraulic conductivity of the overall rock mass was decreased to the extent that the rock bar once again acted as a natural weir to maintain the persistence of its upstream pool (HCPL, 2008a).

Following the conduct of the stream remediation trials at the Pool F rock bar, stream remediation campaigns using polyurethane were conducted at the Pool A rock bar (also known as WRS3) in the period between 2009 and June 2012.

A further stream remediation campaign was conducted at the Pool F rock bar between 24 September 2014 and 29 June 2015 following the completion of Longwalls 20-22, followed by stream remediation at the Pool G rock bar between 8 September 2015 to 31 August 2016.

In the event stream remediation activities are required at any additional pools/rock bars, Metropolitan Coal will prepare stream remediation plans in consultation with the Department of Planning, Industry and Environment (DPIE), Resources Regulator and WaterNSW and include the plans in Attachment 1. Metropolitan Coal will also provide the DPIE, Resources Regulator and WaterNSW with 14 days' notice of their intention to commence stream remediation activities at each pool/rock bar.

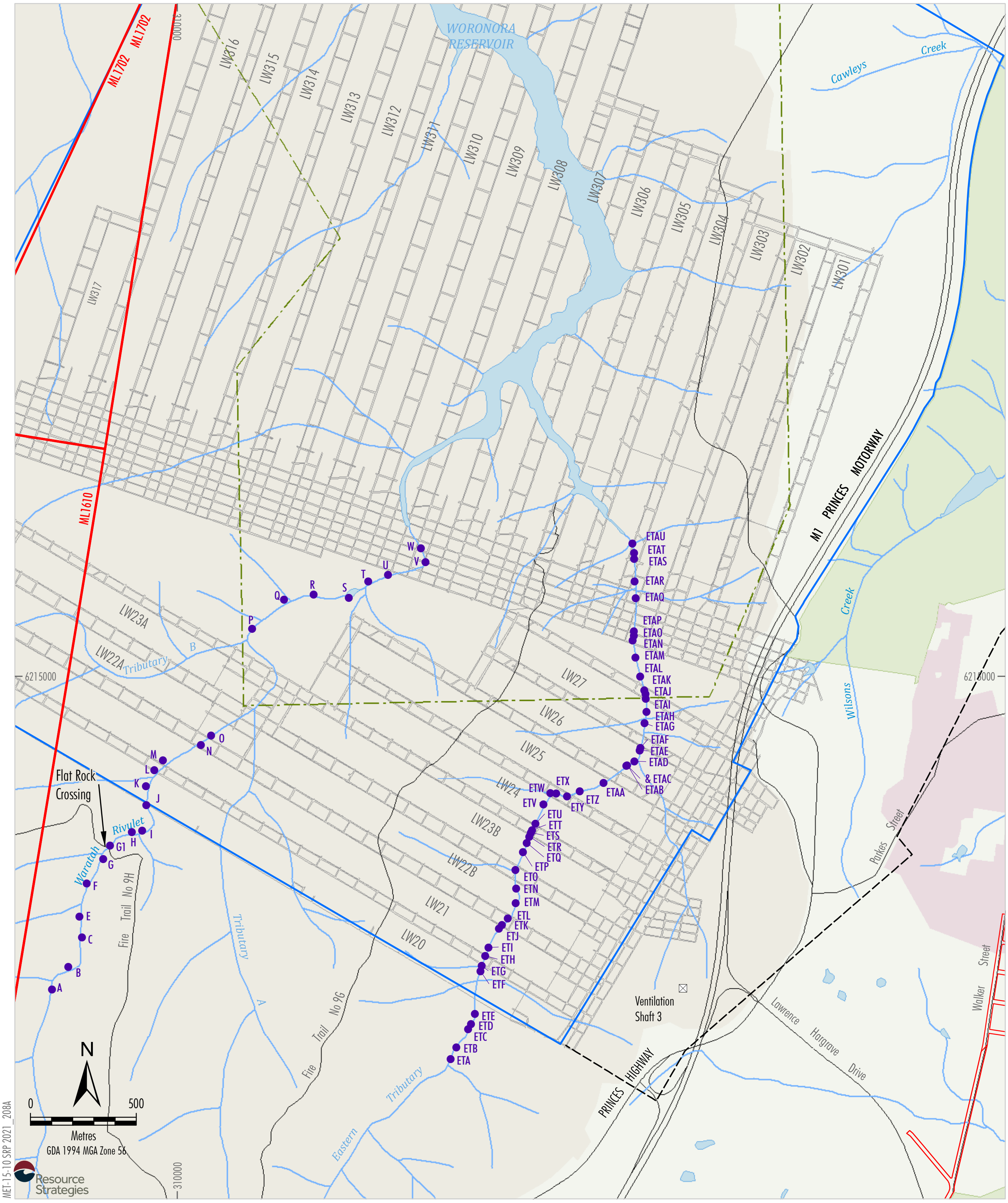


Peabody

METROPOLITAN COAL

Stream Remediation Process for Waratah Rivulet and Eastern Tributary

Figure 3



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Woronora Notification Area
- Existing Underground Access Drive (Main Drift)
- Pool

Notes: 1. The streams are based on mapping by the Lands Department (2006). More detailed and accurate mapping of the streams is provided in WMP Appendices 1 to 4.

Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2019)

Peabody

METROPOLITAN COAL

Waratah Rivulet and Eastern Tributary Pools

Figure 4

Stream remediation will be triggered at Pools H or I on the Waratah Rivulet if the water depth in a pool falls below the water depth required for continuous flow over the corresponding downstream rock bar (i.e. stops overflowing), except if as a result of climatic conditions. The control pools on Woronora River will be inspected (for a similar response).

Metropolitan Coal will advise the DPIE, Resources Regulator, WaterNSW, Biodiversity and Conservation Division (BCD) (now part of DPIE), DPIE – Water and Department of Primary Industries – Fisheries (DPI – Fisheries) if the stream remediation process has been triggered.

2.1.2 Downstream of Longwalls 1-13 Mining Area (Longwall 20 Tailgate to Longwall 23 Maingate)

Pools J, K, L, M, N and O on the Waratah Rivulet are situated downstream of the completed Longwalls 1-13 mining area, between the Longwall 20 tailgate and Longwall 23 maingate (Figure 4).

As a result of mining, the water levels in Pool N were impacted by mine subsidence in early September 2012. A stream remediation plan for Pool N is included in Attachment 1. To date (December 2018), Pool N has overflowed its rock bar since December 2014, with the exception of relatively short periods. Pools on the Woronora River also stopped flowing within the same periods. Monitoring of Pool N will continue to be conducted.

Stream remediation will be triggered at Pools J, K, L or M on the Waratah Rivulet if the water depth in a pool falls below the water depth required for continuous flow over the corresponding downstream rock bar (i.e. stops overflowing), except if as a result of climatic conditions. The control pools on Woronora River will be inspected (for a similar response). Stream remediation will be triggered at Pool O on the Waratah Rivulet (boulderfield control) if the pool water levels are considered to be inconsistent with natural behaviour.

Metropolitan Coal will advise the DPIE, Resources Regulator, WaterNSW, BCD, DPIE – Water and DPI – Fisheries if the stream remediation process has been triggered. Stream remediation plans for rock bars J, L and N are provided in Attachment 1.

The water level in Pool K is considered to be substantially controlled by the rock bar of Pool L. As a result, Metropolitan Coal anticipates that the restoration of surface flow and pool holding capacity at Pool L will restore the surface flow and pool holding capacity of Pool K. Metropolitan Coal will assess whether additional stream remediation works are required at Pool K once stream remediation activities at Pool L have been completed. In the event stream remediation activities are required at Pool K once stream remediation activities at Pool L have been completed, Metropolitan Coal will prepare a stream remediation plan in consultation with the DPIE, Resources Regulator and WaterNSW and include the plan in Attachment 1. If stream remediation works are required at Pool O, Metropolitan Coal will prepare a stream remediation plan in consultation with the DPIE, Resources Regulator and WaterNSW and include the plan in Attachment 1.

Metropolitan Coal will also provide the DPIE, Resources Regulator and WaterNSW with 14 days’ notice of their intention to commence stream remediation activities at each pool/rock bar.

2.1.3 Downstream of Longwall 23 Maingate

Pools P, Q, R, S, T, U, V and W on the Waratah Rivulet are situated between the Longwall 23 maingate and the full supply level of the Woronora Reservoir (Figure 4).

Although not anticipated to be required, stream remediation will be triggered at Pools P, Q, R, S, T, U, V or W if the assessment of monitoring results indicates the subsidence impact performance measure:

> *negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, …….) on the Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P)*

has been exceeded.

2.2 EASTERN TRIBUTARY STREAM REMEDIATION

The location of pools/rock bars along the Eastern Tributary are shown on Figure 4 and on the detailed mapping in Appendix 2 of the Metropolitan Coal Water Management Plan.

As described in Section 2, the Project Approval required Metropolitan Coal to have negligible environmental consequences over at least 70% of the stream length on the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26 (which includes Pools ETAG to ETAU).

Monitoring conducted in accordance with the Metropolitan Coal Longwalls 23-27 Water Management Plan identified that the Eastern Tributary watercourse performance measure was exceeded in relation to *minimal iron staining* and *no diversion of flows, no change in the natural drainage behaviour of pools*. The exceedance of the Eastern Tributary watercourse performance measure (referred to as the Eastern Tributary Incident) was reported to the Department of Planning and Environment (DP&E) (now DPIE) and other relevant agencies in October 2016.

Metropolitan Coal provided the DP&E with a proposed course of action in relation to the exceedance of the Eastern Tributary subsidence impact performance measure, focused on the implementation of stream remediation measures.

In accordance with Condition 1, Schedule 6 of the Project Approval, Metropolitan Coal is required to restore surface flow and pool holding capacity on the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26.

2.2.1 Between the Woronora Reservoir Full Supply Level and the Maingate of Longwall 26

Pools ETAG to ETAU on the Eastern Tributary are situated between the full supply level of the Woronora Reservoir and the maingate of Longwall 26 (Figure 4).

Inspection results of fresh iron staining/flocculent within the performance measure reach indicates the extent of iron staining/flocculent has varied over time since the exceedance.

The iron staining/flocculent is associated with Eastern Tributary water quality impacts, which have occurred in association with the exceedance of the Eastern Tributary watercourse performance measure. Reducing conditions (through water saturation excluding oxygen) has solubilised iron (and manganese) in the groundwater. The soluble iron and manganese have been transferred to surface water through mine-induced cracking, resulting in increases in iron and manganese concentrations in the Eastern Tributary. The soluble iron (iron (II) ion, Fe^{2+}), rapidly oxidises to iron (III) Fe^{3+}, and forms insoluble hydrated ferric hydroxide in colloidal (<0.45 micrometres [µm]) and particulate (>0.45 µm) forms (The University of Queensland, 2018). Iron oxidising bacteria can also create oxidised iron precipitate (Australian Drinking Water Guidelines, 2011). The iron floc is a mixture of precipitated iron oxyhydroxide material >0.45 µm size and colloidal material which is <0.45 µm size. The colloidal material coagulates to give the larger size precipitated material and coats the creek bed rock surfaces (The University of Queensland, 2018). The iron oxyhydroxide gradually converts to goethite (Yee *et al*., 2006) which has a darker colour and is commonly found in the creek sediment. It is anticipated that the stream remediation activities will reduce the transfer of iron and manganese from the groundwater to the Eastern Tributary.

The drainage behaviour of 12 pools on the Eastern Tributary (Pools ETAG to ETAR) were impacted by mine subsidence during the mining of Longwall 27. The drainage behaviour of Pools ETAS, ETAT and ETAU on the Eastern Tributary have not been impacted.

Within the performance measure reach of the Eastern Tributary, Metropolitan Coal will commence stream remediation at Pools ETAH, followed by ETAK. Stream remediation plans for Pools ETAH and ETAK are included in Attachment 1.

Indicative stream remediation plans have also been prepared for pools on the Eastern Tributary downstream of Pool ETAK and are included in Attachment 1. Metropolitan Coal will review, and where required, update the stream remediation plans of the pools proposed to be remediated after Pool ETAK (on a progressive basis).

While stream remediation plans have been prepared for the priority targets, Metropolitan Coal recognise that it may be necessary depending on the results of the progressive stream remediation to identify further areas for stream remediation.

Metropolitan Coal will provide the DPIE, Resources Regulator and WaterNSW with 14 days' notice of their intention to commence stream remediation activities at each pool/rock bar.

2.2.2 Upstream of the Reach Subject to the Eastern Tributary Performance Measure

Metropolitan Coal will conduct stream remediation at Pool ETO on the Eastern Tributary, which is situated immediately upstream of the Fire Road 9J. Metropolitan Coal will conduct stream remediation at Pool ETO prior to commencing remediation at Pools ETAH and ETAK. An indicative stream remediation plan has been prepared for Pool ETO on the Eastern Tributary and is provided in Attachment 1.

Metropolitan Coal recognise that it may be necessary depending on the results of the stream remediation described in Section 2.2.1 to identify further areas for stream remediation, including those upstream of the reach that is subject to the Eastern Tributary performance measure.

Metropolitan Coal will provide the DPIE, Resources Regulator and WaterNSW with 14 days' notice of their intention to commence stream remediation activities at rock bar ETO.

3 BASELINE DATA

3.1 VEGETATION AND ABORIGINAL HERITAGE INFORMATION

Baseline data of relevance to areas requiring stream remediation includes information relevant to pre-disturbance vegetation and Aboriginal heritage management.

3.1.1 Vegetation Management

Baseline information relevant to pre-disturbance vegetation management incudes:

- Vegetation community mapping by Bangalay Botanical Surveys (2008) and Eco Logical Australia (2015; 2016; 2018) (Figure 5).
- Threatened flora species recorded in the Project underground mining area and surrounds (Figure 6).
- Vegetation data and information included in the Project Environmental Assessment (Project EA) (Helensburgh Coal Pty Ltd [HCPL], 2008b).

3.1.2 Aboriginal Heritage Management

Baseline information relevant to pre-disturbance Aboriginal heritage management incudes:

- Known Aboriginal heritage sites recorded in the Project underground mining area and surrounds (Figure 7).
- Aboriginal heritage site data and baseline information described in the Metropolitan Coal Heritage Management Plan.
- Aboriginal heritage data and information included in the Project EA (HCPL, 2008b).

3.2 WARATAH RIVULET AND EASTERN TRIBUTARY WATERCOURSES

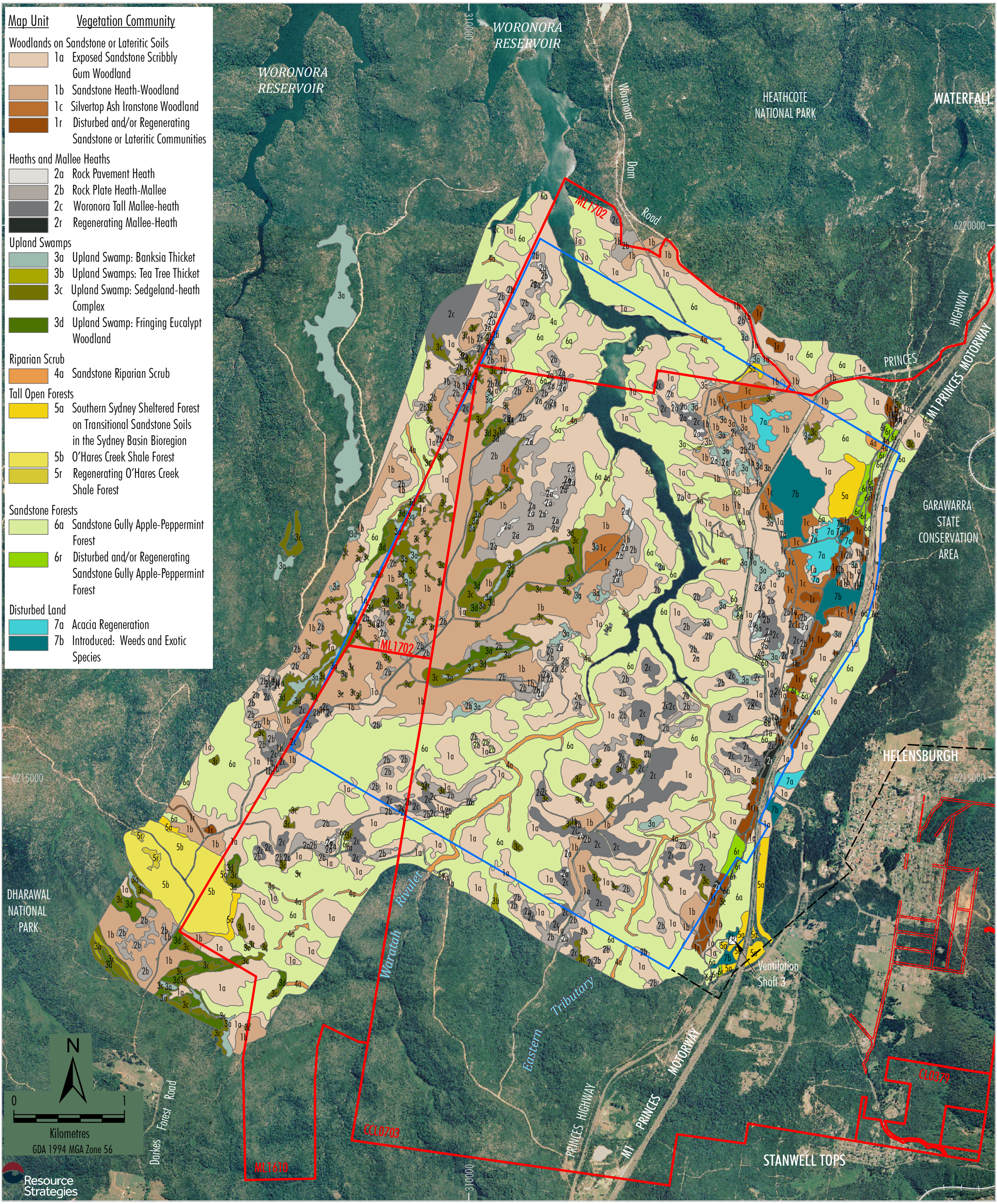
Baseline data of relevance to the stream remediation activities is described in Sections 3.2.1 to 3.2.5.

3.2.1 Stream Mapping

Prior to the commencement of Longwall 20, Mine Subsidence Engineering Consultants (MSEC) compiled a comprehensive survey and photographic record of the Waratah Rivulet (from Flat Rock Crossing to the Woronora Reservoir full supply level) and the Eastern Tributary (from the east-west headings to the Woronora Reservoir full supply level). The detailed mapping and photographic record of the Waratah Rivulet and Eastern Tributary is provided in Appendices 1 and 2 of the Metropolitan Coal Water Management Plan, respectively.

3.2.2 Photographic Records

Various photographic records are available for pools on the Waratah Rivulet and Eastern Tributary, including those taken by photographic surveys conducted in accordance with the Metropolitan Coal Water Management Plans.



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Existing Underground Access Drive (Main Drift)

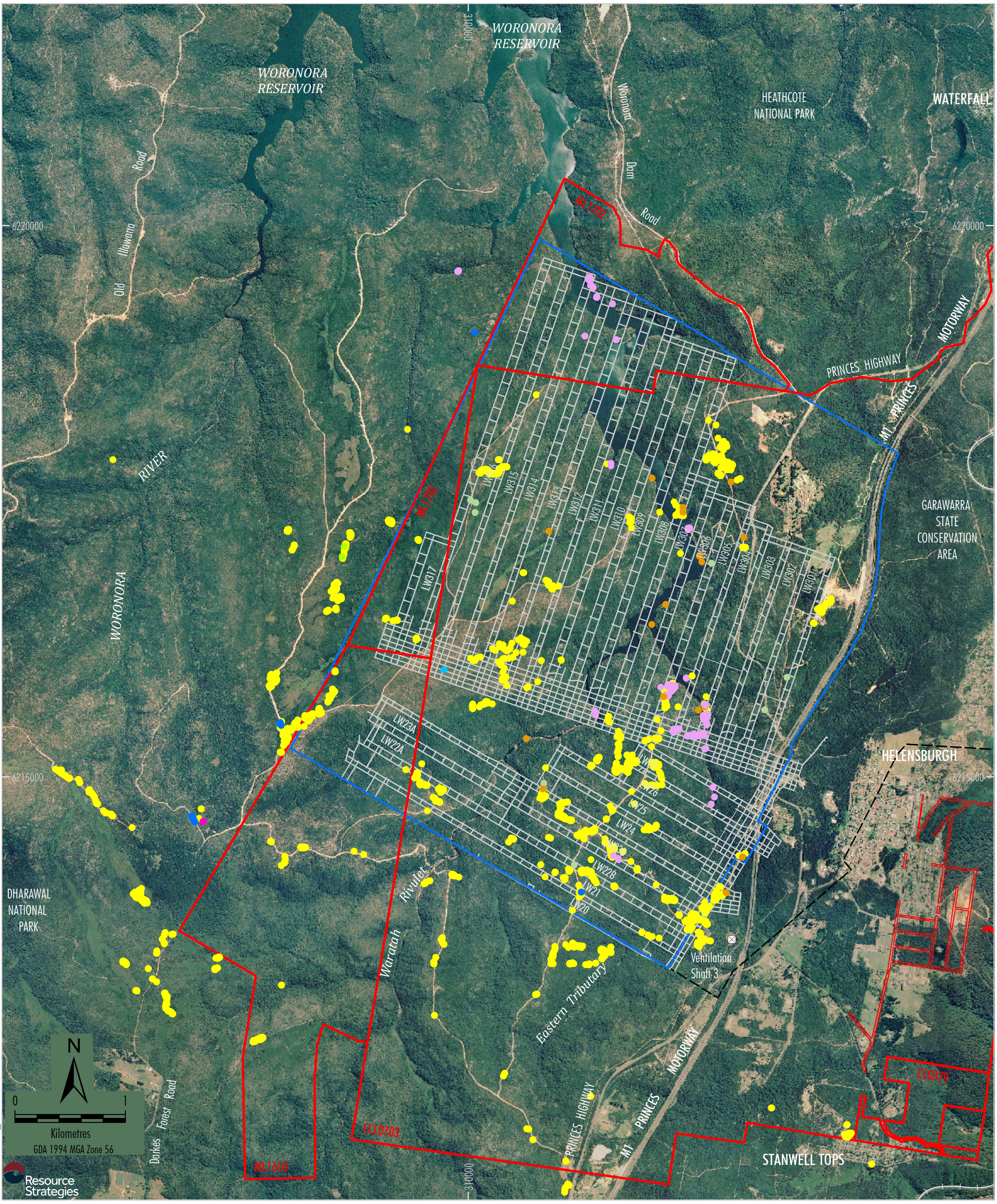
Note: The NSW Native Vegetation Interim Type Standard 2009 requires patches of vegetation to be mapped if the dimensions of the representative polygon on a map sheet are 2 mm x 2 mm or greater (i.e. 0.25 hectares or greater at a scale of 1:25,000). Eco Logical Australia conducted field inspections of upland swamp vegetation previously mapped by Bangalay Botanical Surveys (2008) overlying or proximal to Longwalls 301-310 to confirm the upland swamp vegetation communities present and to confirm or update the swamp vegetation boundaries. It is noted that the revised boundaries of a number of upland swamps (Swamps 37, 38, 42, 48, 54, 58, 61, 63, 65/66, 67, 68a, 68b, 70, 73, 83, 86 and 88) are less than 0.25 hectares in area and consistent with NSW vegetation mapping guidelines are not required to be mapped. Notwithstanding, the revised swamp vegetation mapping boundaries (including those swamps less than 0.25 hectares in area) are shown on this figure to document the changes to previous vegetation mapping.

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2019); after NPWS (2003), Bangalay Botanical Surveys (2008) and Eco Logical Australia (2015; 2016; 2018)

Peabody
METROPOLITAN COAL

Mapped Vegetation Communities Within the Project Underground Mining Area and Surrounds

Figure 5



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Existing Underground Access Drive (Main Drift)

Confirmed Threatened Species

- *Astrotricha crassifolia*
- *Acacia bynoeana*
- *Acacia baueri* subsp. *aspera*
- *Melaleuca deanei*
- *Pultenaea aristata*
- *Cryptostylis hunteriana*

Potential (Unconfirmed) Threatened Species

- *Epacris purpurascens* var. *purpurascens*
- *Leucopogon exolasius*

Notes 1. Includes threatened species records up to and including the Autumn 2018 surveys.
2. Each symbol is indicative of a specific location rather than the number of individuals of each species.

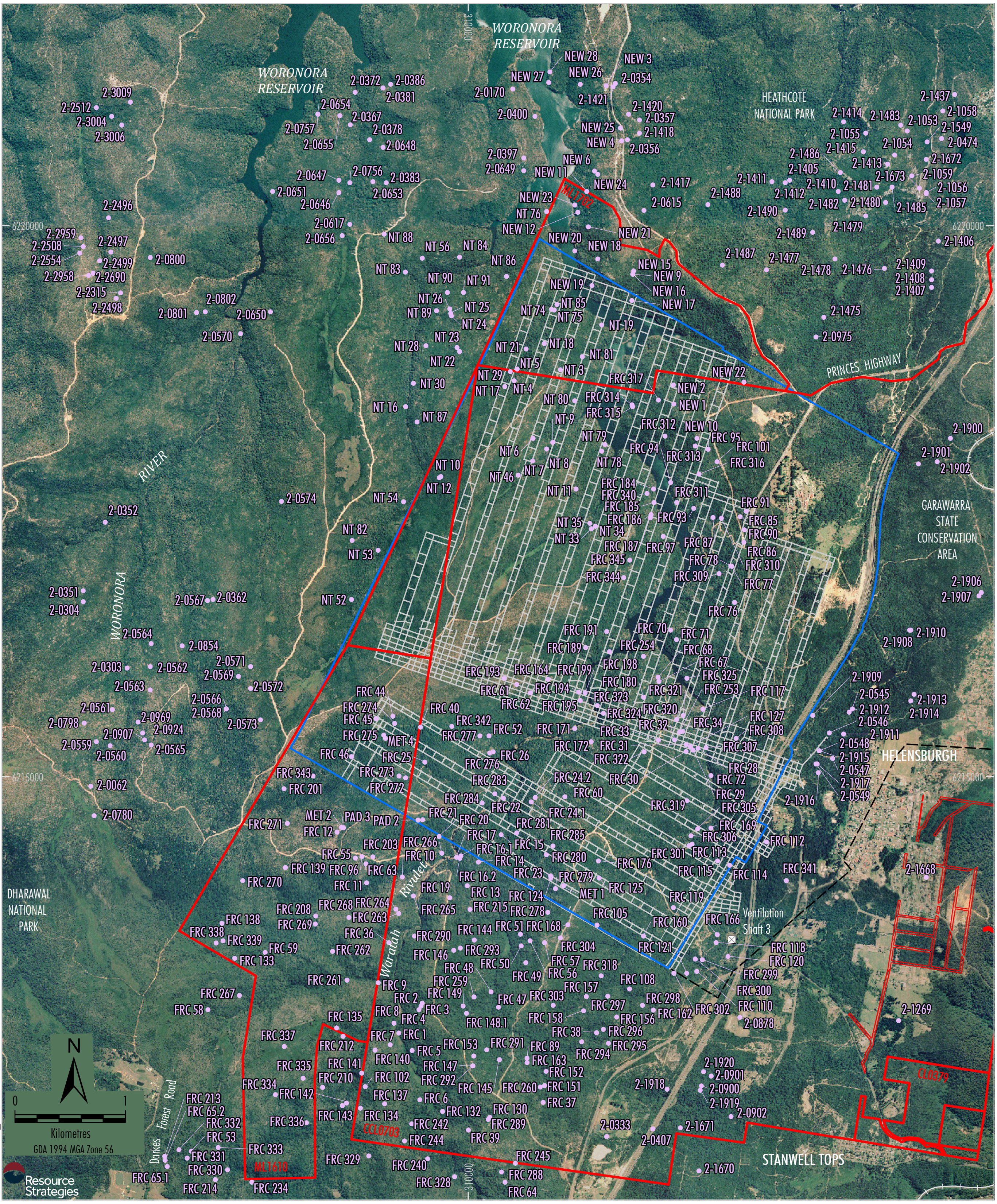
Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2019); Threatened species recorded by Bangalay Botanical Surveys (2008); FloraSearch (2008, 2009); Eco Logical (2010-2018)

METROPOLITAN COAL

Threatened Flora Recorded During Metropolitan Coal Surveys

Figure 6

MET-15-10 SRP 2021_210A



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Existing Underground Access Drive (Main Drift)
- Aboriginal Heritage Site

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2019); Illawarra Prehistory Group (2007; 2008); AHIMS (2007); Kayandel Archaeological Services (2006; 2007; 2008); Niche Environment and Heritage (2013)

Peabody

METROPOLITAN COAL

Known Aboriginal Heritage Sites Within Project Underground Mining Area and Surrounds

Figure 7

3.2.3 Rainfall

Regional and local meteorological data is available from the Bureau of Meteorology (BoM) weather stations at Lucas Heights (Station Number 66078), Woronora Dam (Station Number 68070), Darkes Forest (Station Number 68024), and 'Reverces' (Station Number 568069) (Table 1). Rainfall data is also available from Metropolitan Coal pluviometers situated in the Waratah Rivulet catchment (site PV1), Woronora River catchment (site PV2), Honeysuckle Creek catchment (site PV5), Waratah Rivulet catchment (site PV6), Eastern Tributary catchment (site PV7) and Woronora Reservoir catchment (site PV8) (Table 1 and Figure 8).

Evaporation data is available from the WaterNSW station at the Woronora Reservoir (566052) (Table 1) and the Metropolitan Coal evaporimeter within the Waratah Rivulet catchment, at site PV1 (Table 1 and Figure 8).

The pluviometers situated in the Waratah Rivulet, Eastern Tributary and Woronora River catchments are of particular relevance to this Stream Remediation Plan.

3.2.4 Surface Water Flow

Surface water flow data relevant to this Stream Remediation Plan is available for the gauging stations listed in Table 2. The locations of the Waratah Rivulet (GS 2132102), Woronora River (GS 2132101), Eastern Tributary (GS 300078), Honeysuckle Creek (GS 300077) Sub-catchment I (GS 300092) and Sub-catchment K (GS 300093) gauging stations are shown on Figure 9. Surface water flow data is available from WaterNSW for the gauging stations on O'Hares Creek: an upstream gauging station at Darkes Forest (GS 213002) and a downstream gauging station near the town of Wedderburn (GS 213200). The O'Hares Creek catchment is located immediately south and west of the Woronora Dam catchment. Longwall mining occurred in the catchment of the Wedderburn gauging station (GS 213200) in 1986 to 1987 and 1990 to 1999.

3.2.5 Pool Water Levels and Downstream Controls

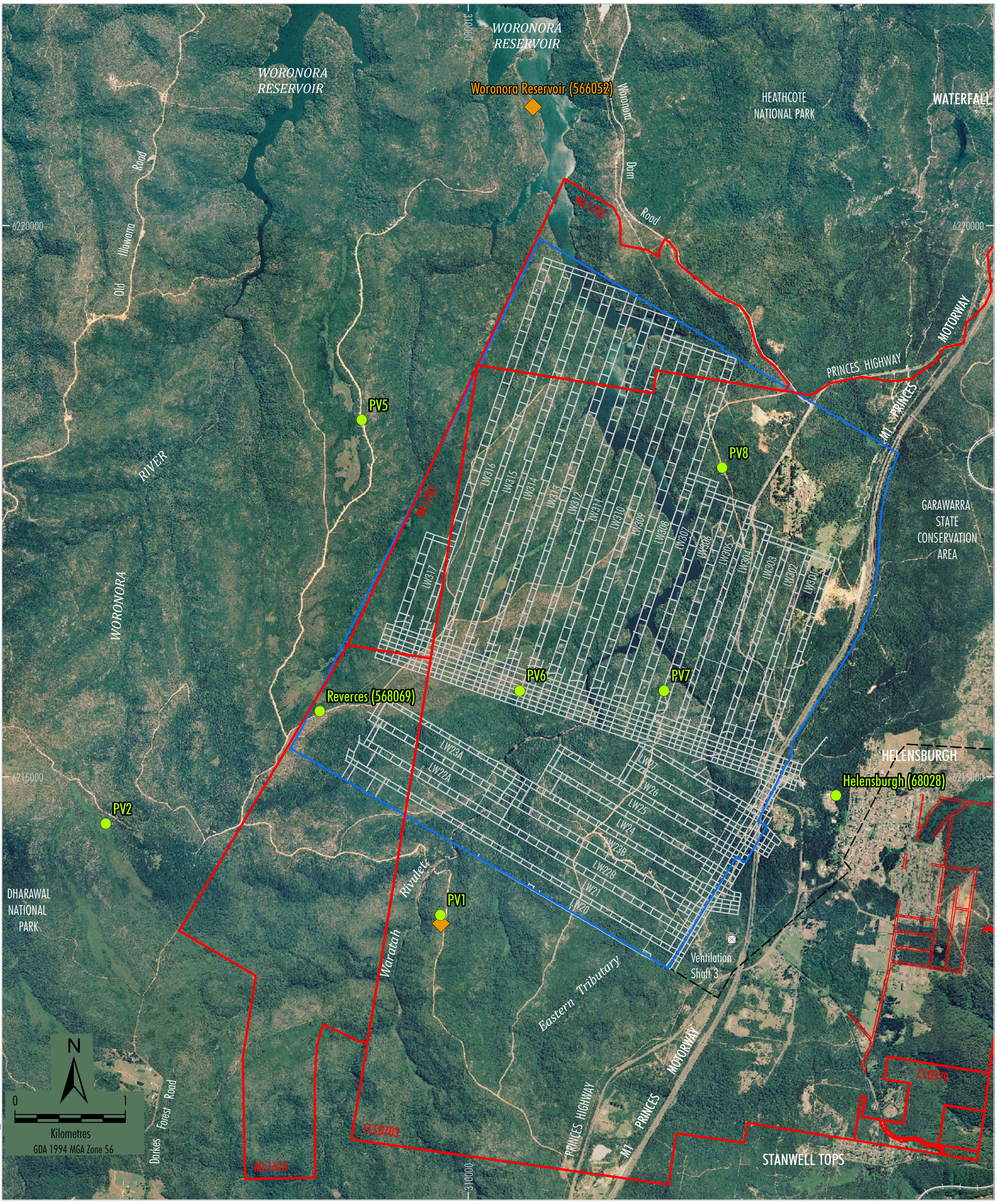
This pool water level data available for Pools A to W on the Waratah Rivulet, Pools ETAG to ETAU on the Eastern Tributary and Pools WRP1 to WRP4 on the Woronora River is summarised in Table 3.

The approximate locations of the pools are shown on Figure 9. Pools and rock bars along the Waratah Rivulet and Eastern Tributary are shown on the detailed mapping and photographs provided in Appendices 1 to 2 of the Metropolitan Coal Water Management Plan.

Water levels in pools are either manually monitored or monitored using a continuous water level sensor and data logger (Table 3).

Pool water levels are controlled by different forms of natural controls with different hydraulic characteristics. Conceptually, these can be grouped into the following three types (Hydro Engineering & Consulting, 2018a):

- an 'effectively impermeable' rock-bar control with limited continuous jointing and fracturing resulting in negligible flow either through or under the rock-bar;
- a 'permeable' rock-bar control where the presence of fractures and open joints in the rock-bar permits significant flow through or under the rock-bar; and
- a boulder field which constricts downstream flow but where a significant flow occurs through the interstices between the boulder rock elements (i.e. braided flow).



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Existing Underground Access Drive (Main Drift)
- Evaporimeter
- Pluviometer

Notes:
1. The Bureau of Meteorology pluviometer at Darkes Forest (68024) is not shown. It is located approximately 3.75 km south of the Metropolitan Coal pluviometer (PV2).
2. The Bureau of Meteorology pluviometer at Lucas Heights (66078) is not shown. It is located approximately 12.5 km north of the Metropolitan Coal pluviometer (PV8).

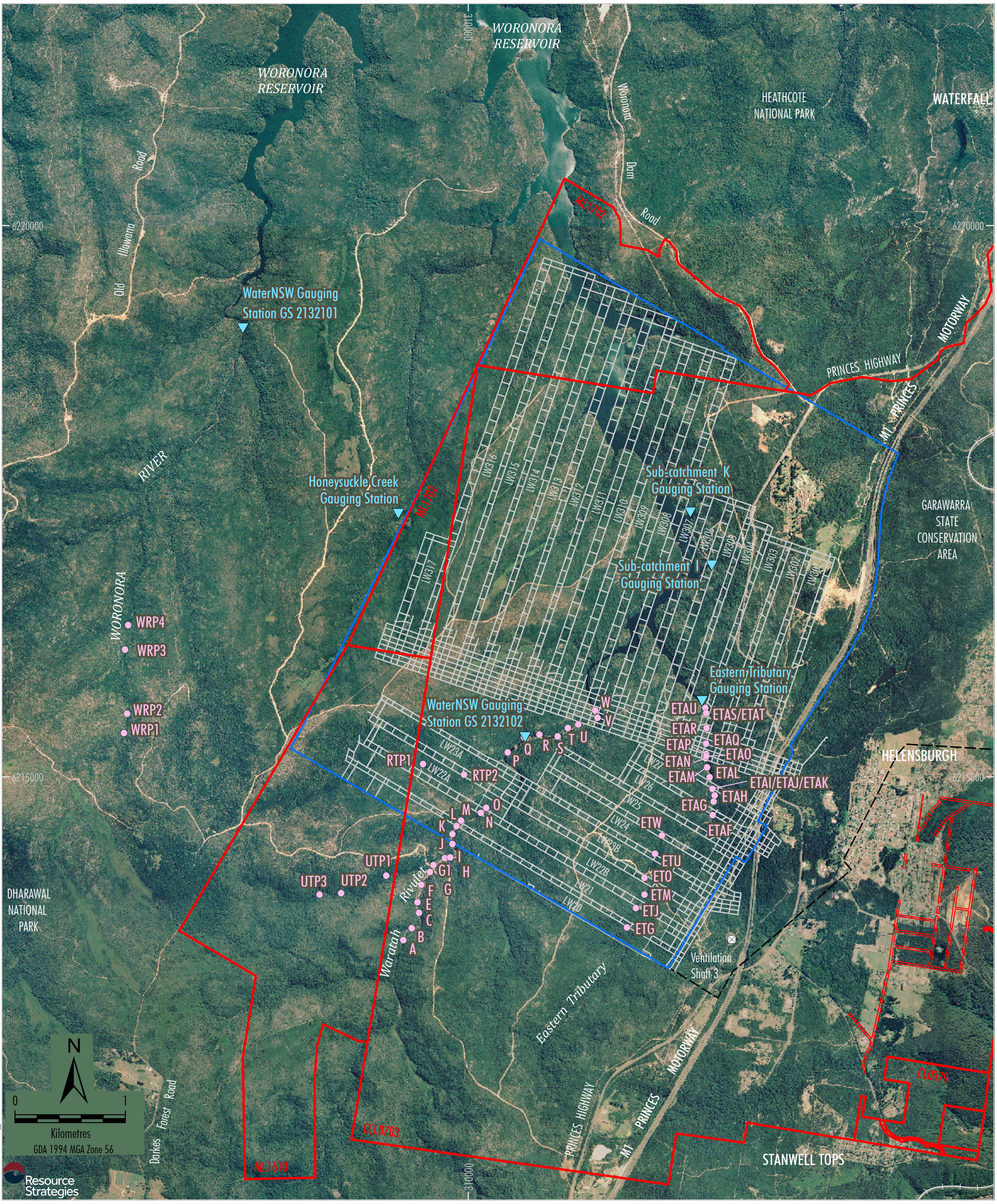
Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2019)

Peabody

METROPOLITAN COAL

Meteorological Sites

Figure 8



LEGEND
- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Existing Underground Access Drive (Main Drift)
- Gauging Station
- Pool Water Level Site

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2019)

Peabody
METROPOLITAN COAL

Surface Water Quantity Sites

Figure 9

Table 1
Meteorological Monitoring Station Locations and Recording Periods

Station Number	Data Type	Period of Record
Lucas Heights (BoM Station Number 66078)	Rainfall (daily read prior to pluviometer installation)	1958 to present
	Rainfall intensity	1958 to 1982, 1997 to present
	Evaporation	1979 to 1982
	Air temperature, wet bulb temperature, barometric pressure, humidity, cloud cover, wind speed, wind direction	1962 to 1982
Darkes Forest (BoM Station Number 68024)	Rainfall (BoM daily read converted to pluviometer)	1894 to present
Woronora Dam (BoM Station Number 68070, WaterNSW Station 566052)	Rainfall (BoM and WaterNSW daily read)	1927 to present
'Reverces' (BoM Station Number 568069)	Rainfall (pluviometer)	2000 to present
Waratah Rivulet (site PV1)	Rainfall (Metropolitan Coal pluviometer)	2006 to present
	Evaporation data (Metropolitan Coal evaporimeter)	2010 to present
Woronora River (site PV2)	Rainfall (Metropolitan Coal pluviometer)	2007 to present
Woronora Reservoir (WaterNSW station 566052)	Evaporation data	1976 to present
Honeysuckle Creek (site PV5)	Rainfall (Metropolitan Coal pluviometer)	2010 to present
Waratah Rivulet (site PV6)	Rainfall (Metropolitan Coal pluviometer)	2010 to present
Eastern Tributary (site PV7)	Rainfall (Metropolitan Coal pluviometer)	2010 to present
Woronora Reservoir catchment (site PV8)	Rainfall (Metropolitan Coal pluviometer)	January 2018 to present

Table 2
Gauging Station Locations and Recording Periods

Station Number	Watercourse	Catchment Area (km^2)	Period of Record
WaterNSW (GS 2132102)	Waratah Rivulet, upstream of the Woronora Reservoir full supply level	20.2	February 2007 to present
WaterNSW (GS 2132101)[1]	Woronora River, upstream of the Woronora Reservoir full supply level	12.4	February 2007 to present
WaterNSW (GS 213002)	O'Hares Creek at Darkes Forest	16	1924 to 1930
WaterNSW (GS 213200)	O'Hares Creek at Wedderburn	73	1978 to present
Metropolitan Coal (GS 300078)	Eastern Tributary, upstream of the Woronora Reservoir full supply level	6.7	January 2013 to present
Metropolitan Coal (GS 300077)	Honeysuckle Creek (control site)	4.6	January 2013 to present
Sub-catchment I (GS 300092)	A tributary of the Woronora Reservoir	0.33	May 2018 to present
Sub-catchment K (GS 300093)	A tributary of the Woronora Reservoir	0.27	May 2018 to present

1 Note, the Woronora River gauging station (GS 2132101) contains periods of missing data.

The downstream control of each pool is provided in Table 3.

In addition, a pool water level meter will be installed in Pool ETO, which is located on the Eastern Tributary upstream of the performance measure reach and will be subject to stream remediation.

Table 3
Data Availability and Downstream Controls for Pools A to W on the Waratah Rivulet, Pools ETAG to ETAU on the Eastern Tributary and Pools WRP1 to WRP4 on the Woronora River

Pool	Data Type	Commencement Date[1]	Downstream Control
WARATAH RIVULET			
A	Manual water level measurements Water level meter	20/09/2005 January 2010	Effectively impermeable rock bar
B	Manual water level measurements	20/09/2005	Effectively impermeable rock bar
C	Manual water level measurements	20/09/2005	Effectively impermeable rock bar
E	Manual water level measurements	20/09/2005	Effectively impermeable rock bar
F	Manual water level measurements Water level meter	20/09/2005 1 January 2010	Effectively impermeable rock bar
G	Manual water level measurements	20/09/2005	Effectively impermeable rock bar
G1	Manual water level measurements	13/10/2005	Effectively impermeable rock bar
H	Manual water level measurements	11/10/2005	Effectively impermeable rock bar
I	Manual water level measurements	11/10/2005	Effectively impermeable rock bar
J	Water level meter	03/04/2007	Effectively impermeable rock bar
K	Water level meter	13/05/2010	Effectively impermeable rock bar
L	Water level meter	11/12/2008	Effectively impermeable rock bar
M	Water level meter	11/12/2008	Effectively impermeable rock bar
N	Water level meter	11/12/2008[2]	Effectively impermeable rock bar
O	Water level meter	11/12/2008	Boulder field
P	Water level meter	11/12/2008	Permeable rock bar
Q	Water level meter	20/02/2007	Effectively impermeable rock bar
R	Water level meter	11/12/2008	Effectively impermeable rock bar
S	Water level meter	11/12/2008	Effectively impermeable rock bar
T	Water level meter	20/1/2010	Permeable rock bar
U	Water level meter	20/1/2010	Boulder field
V	Water level meter	20/1/2010	Permeable rock bar
W	Water level meter	20/1/2010	Boulder field
EASTERN TRIBUTARY			
ETAG	Water level meter	12/11/2010	Boulder field
ETAH	Water level meter	19/01/2011	Permeable rock bar
ETAI ETAJ ETAK	Water level meter[3]	19/01/2011	Rock bar
ETAL	Water level meter	03/10/2018	Boulder field

Table 3 (Continued)
Data Availability and Downstream Controls for Pools A to W on the Waratah Rivulet, Pools ETAG to ETAU on the Eastern Tributary and Pools WRP1 to WRP4 on the Woronora River

Pool	Data Type	Commencement Date[1]	Downstream Control
EASTERN TRIBUTARY (Continued)			
ETAM	Water level meter	03/10/2018	Boulder field
ETAN	Water level meter	03/10/2018	Rock bar
ETAO	Water level meter	03/10/2018	Rock bar
ETAP	Water level meter	03/10/2018	Boulder field
ETAQ	Water level meter	17/01/2011	Effectively impermeable rock bar
ETAR	Water level meter	03/10/2018	Rock bar
ETAS	Water level meter[4]	24/5/2018	Permeable rock bar
ETAT			Effectively impermeable rock bar
ETAU	Water level meter	23/9/2012	Concrete weir/flume
WORONORA RIVER[5]			
WRP1	Woronora River (Control Site)	1/1/2016	Rock bar
WRP2	Woronora River (Control Site)	1/1/2016	Permeable Rock bar
WRP3	Woronora River (Control Site)	1/1/2016	Rock bar
WRP4	Woronora River (Control Site)	1/1/2016	Permeable Rock bar

Notes:

1 The dates provided represent the dates from which pool water level monitoring commenced, however, some of the data is known to be unreliable and could not be used for the assessment of pre-impact behaviour.

2 Data from 11 December 2008 contains periods of missing data and periods where data is considered to be largely unreliable due to sensor error/instability.

3 Only small rock bars separate Pools ETAI, ETAJ and ETAK. Pools join to become the one large pool. Pool ETAK is controlled by a rock bar. The water level meter is situated in Pool ETAI.

4 Due to the nature of rock bar ETAS, Pool ETAS and Pool ETAT typically sit at the same level.

5 Pool water level data for the Woronora River pools prior to January 2016 is considered to be largely unreliable as a result of water level sensor issues.

4 STREAM REMEDIATION MEASURES

This section describes the measures that will be implemented to remediate impacts associated with subsidence impacts on stream pools and rock bars.

Stream remediation measures will be implemented, as appropriate, to comply with the relevant statutory requirements and the Project rehabilitation objectives.

Sections 4.1 and 4.2 describe the vegetation and Aboriginal heritage management measures that will be implemented at a stream remediation site prior to the commencement of remediation activities.

Section 4.3 describes the fracture characterisation activities that will be implemented at rock bars requiring remediation and Section 4.4 describes the stream grouting techniques that will be used.

Section 4.5 describes the site layout of stream remediation activities at each rock bar and Section 4.6 describes the environmental management measures that will be implemented during the conduct of the stream remediation activities.

4.1 PRE-DISTURBANCE VEGETATION MANAGEMENT

Vegetation clearance activities (i.e. the removal, lopping or slashing of vegetation) may be required for stream remediation activities. Management measures will be implemented at sites where vegetation clearance is necessary. The vegetation management of proposed stream remediation sites is described below.

Threatened Flora Surveys

Prior to disturbance, surveys for threatened flora species will be conducted within the proposed stream remediation area. Works will be relocated, where feasible, to avoid or minimise impacts on any threatened species population.

In the event field inspections identify individuals of a threatened flora species within a proposed stream remediation area that are not practicable to avoid, the potential impacts of the proposed works on the population of the threatened flora species will be assessed by a suitably qualified and experienced ecologist.

In the event the proposed stream remediation activities are considered likely to have a significant impact on a population of the threatened species listed under the *Biodiversity Conservation Act, 2016* or *Environment Protection and Biodiversity Conservation Act, 1999*, the proposed works will be modified to avoid such an outcome.

It is anticipated that the majority of activities will be able to avoid disturbance to individuals of a threatened flora species.

Site Inspection

An inspection of the proposed stream remediation area will be conducted to identify management measures to be implemented to minimise impacts on flora, prior to, during and/or following the completion of the stream remediation works. Potential management measures include:

- Restricting vegetation clearance to the slashing of vegetation (i.e. leaving the lower stem and roots *in-situ* to maximise the potential for natural regrowth), rather than the removal of trees.
- Lopping of branches, rather than the removal of trees.
- The use of existing fire trails to access sites to minimise the disturbance of soils.
- Limiting the amount of soil disturbance to the minimum required for the mobilisation, placement and operation of equipment and for maintaining access to equipment.
- The use of rubber lattice matting or other measures to delineate work areas and to minimise disturbance to soils and vegetation.
- Identification of specific management measures to minimise impacts on terrestrial fauna and their habitats (e.g. avoiding the removal of trees or branches containing hollows, the placement of lopped branches in the general vicinity etc.).
- Identification of specific rehabilitation measures (e.g. placing stockpiled vegetative material over cleared areas to encourage natural regeneration).

Final Site Selection and Works Design

The results of the surveys/assessments will be used to inform final site selection and works design to minimise the amount of vegetation clearance required.

4.2 PRE-DISTURBANCE ABORIGINAL HERITAGE MANAGEMENT

Pre-Clearance Surveys

In accordance with the Metropolitan Coal Heritage Management Plan, pre-clearance surveys will be undertaken to identify the most appropriate location for stream remediation activities. Pre-clearance surveys will involve the following:

1. Developing an inventory of surface infrastructure and conducting an initial desktop risk assessment based on the location of known sites.
2. Undertaking a pre-clearance survey of the proposed stream remediation site(s).
3. Assessing potential impacts to nearby Aboriginal heritage site(s) based on the results of the pre-clearance surveys and determining the most appropriate location for stream remediation activities.
4. Where practicable, stream remediation activities will be located so as to avoid or minimise impacts to Aboriginal heritage sites. If impacts cannot be avoided, appropriate management and/or mitigation measures will be undertaken in accordance with the Metropolitan Coal Heritage Management Plan.

Where Aboriginal heritage sites are located close to required stream remediation works, the surface disturbance protocol described below will be conducted.

Surface Disturbance Protocol

The surface disturbance protocol aims to avoid accidental damage to Aboriginal heritage sites located close to surface disturbance works. As described above, pre-clearance surveys will be undertaken to identify the most appropriate location for stream remediation activities.

This protocol will apply to surface disturbance works (e.g. exploration works, installation/operation/ maintenance of surface infrastructure, construction/maintenance of access tracks, monitoring and stream restoration) proposed to be located close to any known Aboriginal heritage site(s).

Stream remediation activities will be undertaken in consideration of the following:

1. Avoidance of impact to Aboriginal heritage sites will be the primary management measure, where practicable.
2. To avoid accidental damage to Aboriginal heritage sites located close to stream remediation activities works, appropriate demarcation will be implemented (e.g. fencing, sign-posting or temporary flagging).
3. Where avoidance is not practicable, a comprehensive baseline record will be developed and consideration of salvage will be undertaken in consultation with Aboriginal stakeholders prior to disturbance.

Recording and Registering New Aboriginal Heritage Sites

Any previously unrecorded Aboriginal heritage sites identified during fieldwork (e.g. pre-clearance surveys) will be recorded using the standard BCD site card. This information will be submitted to the BCD for registration on the BCD Aboriginal Heritage Information Management System (AHIMS) database. Any previously unrecorded sites will also be subject to archaeological and cultural significance assessment, in consultation with Aboriginal stakeholders. Any previously unrecorded sites will be managed in accordance with the requirements of the Metropolitan Coal Heritage Management Plan.

Aboriginal Stakeholder Participation

The number of participants in an effective field team is governed by a number of safety, logistic and access considerations, including:

- **Safety:** a large group can be difficult to keep together when moving through dense vegetation in steep terrain. Large groups move slowly (especially through dense vegetation and in steep terrain) and can prevent a rapid response (i.e. evacuation) to imminent dangers that can often be encountered (e.g. bush fire warnings and electrical storms).
- **Logistics:** Participant numbers are limited by vehicle availability and safety restrictions. The remote nature of the area requires the use of vehicles for efficient field work.
- **Access Restrictions:** The area is within a WaterNSW Schedule One special area. Public access is controlled in this area to protect water quality and ecological integrity (WaterNSW and Office of Environment & Heritage [OEH], 2015). Excessive access into this area is not consistent with the *Special Areas Strategic Plan of Management 2015* (WaterNSW and OEH, 2015).

Aboriginal stakeholders will be invited to attend relevant scheduled fieldwork in consideration of the above and also in accordance with relevant BCD consultation guidelines. In accordance with the Metropolitan Coal Heritage Management Plan, scheduled fieldwork to which Aboriginal stakeholders will be invited to attend includes:

- Aboriginal heritage monitoring;
- supplementary fieldwork and pre-clearance surveys; and
- the planning for and/or implementation of management and mitigation measures.

Invitations to attend scheduled fieldwork will be provided in writing with at least five business days' notice. Dates for undertaking fieldwork will be subject to consultation with Aboriginal stakeholders and archaeologists. Prior to undertaking fieldwork, all participating Aboriginal stakeholders and archaeologists will be required to comply with Metropolitan Coal's workplace health and safety requirements. These requirements include the provision of copies of current relevant insurances (i.e. public liability and workers compensation) and appropriate personal protection equipment.
All Metropolitan Coal staff and contractors (including Aboriginal stakeholders and archaeologists) may be subject to random drug and alcohol testing. All Metropolitan Coal staff and contractors (including Aboriginal stakeholders and archaeologists) must be able bodied and fit to undertake the work required.

Metropolitan Coal will maintain a consultation log to record all correspondence with Aboriginal stakeholders (e.g. emails, telephone calls, letters, meeting minutes, etc.).

Aboriginal stakeholders will be invited to comment on relevant draft documentation regarding the management of Aboriginal cultural heritage, if and when required.

4.3 FRACTURE CHARACTERISATION

Fracture characterisation activities will be conducted to measure the depth and lateral extent of the sub-surface fracture network at each rock bar requiring stream remediation, extending up to 20 metres (m) up the bank of the watercourse. Fracture characterisation activities will include the drilling of cored holes to a depth of approximately 20 m, or to 5 m below the deepest identified fracture, whichever is deeper, to:

- determine the depth of fracturing;
- measure the relative volume of fine versus large void spaces; and
- determine the horizontal connectivity between fractures.

A borehole calliper will be used to identify the location of individual fractures intersecting the drill holes.

The stream remediation plans provided in Attachment 1 provide the indicative location of the fracture characterisation activities at the Waratah Rivulet rock bars (F, G, G1, H, I, J, L and N) and the Eastern Tributary rock bars (ETO, ETAH, ETAK, ETAL, ETAM, ETAN, ETAP, ETAQ and ETAR). The number and location of fracture characterisation holes may vary during the conduct of the stream remediation activities in consideration of ground and flow conditions, as well as the findings of the pre-clearance surveys.

4.4 STREAM GROUTING TECHNIQUES

The principal management measure that will be used to restore surface flow and pool holding capacity is the injection of polyurethane (PUR) grouting products into the fracture network. The grouting product that will be used in the remediation activities is Spetec H100, which is a single component, inert, potable water compatible product used for consolidation, stabilisation and/or sealing of strata. A desktop risk assessment review of Spetec H100 has been prepared by Dr Barry Noller of the Centre for Mined Land Rehabilitation. The review is provided as Attachment 2.

The injection of PUR grout reduces the permeability of the overall rock mass by filling voids and thereby reducing sub-surface flow pathways. PUR grout injection of rock bars will commence with shallow pattern grouting which is the drilling of shallow holes using small hand-held drilling equipment and low pressure injection of a PUR grout. A grout curtain may then be constructed across a rock bar by drilling a line of holes at regular intervals (approximately 2 m) and progressively injecting PUR at a range of depths (approximately 20 m to surface).

Other potential stream remediation techniques and their possible application to different situations include:

- Hand grouting – the sealing of cracks exposed on the surface using hand applicators.
- Shallow pattern grouting – drilling shallow holes using small hand-held drilling equipment and low pressure injection of a grout using a portable pump.
- Deep pattern or curtain grouting – drilling deeper holes using traditional air and or reverse circulation drilling rigs. Higher pressure grouting techniques can also be used.
- Deep angle hole cement grouting – remote directional drilling techniques can be used to access otherwise inaccessible sites. The same grouting methods as deep pattern/curtain grouting outlined above can be used.

The full range of available techniques will be considered in the design of stream remediation programs for individual rock bars.

The Stream Remediation Plan currently includes management measures applicable to the use of PUR grouting products. In the event an alternative stream remediation technique is proposed to be used, the Stream Remediation Plan will be revised in consultation with the DPIE, Resources Regulator, WaterNSW, BCD and DPI – Fisheries.

4.5 SITE LAYOUT

The remediation activities will primarily involve the drilling of holes and injection of grout into sub-surface fractures. Associated activities include the mobilisation, placement and operation of equipment and the implementation of a variety of environmental management measures.

The plans included in Attachment 1 for Waratah Rivulet rock bars (F, G, G1, H, I, J, L and N) and Eastern Tributary rock bars (ETO, ETAH, ETAK, ETAL, ETAM, ETAN, ETAP, ETAQ and ETAR) illustrate the indicative location of the grout injection zone, as well as the approximate positioning of major equipment and controls. Adjustments may be made to the site layout in consideration of ground and flow conditions as well as the findings of the pre-clearance surveys.

Drilling equipment will range from diesel-operated rubber tracked minidrill rig, man portable drill rig and hand operated rock drills. Injection equipment will include a pneumatic PUR injection pump, portable air compressor, grout injection hoses, grout header, injection tubes and inflatable packers. A temporary shelter may also be erected at the injection site and/or pump site to provide personnel with shelter.

The plans included in Attachment 1 also show the approximate location of equipment for drilling and grout injection activities. The positioning of some equipment (such as the drill rig, compressed air pumps, hoses, bunded pumps, first aid kits etc.) will change during the conduct of activities. The environmental controls pertaining to the drilling location will be moved according to the change in the position of the drilling and grouting injection activities.

To further improve flow over the rock bar, targeted shallow holes may also be drilled and injected with grout across the broader streambed area (i.e. outside the grout injection zones illustrated in Attachment 1), These works would target shallow fractures and would be carried out using man portable drill rig and/or hand operated rock drills.

Barriers (i.e. tape) will be erected at access points to the remediation area to establish the area as a restricted entry area. All non-essential personnel will be restricted from the injection area during the pumping process.

Access to rock bars and pools on the Waratah Rivulet between Pool G and Pool O by Metropolitan Coal personnel and contractors will be via a single track along the Waratah Rivulet. Access to the drilling and grout injection work area for track mounted machinery (drill rig and mini tipper) may occur along areas of exposed rock outcrop within the bed of the Waratah Rivulet. Where sudden changes in bed level occur, access will be facilitated by use of temporary steel ramps or sand bags as necessary. Rubber track or lattice matting will also be used in areas to minimise impacts. A helicopter may be used to access areas/deliver drilling equipment not accessible by tramming the drill rig. Equipment that is unable to be carried in by hand (e.g. settling tanks, drill rig etc.) will be transported by helicopter to the remediation site. Remediation activities at Pools L and N (should they be required) will also involve the placement (and checking) of delivery hoses from the pumping station located on Fire Road 9C to the remediation site.

Access to the Pool ETO rock bar on the Eastern Tributary by Metropolitan Coal personnel and contractors will be via Fire Trail 9J. Access to rock bars and pools on the Eastern Tributary at Pools ETAG and ETAR by Metropolitan Coal personnel and contractors will be via a single track along the Eastern Tributary and connecting to a temporary laydown area at the fire road parallel to the M1 Princes Motorway. Access to the drilling and grout injection work area for track mounted machinery drill rig may occur along areas of exposed rock outcrop within the bed of the Eastern Tributary at Fire Road 9J. Rubber track or lattice matting will also be used in areas to minimise impacts. Remediation activities at Pools ETO, ETAH, ETAI, ETAJ, ETAK, ETAL, ETAM, ETAN, ETAO, ETAP, ETAQ and ETAR will also involve the placement (and checking) of delivery hoses from the pumping stations to the remediation site. While it is not anticipated to be necessary for the Eastern Tributary stream remediation activities, a helicopter may be used to deliver materials and equipment to the stream remediation site.

Checks relevant to site layout will be conducted, similar to the example Activity Checklists provided in Attachment 3. The example Activity Checklists provided in Attachment 3 have been developed for stream remediation activities at the Waratah Rivulet Pool G rock bar.

4.6 ENVIRONMENTAL MANAGEMENT MEASURES

A range of environmental management measures will be implemented during the conduct of stream remediation works including:

- management of any soil and vegetation disturbance;
- erosion and sediment controls to minimise the potential for any downstream effects; stream flow diversion and reduction of sub-surface flows during the application of PUR grouting products;
- drill cuttings containment and disposal;
- fuel management;
- management of grouting products and injection operations;
- waste management; and
- transport and handling of equipment and materials.

These environmental management measures are described in detail in Sections 4.6.1 to 4.6.10.

4.6.1 Soil and Vegetation Management

The disturbance of soils will be limited to the minimum required for the mobilisation, placement and operation of the drilling and injection equipment and for maintaining access to equipment.

Where possible, existing fire trails will be utilised for the siting/delivery of equipment and for access to remediation sites. The positioning of equipment and controls will be site specific, with indicative locations detailed in Attachment 1 for each rock bar that is anticipated to require stream remediation works.

Vegetation disturbance will be kept to a practical minimum. To minimise impacts on terrestrial vegetation, vegetation clearance will generally be restricted to the slashing of vegetation (i.e. leaving the lower stem and roots *in-situ* to maximise the potential for re-growth) and lopping of branches, where practicable, rather than the removal of trees. Any lopped branches will be left on the site in a random pattern. Rubber lattice matting will be used to minimise vegetation disturbance in high traffic areas.

Vehicles and equipment will be maintained to suitable standards to minimise the risk of the introduction of weeds. Weed control measures will be implemented where required.

A checklist of tasks relating to the implementation of soil and vegetation management measures will be completed on a regular basis similar to the example Environment Checklist provided in Attachment 3.

4.6.2 Erosion and Sediment Control

An Erosion and Sediment Control Plan will be developed for each stream remediation site, similar to the example provided in Attachment 4 for stream remediation activities at the Pool G rock bar. The Site Supervisor will oversee the implementation of the Erosion and Sediment Control Plan and will have authority to cease drilling or injection activities if erosion or sediment controls are not working effectively.

A checklist of tasks relating to the implementation of erosion and sediment control measures will be completed on a regular basis similar to the example Environment Checklist provided in Attachment 3.

4.6.3 Drilling Method, Drill Cuttings Containment and Disposal of Drill Core

Drill holes will be drilled during forecast dry weather, where practicable. Only cored holes will be drilled for boreholes of depths greater than 2 m of where surface water is present or groundwater is encountered. Water or air will be used to clear the fine drill cuttings from the holes.

Drill core will temporarily be stored in drill core trays high on the bank of the stream in an elevated equipment storage area. The drill core trays will be removed from the site at the completion of the remediation activities.

A checklist of tasks relating to drill core management will be completed on a regular basis, similar to the example Environment Checklist provided in Attachment 3. As described in Section 4.6.2 and Attachment 3, the Site Supervisor will also conduct checks relevant to erosion and sediment control.

4.6.4 Stream Flow Diversion and Reduction of Sub-Surface Flows

The objective of stream flow diversion is to divert as much water as practicable from the sub-surface fracture network if required. If pumping cannot reduce sub-surface flows sufficiently to allow the controlled injection of PUR, then grouting activities will cease until a suitable flow regime can be established.

Prior to and during grout injection activities, sub-surface flows in the vicinity of the grout injection hole(s) may be reduced to allow accurate placement of PUR product below surface by using pumps to reduce the standing water level. The pump inlets will vary according to the stream remediation site, however, will typically include the pool subject to remediation activities and existing boreholes in the vicinity of the injection activities.

Water extracted from the pool subject to the remediation activities and the existing boreholes will be conveyed downstream of the site sediment controls (back into Waratah Rivulet or Eastern Tributary) via hoses. 'Lay flat' hoses will potentially be used for ease of handling, however, if abrasion damages the lay flat hoses, then rubber hoses will be used.

The number of pumps and the type of pump (petrol or compressed air) for the transfer of water will be determined on the basis of the flows encountered and the ability of the PUR to be placed without compromise to the quality of injection. If an additional air compressor is required to power the pumps, then it will be located consistent with the detailed site plans provided in Attachment 1 and will be bunded separately. Bunding will be constructed around diesel operated compressors and petrol pumps as described in Section 4.6.5.

Stand-by pumps will be stored in the elevated equipment storage area designated on the detailed plans in Attachment 1.

A checklist of tasks relating to the stream flow diversion and reduction of sub-surface flows will be completed on a regular basis, similar to the example Environment Checklist provided in Attachment 3.

4.6.5 Fuel and Spill Management

The use of fuels and oils will be managed to minimise the risk of spills or leaks as described below.

Large quantities of fuel will not be stored on-site. Small amounts of fuel will be required for equipment and will be transported by vehicle and carried in by hand to the drilling site. Fuel will be transported/carried in a closed container (e.g. jerry can) and re-fuelling will be undertaken using an appropriately sized funnel.

Equipment (e.g. drill rigs, compressors, pumps) will be regularly inspected for leaks of oil/fuel/coolant, as described in the example Activity Checklists and Duty Cards provided in Attachment 3.

Bunding will be installed around all diesel operated equipment. Bunds will be lined with a solid continuous plastic liner or equivalent covering the entire floor in one continuous sheet. The bunds will have sufficient capacity to contain in excess of 10% above the maximum fuel/oil storage capacity of the equipment.

Bunding will also be installed around petrol pumps. Bunds will be lined with a solid continuous plastic liner or equivalent covering the entire floor in one continuous sheet. The bunded area will have sufficient capacity to contain in excess of 10% above the maximum fuel/oil storage capacity of the pump.

Spill containment/treatment resources (i.e. spill kits) will be provided and personnel will be trained in their use. The spill kits will include: absorbent material 40 litre bag of Organic Oil/Fuel absorbent; absorbent pads: 20 of 480 x 430 millimetre (mm) pads; garbage bags; shovel; and bag of rags.

The spill kits will be located:

- In each vehicle transporting the grouting products. These spill kits will remain with the vehicles at all times. The vehicle spill kits will also service the PUR pump site during grouting activities.
- At the bunded air compressor.
- At the injection/drilling site.

Any spill that occurs will be immediately cleaned up and reported to the:

- Site Supervisor;
- Metropolitan Coal – Technical Services Manager;
- WaterNSW (via their Incident Management Number – 1800 061 069); and
- Resources Regulator.

The Site Supervisor and the Metropolitan Coal – Technical Services Manager (or delegate) will investigate any spills.

Metropolitan Coal will train personnel in the containment and treatment of spills and the use of spill kits. The Metropolitan Coal Spill Response Procedure is detailed in Attachment 5.

4.6.6 Management of Grouting Products and Injection Operations

A series of Duty Cards will be developed which identifies the responsibility of each key operator involved in the stream remediation activities including the PUR transport driver, pump operator and Site Supervisor. Example Duty Cards are provided in Attachment 3.

A series of Activity Checklists will also be developed to manage the transport of PUR, set-up, start-up (pre-injection), and clean-up activities to check that all controls are in place and working effectively. Each operator will have clearly identified Activity Checklist(s) to work through. Example Activity Checklists are provided in Attachment 3.

Formal inspections by the Site Supervisor will be conducted: a) prior to the commencement of daily activities; b) during the conduct of daily activities; and c) at the completion of daily activities. In addition, site personnel will be required to regularly inspect/observe the management measures and controls whilst undertaking their duties.

The Activity Checklists will be countersigned by the Site Supervisor to provide an additional layer of control (refer to the examples in Attachment 3).

Management controls overlap between Activity Checklists, for example, inspection of the hose couplings is conducted by two people to provide additional layers of risk mitigation.

The Site Supervisor is authorized to cease the remediation activities if handling or injection operations or Activity Checklists are identified as not being undertaken in accordance with the Stream Remediation Plan.

Attachment 7 provides additional information on the management of grouting products and injection activities that will be implemented to prevent or minimise impacts on the environment.

4.6.7 Contingency Plans in the Event of Wet Weather

In the event of imminent heavy rain, drilling will cease and equipment will be moved to high ground on the bank of the stream at the equipment storage area(s) shown on the stream remediation plans in Attachment 1. In addition, drilling and pumping equipment will be moved to high ground at the end of each day.

4.6.8 Waste Management

Rubbish will be collected daily for disposal off-site. On completion of the remediation activities, equipment and all waste (such as litter, used materials, etc.) will be removed from the site.

A portable chemical toilet will be located on a nearby fire road. Personnel will be instructed to use the facility. Sewage wastes will be removed from the site by a registered contractor and disposed of in an appropriate manner.

4.6.9 Transport Management

Measures will be implemented to minimise the potential impacts of vehicles. These include:

- Only 4WD vehicles are permitted.
- Vehicles movements will be kept to the minimum necessary.

- Vehicles will be required to observe the 40 kilometres per hour speed limit on all roads within the catchment.
- The remediation areas will be accessed by two locked gates from the Princes Highway using existing fire trails. All gates will be kept locked at all times.
- Vehicles will be parked along adjacent fire roads.
- No vehicles are permitted within the bed of the Waratah Rivulet or Eastern Tributary to the drilling and grout injection work area.
- The potential use of a helicopter to access areas/deliver equipment otherwise not accessible.
- Access to the drilling and grout injection work area for track mounted machinery (drill rig and mini tipper) may occur along areas of exposed rock outcrop within the bed of the Waratah Rivulet or Eastern Tributary. Where sudden changes in bed level occur, access will be facilitated by use of temporary steel ramps or sand bags as necessary.
- Access to the catchment area will not occur after 10 mm of rain has been received in any 24 hour period or at the discretion of WaterNSW Manager Catchment Operations South East.
- Vehicles will not be used in the catchment unless they have been serviced and maintained to an acceptable standard. No servicing or maintenance of vehicles will be conducted in the catchment.

4.6.10 Bushfire Preparedness and Management

A Bushfire Preparedness Plan will be developed for each stream remediation site. An example Bushfire Preparedness Plan is provided in Attachment 6.

Hot work will be carried out in accordance with WaterNSW Hot Work Policy for the Bushfire Season and no hot work will occur without a WaterNSW Hot Work Permit.

4.7 TIMING OF STREAM REMEDIATION ACTIVITIES

The specific timing of stream remediation activities will be influenced by practical considerations. For example, the catchment may be closed due to rainfall or stream remediation activities are unable to be conducted as a result of high stream flows.

It is anticipated that remediation activities would generally follow mining in a downstream direction however additional remediation efforts may be required for some pools.

Metropolitan Coal is committed to stream remediation at the earliest opportunity, with an aspirational target date for the completion of grouting works of 31 December 2024.

5 MONITORING

5.1 PHOTOGRAPHIC RECORDS

Photographic surveys will be conducted along the Waratah Rivulet from Pool P to the full supply level of the Woronora Reservoir and along the Eastern Tributary from the full supply level of the Woronora Reservoir to the maingate of Longwall 26 in accordance with the Metropolitan Coal Water Management Plan.

5.2 RAINFALL

Rainfall will be monitored using pluviometers in the Eastern Tributary catchment (site PV7), the Waratah Rivulet catchment (sites PV1 and PV6) and the Woronora River catchment (site PV2) (Figure 8), and will be used to inform the assessment of stream remediation.

This data will be supplemented by rainfall and/or climate data from nearby Bureau of Meteorology stations or WaterNSW owned monitoring equipment, as required.

5.3 SURFACE WATER FLOW

Surface water flow monitoring will include continuous flow monitoring at (Figure 9):

- the WaterNSW owned gauging station on the Waratah Rivulet, close to the inundation limits of the Woronora Reservoir (GS 2132102);
- the WaterNSW owned gauging station on the Woronora River, close to the inundation limits of the Woronora Reservoir (GS 2132101);
- the Metropolitan Coal owned gauging station on the Eastern Tributary, close to the inundation limits of the Woronora Reservoir (GS 300078); and
- the Metropolitan Coal owned gauging station on Honeysuckle Creek, close to the inundation limits of the Woronora Reservoir (GS 300077).

Data from the WaterNSW owned gauging stations will continue to be downloaded monthly by WaterNSW and provided to Metropolitan Coal in accordance with a data exchange agreement.

The surface water flow monitoring data may be used to inform the assessment of stream remediation.

5.4 POOL WATER LEVELS

The water level in Pools B, C, E, G, G1, H and I on Waratah Rivulet will be manually monitored daily, while Pools A, F, J, K, L, M, N, O, P, Q, R, S, T, U, V and W on Waratah Rivulet will be monitored using a continuous water level sensor and data logger (Figure 4).

Pools ETAG, ETAH, ETAI/ETAJ/ETAK[1], ETAL, ETAM, ETAN, ETAO, ETAP, ETAQ, ETAR, ETAS/ETAT[2] and ETAU, downstream of maingate 26 on the Eastern Tributary will also be monitored using a continuous water level sensor and data logger (Figure 4).

Continuous water level sensors and loggers will also monitor water levels in control Pools WRP1, WRP2, WRP3 and WRP4 on the Woronora River.

Data from these water level meters will be downloaded monthly.

During manual water level measurements and monthly download of water level meters, Metropolitan Coal will record whether there is flow over the rock bar or flow observed entering the boulder field.

---

1 Only small rock bars separate Pools ETAI, ETAJ and ETAK. Pools join to become the one large pool. Pool ETAK is controlled by a rock bar. The water level meter is situated in Pool ETAI.

2 Due to the nature of rock bar ETAS, Pool ETAS and Pool ETAT typically sit at the same level.

5.5 STREAM REMEDIATION ACTIVITIES

5.5.1 Stream Remediation Measures and Environmental Controls

The Site Supervisor will be responsible for ensuring the work is undertaken in a safe manner and that the environmental management undertakings and commitments are implemented.

The duties and responsibilities of each role will be outlined in Duty Cards (examples are provided in Attachment 3). An inspection and reporting system will be used during the activities to check that all controls are in place and working effectively. A copy of the example inspection checklists are provided in Attachment 3. The checklists reflect the various phases of the remediation activities and the specific environmental controls to be performed according to each task. Each operator responsible for a given task, for example transportation of PUR, will be required to complete a checklist and the Site Supervisor will confirm that all checklists comply with the necessary controls.

5.5.2 Water Monitoring Program

<u>During Grouting Activities</u>

Daily surface water quality will be monitored at two sites upstream and at two sites downstream of the remediation works. Field-based parameters will include pH, electrical conductivity (EC), turbidity and total organic carbon (TOC). pH, EC and turbidity will be sampled in the field using hand-held meters. TOC will be sampled in the field and analysed within approximately 4 hours of sampling.

Should field samples indicate values at the downstream sites outside the previously recorded (i.e. prior to the stream remediation activities commencing) water quality data have occurred, samples will be collected and sent for laboratory testing.

Laboratory-based parameters will include pH, EC, turbidity, Oxidation Reduction Potential (Eh), TOC, dissolved organic carbon (DOC), major ions (calcium [Ca], magnesium [Mg], sodium [Na], potassium [K], chloride [Cl], sulphate [SO_4] and bicarbonate [HCO_3]) and trace metals (aluminium [Al], iron [Fe] and manganese [Mn]). Samples collected for laboratory cation, anion and metal analysis will be field filtered.

<u>Data Analysis</u>

Field based water quality results obtained during the conduct of grout injection activities will be compared to previously recorded (i.e. prior to the stream remediation activities commencing) water quality data immediately upon receipt of the results. Where monitoring results at the downstream sites indicate values outside (i.e. higher or lower) than the previously recorded water quality data, the values will be compared to the results (for the same sampling time) for the upstream sites. If any field test result of a downstream site is above (outside) previously recorded values and is also above (outside) values obtained from testing at an upstream site on that day, drilling and injection activities will cease and the water quality samples will be sent to the laboratory for analysis.

In the event laboratory testing confirms the downstream results are outside previously recorded water quality data and the results for the upstream sites, an investigation will be triggered and drilling and injection activities will immediately cease. WaterNSW will be notified immediately via the Incident Number 1800 061 069.

Water Quality Data Investigation

An investigation will be undertaken in the event the laboratory testing of monitoring results at the downstream sites indicate values outside the previously recorded water quality data and the results for the upstream sites. The investigation will include but not be limited to the following:

- Review of any trends in the data.
- Consideration of the site activities being undertaken at the time (e.g. drilling versus grout injection).
- Consideration of the prevailing and preceding meteorological conditions.
- Consideration of any other significant events that may have an influence on water quality (e.g. bushfires).

As a result of the investigation, a specialist assessment will be made of whether the water quality variation is being caused by the remediation activities and could potentially result in a significant impact on aquatic ecology or downstream water supplies.

Further grout injection works will not be undertaken unless the specialist assessment concludes that it is safe to do so without resulting in a significant impact on aquatic ecology or downstream water supplies. The results of the investigation will be reported to the DPIE, Resources Regulator and WaterNSW.

6 ASSESSMENT OF STREAM REMEDIATION PROGRESS

6.1 STATISTICAL ASSESSMENT METHODS

WaterNSW and OEH recommended Metropolitan Coal develop a statistically robust methodology to assess the success of the stream remediation measures.

Metropolitan Coal engaged Emeritus Professor Thomas McMahon (The University of Melbourne) to investigate and review potential methods to statistically assess the progress/success of stream remediation.

Emeritus Professor McMahon (2018) identified five potential approaches to assessing pre-impact – post-impact – post remediation relationships:

1. Paired catchment approach (target compared to control):
   i) Pool water level (target) vs measured discharge (control).
   ii) Pool water level (target) vs estimated discharge by rainfall-runoff model (control which could be the target pool).
   iii) Pool water level (target) vs pool water level (control).
2. Sequential analyses:
   i) Analysis of recession curve directly.
   ii) Recession slope analysis.

Following extensive testing of the potential approaches using available Metropolitan Coal pool water level data, McMahon (2018) concluded that it is inappropriate to recommend a specific null hypothesis test that can be prescribed and adopted universally to address the question of assessing statistically the change in water levels as a result of longwall mining impact or pool remediation.

Investigations were conducted using parametric (standard t-test) and non-parametric (Mann-Whitney) tests on Pools G, J and Q water level data. Analyses were also conducted for Pools J and Q using water levels that were equal to or below the median water level. The analyses demonstrated that except for a limited interpretation of the Mann-Whitney test, a null hypothesis statistical test could not be applied to the water levels in the pools investigated.

Emeritus Professor McMahon's report (McMahon, 2018) *Review of Null Hypothesis Testing whether Remediation of Pools Impacted by Longwall Mining is Effective* is provided in Attachment 8[3].

6.2 QUANTITATIVE ASSESSMENT METHODS

6.2.1 Stream Remediation Assessment Methods

In parallel to the investigation of potential statistical assessment methods, Metropolitan Coal engaged Mr Lindsay Gilbert (Hydro Engineering & Consulting) to further develop quantitative assessment methods to assess the progress of the stream remediation activities.

The quantitative assessment methods have been developed in consideration of:

- the availability of pool water level data (i.e. pre-impact and post-remediation); and
- the pool's downstream control type.

Tables 4 and 5 provide details of the pre-impact, post impact and post remediation data availability for pools on the Waratah Rivulet and Eastern Tributary, respectively. The data available influences the assessment method that can be used to assess the progress of the stream remediation measures. For example, Pools J, K, L, M, N, P, Q, R, S, T and V on the Waratah Rivulet have pre-impact data available, whereas Pools A to G on the Waratah Rivulet do not.

Tables 4 and 5 also provide details of the downstream control of pools on the Waratah Rivulet and Eastern Tributary, respectively. The methods that will be used to assess pools with rock bars will differ to the assessment methods for pools with boulder field controls. The water levels in pools with boulder field controls can change over time as a result of movement of rocks/boulders during high energy flows and clogging of voids between rock elements during lower flows. It should also be noted that the behaviour of pools with boulder field controls may differ between pools.

Three quantitative stream remediation assessment methods have been developed to assess the progress of stream remediation methods on the Waratah Rivulet and Eastern Tributary.

Pools with Pre-Impact Water Level Data Available

Method 1 - Analysis of pre-impact and post-remediation pool water level recession behaviour (rock bar control), supplemented with a comparative analysis of post-remediation pool water level recession behaviour to similar, un-impacted control pool(s) during the post remediation periods (refer Method 3).

Method 2 - Analysis of pre-impact and post-remediation pool water level recession behaviour (boulder field control), supplemented with a comparative analysis of post-remediation pool water level recession behaviour to similar, un-impacted control pool(s) during the post remediation periods (refer Method 3).

---

3 Subsequent consideration was given by Emeritus Professor Tom McMahon (McMahon, 2019) to the implementation of time-series intervention analysis or stochastic modelling, the outcomes of which were discussed at a workshop with stakeholders in July 2019.

Pools with No Pre-Impact Water Level Data Available

Method 3 - Analysis of post-remediation pool water level recession behaviour (rock bar and boulder field control) and similar, un-impacted pools.

Control (un-impacted) pools would be selected based on:

1. proximity to the remediated pool;
2. similarity of low flow control; and
3. comparability of available stage record.

The validity of the control pool(s) would be established/quantified by conducting a comparative analysis of pool water levels during the pre-impact period.

The assessment methods are described in Sections 6.2.2 to 6.2.4. Performance indicators have also been developed to assess and report the progress of the stream remediation measures. While the methodologies described in Sections 6.2.2 to 6.2.4 will be followed, it does not exclude other investigations from being undertaken to establish or support Metropolitan Coal's assessment of stream remediation progress and/or success.

Dry weather (defined as a minimum of five days when the maximum recorded daily rainfall is 0.5 mm) is proposed to be used to identify periods when there would be no or negligible runoff being generated in the catchment and as a consequence when pool water levels are unaffected by rainfall/runoff processes in the catchment. Pool water level recessionary behaviour will be most sensitive to subsidence induced impacts to pools in the absence of direct rainfall/runoff processes.

It will be necessary to have sufficient, representative dry periods in the data sets in order to make appropriate comparisons between pools. Assessments against the performance indicators can be conducted following dry periods in the post-remediation period to assess stream remediation progress. The assessments may indicate further monitoring or remediation effort is required. However, as a general guide it is anticipated that a minimum of 15 dry spells in the pre-impact and post-remediation data sets (i.e. periods with a minimum of five days when the maximum recorded daily rainfall is 0.5 mm) and at least two of these lasting ten days will be required to assess the success of the stream remediation against the rehabilitation objective (refer Section 7). The pre-impact and post-impact dry weather recession data should include a similar seasonal spread. This may require monitoring over one or more years (up to 3-5 years) post-remediation to gather sufficient low-flow data to assess the success of the stream remediation.

In addition to the methods described below, photographic records of the pools may be used to support the assessment of stream remediation progress.

In the event diversion of flow or changes in natural drainage behaviour are recorded for Pools P, Q, R, S, T, U, V or W on the Waratah Rivulet or Pools ETAS, ETAT or ETAU on the Eastern Tributary, this will represent an exceedance of the Waratah Rivulet watercourse performance measure or further exceedance of the Eastern Tributary watercourse performance measure and will be subject to Water Management Plan Incident Reporting and Contingency Measures. The pools are included in the assessment methods on the basis that the Rehabilitation Objective applies to these sites. Metropolitan Coal will implement adaptive management measures, as necessary, to achieve the watercourse performance measures.

Table 4
Pre-Impact, Impact and Post-Remediation Data Availability for Pools on the Waratah Rivulet

<table>
<tr><th rowspan="2">Pool</th><th rowspan="2">Downstream Control</th><th rowspan="2">Data Type[1]</th><th colspan="3">Data Availability</th></tr>
<tr><th>Pre-Impact</th><th>Impact</th><th>Post Remediation</th></tr>
<tr><td>A</td><td>Effectively impermeable rock bar.</td><td>Water level meter and manual water level measurements</td><td rowspan="5">No pre-impact data (impacted prior to the commencement of mining of Longwall 20)
• Pool A impacted by Longwall 11 in 2004-2005.
• Pool F impacted by Longwall 12 in 2005.
• Pools B, C and E impacted at a similar time.</td><td>Manual measurement of water levels commenced on 20/09/2005.
Water level meter data available from January 2010.</td><td>Most recent remediation campaign completed in June 2012.</td></tr>
<tr><td>B</td><td>Effectively impermeable rock bar.</td><td>Manual water level measurements</td><td>Manual measurement of water levels commenced on 20/09/2005.</td><td>Not subject to direct remediation, however influenced by remediation efforts at Pools A and F.</td></tr>
<tr><td>C</td><td>Effectively impermeable rock bar.</td><td>Manual water level measurements</td><td>Manual measurement of water levels commenced on 20/09/2005.</td><td>Not subject to direct remediation, however influenced by remediation efforts at Pools A and F.</td></tr>
<tr><td>E</td><td>Effectively impermeable rock bar.</td><td>Manual water level measurements</td><td>Manual measurement of water levels commenced on 20/09/2005.</td><td>Not subject to direct remediation, however influenced by remediation efforts at Pools A and F.</td></tr>
<tr><td>F</td><td>Effectively impermeable rock bar.</td><td>Water level meter and manual water level measurements</td><td>Manual measurement of water levels commenced on 20/09/2005.
Water level meter data available from January 2010.</td><td>Stream remediation polyurethane trials (17-23 March 2008, expanded trial section 3 April to 19 May 2008), and stream remediation polyurethane injection from 24 September 2014 to 29 June 2015.</td></tr>
<tr><td>G</td><td>Effectively impermeable rock bar.</td><td>Manual water level measurements</td><td>Manual measurement of water levels commenced on 20/09/2005.
Pre-impact data available to 9/08/2006[2].</td><td>Impacted during the mining of Longwall 13. Impact data from 14/8/2006.</td><td>Stream remediation conducted between 8 September 2015 and 31 August 2016.</td></tr>
<tr><td>G1</td><td>Effectively impermeable rock bar.</td><td>Manual water level measurements</td><td>Manual measurement of water levels commenced on 13/10/2005.
Pre-impact data available to 24/02/2011[2].</td><td>Impacted during the mining of Longwall 20 in 2011. Impact data from 1/3/2011.</td><td>Not subject to direct remediation, however influenced by remediation efforts at Pool F and Pool G.</td></tr>
<tr><td>H</td><td>Effectively impermeable rock bar.</td><td>Manual water level measurements</td><td>Manual measurement of water levels commenced on 11/10/2005.</td><td>No impacts to date.</td><td>-</td></tr>
</table>

Table 4 (Continued)
Pre-Impact, Impact and Post-Remediation Data Availability for Pools on the Waratah Rivulet

Pool	Downstream Control	Data Type[1]	Data Availability		
			Pre-Impact	Impact	Post Remediation
I	Effectively impermeable rock bar.	Manual water level measurements	Manual measurement of water levels commenced on 11/10/2005.	No impacts to date.	-
J	Effectively impermeable rock bar.	Water level meter	Water level meter monitoring commenced on 03/04/2007	No impacts to date.	-
K	Effectively impermeable rock bar.	Water level meter	Water level meter monitoring commenced on13/5/2010.	No impacts to date.	-
L	Effectively impermeable rock bar.	Water level meter	Water level meter monitoring commenced on 11/12/2008.	No impacts to date.	-
M	Effectively impermeable rock bar.	Water level meter	Water level meter monitoring commenced on 11/12/2008.	No impacts to date.	-
N	Effectively impermeable rock bar.	Water level meter	Water level meter monitoring commenced on 11/12/2008. Pre-impact data available to 1/8/2012[3].	Impacted by mining in September 2012 (based on visual observations). Impact data available from 2/11/2012.	-
O	Boulder field.	Water level meter	Water level meter monitoring commenced on 11/12/2008.	No impacts to date.	-
P	Permeable rock bar.	Water level meter	Water level meter monitoring commenced on 11/12/2008.	No impacts to date.	-
Q	Effectively impermeable rock bar.	Water level meter	Water level meter monitoring commenced in 20 February 2007.	No impacts to date.	-
R	Effectively impermeable rock bar.	Water level meter	Water level monitoring commenced on 11/12/2008.	No impacts to date.	-

Table 4 (Continued)
Pre-Impact, Impact and Post-Remediation Data Availability for Pools on the Waratah Rivulet

Pool	Downstream Control	Data Type[1]	Data Availability		
			Pre-Impact	Impact	Post Remediation
S	Effectively impermeable rock bar.	Water level meter	Water level monitoring commenced on 11/12/2008.	No impacts to date.	-
T	Permeable rock bar.	Water level meter	Water level meter monitoring commenced on 20/01/2008.	No impacts to date.	-
U	Boulder field.	Water level meter	Water level meter monitoring commenced on 20/01/2008.	No impacts to date.	-
V	Permeable rock bar.	Water level meter	Water level meter monitoring Commenced on 20/01/2008.	No impacts to date.	-
W	Boulder field.	Water level meter	Water level meter monitoring Commenced on 20/01/2008.	No impacts to date.	-

[1] The manual water level measurements are recorded daily, except for weekends and public holidays.

[2] Note, the pre-impact period represents a conservative estimate (i.e. the end date of the pre-impact period is in advance of any pool water level impact).

[3] The Pool N water level meter was not functioning at time of impact. The pre-impact period represents the data available prior to impact.

Table 5
Pre-Impact, Impact and Post-Remediation Data Availability for Pools on the Eastern Tributary

Pool	Downstream Control	Data Type	Data Availability (Natural Drainage Behaviour)		
			Pre-Impact	Impact	Post Remediation
ETAG	Boulder field.	Water level meter	Water level meter monitoring commenced on 12/11/2010. Pre-impact data available to 13/12/2016[1]	Impacted during the mining of Longwall 27 in late December 2016/ January 2017, Impact data from 20/12/2016.	-
ETAH	Permeable rock bar.	Water level meter	Water level meter monitoring commenced on 19/01/2011. Pre-impact data available to 29/11/2016[1].	Impacted during the mining of Longwall 27 in December 2016. Impact data from 1/12/2016.	-
ETAI/ ETAJ/ ETAK	Only small rock bars separate Pools ETAI, ETAJ and ETAK. Pools join to become the one large pool. Pool ETAK is controlled by a rock bar.	Water level meter (Pool ETAI)	Water level meter monitoring commenced on 19/01/2011 (Pool ETAI only). Pre-impact data available to 29/11/2016[1].	Impacted during the mining of Longwall 27 in December 2016. Impact data from 6/12/2016.	-
ETAL	At the time of the baseline survey it was evident that flow emerges approximately 30 m downstream of the pool from a small boulder field onto exposed sandstone. (Boulder field)	Water level meter	No pre-impact data.	Impacted during the mining of Longwall 27 in December 2016. Water level meter monitoring commenced on 3/10/2018.	-
ETAM	At the time of the baseline survey it was evident that the controlling boulder field did not have surface flow. (Boulder field)	Water level meter	No pre-impact data.	Impacted during the mining of Longwall 27 in December 2016. Water level meter monitoring commenced on 3/10/2018.	-
ETAN	Rock bar separating Pools ETAN and ETAO, some cross bedding and potholes are present in the rock bar.	Water level meter	No pre-impact data.	Impacted during the mining of Longwall 27 in December 2016. Water level meter monitoring commenced on 3/10/2018.	-
ETAO	Rock bar.	Water level meter	No pre-impact data.	Impacted during the mining of Longwall 27 in late December 2016 to mid January 2017. Water level meter monitoring commenced on 3/10/2018.	-
ETAP	Stream becomes braided flow through boulder field downstream of the pool. Some sandstone bedrock is exposed in the boulder field. (Boulder field)	Water level meter	No pre-impact data.	Impacted during the mining of Longwall 27 in late December 2016 to mid January 2017. Water level meter monitoring commenced on 3/10/2018.	-

Table 5 (Continued)
Pre-Impact, Impact and Post-Remediation Data Availability for Pools on the Eastern Tributary

Pool	Downstream Control	Data Type	Data Availability (Natural Drainage Behaviour)		
			Pre-Impact	Impact	Post Remediation
ETAQ	Effectively impermeable rock bar.	Water level meter	Water level meter monitoring commenced on 17/01/2011. Pre-impact data available to 6/12/2016.	Impacted during the mining of Longwall 27 in December 2016. Impact data from 13/12/2016.	-
ETAR	Rock bar.	Water level meter	-	Impacted during the mining of Longwall 27 in December 2016. Water level meter monitoring commenced on 3/10/2018.	-
ETAS	Permeable rock bar	The water level meter in Pool ETAT is applicable to Pool ETAS[2]	Water level meter monitoring commenced on 24/5/2018	No impacts to date	-
ETAT	Effectively impermeable rock bar			No impacts to date	-
ETAU	Pool ETAU flows through the Eastern Tributary gauging station, over a rock bar/waterfall	Water level meter	Water level meter monitoring commenced in 23/9/2012.	No impacts to date	-

[1] Note, the pre-impact period represents a conservative estimate (i.e. the end date of the pre-impact period is in advance of any pool water level impact).

[2] Due to the nature of rock bar ETAS, Pool ETAS and Pool ETAT typically sit at the same level.

6.2.2 Assessment Method 1 - Analysis of Pre-Impact and Post-Remediation Pool Water Level Recession Behaviour (Rock Bar Control)

6.2.2.1 Applicable Pools

A comparison of pre-impact and post-remediation pool water level recession behaviour will be conducted for the pools listed in Table 6 subject to stream remediation activities.

These pools have effectively impermeable or permeable rock-bar controls and pre-impact water level data.

Table 6
Pools with Rock Bar Controls and Pre-Impact Water Level Data

Stream	Pools
Waratah Rivulet	G1[1], H, I, J, K, L, M, N[1], P, Q, R, S, T and V
Eastern Tributary	ETAH, ETAI/ETAJ/ETAK[2], ETAQ, ETAS/ETAT[3] and ETAU

Notes:

1 If there is insufficient appropriate pre-impact data, Pool G1 and/or Pool N will be assessed using Method 3.

2 Only small rock bars separate Pools ETAI, ETAJ and ETAK. Pools join to become the one large pool. Pool ETAK is controlled by a rock bar. The water level meter is situated in Pool ETAI.

3 Due to the nature of rock bar ETAS, Pool ETAS and Pool ETAT typically sit at the same level (i.e. Pool ETAS can be assessed using the water level meter in Pool ETAT).

6.2.2.2 Assessment Method

Method 1 involves comparison of pool water level recession data during dry climatic conditions (dry weather) obtained from the remediated pool prior to impact (i.e. pre-impact) and the period following stream remediation (i.e. post-remediation).

Dry weather is defined as a minimum of five days when the maximum recorded daily rainfall is 0.5 mm.

Analysis of the pre-impact and post-remediation recession curves would be undertaken as follows:

1. Dry weather recessionary events will be identified in the available record for the pre-impact period and the post-remediation period. Where there is some uncertainty in relation to the specific end date of the pre-impact period, a conservative approach will be taken (i.e. only data away from the impact period will be used).
2. The recorded dry weather water level data for the pre-impact and post-remediation periods will be converted to daily averaged water level data.
3. The following steps will then be conducted for the pre-impact data:
    i. The average daily water level data will be plotted as a series of recession curves for each dry weather recessionary event. The start time of each recessionary event is manually adjusted to form a single recession curve (i.e. so it is plotted on a single time scale).
    ii. An interpolating exponential equation will be fitted to the manually derived single recession curve for the pre-impact data set.
    iii. The start time for each recession event (on the single recession curve) will be readjusted using the interpolating exponential equation to produce a mathematically refined recession curve for the pre-impact data set. This refined recession curve is adopted for comparison with the post-remediation data set and is considered to be representative of the dry weather water level recessionary behaviour of the pre-impacted pool.

4. For the post-remediation data, the start time for each post-remediation recession event will be adjusted using the adopted pre-impact interpolating exponential equation to produce a recession curve for the post-remediation data.
5. The pre-impact and post-remediation recession curves will be compared and assessed against the Performance Indicator.

As evaporation during the dry weather recessionary events may differ, where possible the water level data used in the pre-impact and post-remediation comparative analysis will contain similar dry periods that experienced similar evaporation potential.

Where warranted, the assessment may also distinguish between different, seasonal dry weather pool water level recession behaviour.

6.2.2.3 Performance Indicator

Metropolitan Coal will assess the progress of the stream remediation measures at the pool against the following performance indicator:

> *Analysis of pool water level recession behaviour indicates post-remediation behaviour is consistent with pre-impact behaviour.*

The performance indicator will be considered to have been met if data analysis indicates the pool's post-remediation water level recession behaviour is consistent with the pool's behaviour prior to being impacted by mine subsidence.

If the performance indicator has not been met, further stream remediation campaigns or monitoring may be required.

6.2.2.4 Method 1 Example

An example of this assessment method is provided by Hydro Engineering & Consulting (2018b) in Attachment 9. The example has been prepared for Pool Q. This pool has not been impacted by mine subsidence, however can be used to demonstrate how the assessment method would be applied by using dry weather events recorded in 2009 (for the purpose of the exercise, nominated as 'pre-impact' pool water level recessions) and dry weather events recorded in 2017 (for the purpose of the exercise, nominated as 'post-remediation' pool water level recessions).

In this example, the analyses demonstrate that the recession behaviour in the 'post-remediation' period would be considered consistent with the 'pre-impact' period.

6.2.3 Assessment Method 2 - Analysis of Pre-Impact and Post-Remediation Pool Water Level Recession Behaviour (Boulder Field Control)

6.2.3.1 Applicable Pools

A comparison of pre-impact and post-remediation pool water level recession behaviour will be conducted for the pools listed in Table 7 subject to stream remediation activities.

These pools have boulder field controls and pre-impact water level data.

Table 7
Pools with Boulder Field Controls and Pre-Impact Water Level Data

Stream	Pools
Waratah Rivulet	O, U and W
Eastern Tributary	ETAG

6.2.3.2 Assessment Method

Method 2 involves the same comparison of pool water level recession behaviour during dry weather for pre-impact and post-remediation data as described in Steps 1 to 5 for Method 1, however two additional assessment steps may be required to consider potential changes in the boulder field over time. The two additional steps (6 and 7) are:

1. In the event the post-remediation water level recession curve is found to be significantly steeper (i.e. greater than could be attributed to data scatter), than the pre-impact water level recession curve, potential changes to the boulder field control over time – but unrelated to subsidence impacts will be investigated. The investigation will include consideration of flow events (in particular, high energy flow events) over time.
2. In the event the investigation indicates there may have been changes in the boulder field over time, an assessment will be made of the pre-impact and post-remediation recession rates of other boulder field pools unaffected by subsidence. The assessment will be conducted for the same time periods using Steps 1-5. In the event the pool with a boulder field control unaffected by mine subsidence demonstrates a similar trend (i.e. a significantly steeper recession curve in the designated 'post-remediation' period, it may be able to be used to compare the post-remediation data sets).

6.2.3.3 Performance Indicators

Metropolitan Coal will assess the progress of the stream remediation measures against the following performance indicator following Step 5 in the assessment method:

> *Analysis of pool water level recession behaviour indicates post-remediation behaviour is consistent with pre-impact behaviour.*

The performance indicator will be considered to have been met if data analysis indicates the pool's post-remediation water level recession behaviour is consistent with the pool's behaviour prior to being impacted by mine subsidence.

Metropolitan Coal will assess the progress of the stream remediation measures against the following performance indicator following Step 7 in the assessment method:

> *Analysis of pool water level recession behaviour for the impacted pool is similar to the unaffected pool in the post-remediation period.*

The performance indicator will be considered to have been met if data analysis indicates the pool's post-remediation water level recession behaviour is consistent with the unaffected pool's behaviour in the post-remediation period.

6.2.3.4 Method 2 Example

An example of the boulder field assessment method is provided by Hydro Engineering & Consulting (2018c) in Attachment 10. The example has been prepared for Pool U on the Waratah Rivulet. This pool has not been impacted by mine subsidence, however can be used to demonstrate how the assessment method would be applied by using dry weather events recorded in 2012/2013 (for the purpose of the exercise, nominated as ‘pre-impact’ pool water level recessions) and dry weather events recorded in 2016-2018 (for the purpose of the exercise, nominated as ‘post-remediation’ pool water level recessions).

In this example, the analyses demonstrate that the recession behaviour in the ‘post-remediation’ period would be considered consistent with the ‘pre-impact’ period. This example does not require Step 6 and Step 7 of the assessment method to be illustrated.

6.2.4 Assessment Method 3 - Analysis of Pool Water Levels (Rock Bar and Boulder Field Control)

6.2.4.1 Applicable Pools

Method 3 involves comparison of pool water levels post-remediation with similar, but un-impacted pools. Un-impacted pools include pools upstream and/or downstream on the same stream, non-impacted pools on other streams and/or control pools on the Woronora River.

Method 3 applies to the pools listed in Table 8 subject to stream remediation activities.

These pools have effectively impermeable rock bars, permeable rock-bars or boulder field controls, however no pre-impact water level data available.

Pool water level meter data is available for Pools A and F on the Waratah Rivulet and Pools ETAL, ETAM, ETAN, ETAO, ETAR and ETAP on the Eastern Tributary, while manual water level measurements are available for Pools A, B, C, E, F, G and G1 on the Waratah Rivulet.

Table 8
Pools with No Pre-Impact Water Level Data Available

Stream/Control Type	Pools
Waratah Rivulet	
• Effectively Impermeable or Permeable Rock Bar Control	A, B, C, E, F, G, G1[1] and N[1]
• Boulder field Control	-
Eastern Tributary	
• Effectively Impermeable or Permeable Rock Bar Control	ETAN, ETAO and ETAR
• Boulder field Control	ETAL, ETAM and ETAP

[1] If there is sufficient and appropriate pre-impact data, Pool G1 and/or Pool N will be assessed using Method 1.

6.2.4.2 Assessment Method

Method 3 involves comparison of post-remediation pool water level fluctuations with data from a minimum of two similar, but un-impacted pools with the same downstream control type.

The water levels of the pools will be adjusted to a common datum to assist the comparison of recessionary behaviour.

6.2.4.3 Performance Indicators

Metropolitan Coal will assess the progress of the stream remediation measures against the following performance indicator:

> *Post-remediation pool water levels during low flow conditions are consistent with the water levels of similar, un-impacted pool(s).*

The performance indicator will be considered to have been met if data analysis indicates pool water levels post-remediation are consistent with similar, un-impacted pools during dry flow conditions.

6.2.4.4 Method 3 Example

An example of the assessment method is provided by Hydro Engineering & Consulting (2018d) in Attachment 11. The example has been prepared for Pool ETAF on the Eastern Tributary. This pool has been impacted by mine subsidence and has not been subject to stream remediation, however can be used to demonstrate how the assessment method would be applied.

The example demonstrates that the water levels in Pool ETAF would be considered inconsistent with the water levels of the un-impacted pools given the relatively rapid recessions and disparate behaviour from September 2017 onward.

6.2.5 Data Validation

All pool level monitoring data to be used in the quantitative assessments described in Section 6.2 would be subject to data validation by a suitably qualified and experienced person. Periods of erroneous and suspect pool water level data considered as part of the analyses described above would be documented.

Where possible and justified, the suspect or erroneous records would be adjusted to remove the effect of the inconsistency. For example, where there has been an erroneous change in pool water level datum, which is not related to subsidence effects, the water level data would be adjusted to remove the datum change. The nature, magnitude and effect of the adjustment(s) would be documented, and the analyses would be undertaken using the adjusted record.

Where it is found impossible to adjust erroneous data or to logically justify an adjustment the inconsistent/erroneous data would be removed from subsequent analyses.

Any adjustment(s) (including removal) of data would be documented in the detailed report on the assessment of remediation success for each pool (refer Section 7).

6.2.6 Data Contingency

As described in Section 6.2.1, it is anticipated that a minimum of 15 dry spells in the pre-impact and post-remediation data sets (i.e. periods with a minimum of five days when the maximum recorded daily rainfall is 0.5 mm) and at least two of these lasting ten days will be required to assess the success of the stream remediation against the rehabilitation objective.

For any pools where there are less than 15 dry spells in the validated pre-impact data set, the available pre-impact data would be used and supplemented by assessment of post-remediation pool data against similar un-impacted control pools in the post-remediation period.

Assessment against the rehabilitation objective would be undertaken after enough validated data has been collected to meet the minimum data requirements described in Section 6.2.

6.2.7 Reporting of Remediation Progress

Remediation progress would be reported on an annual basis as part of the Metropolitan Coal Annual Reviews, required in accordance with Condition 3, Schedule 7 of the Project Approval.

7 ASSESSMENT AGAINST STREAM REMEDIATION OBJECTIVE

The rehabilitation objective for the Waratah Rivulet (between the downstream edge of Flat Rock Swamp and the full supply level of the Woronora Reservoir) and the Eastern Tributary (between the full supply level of the Woronora Reservoir and the maingate of Longwall 26) is:

Restore surface flow and pool holding capacity as soon as reasonably practicable.

As described in Section 6.2.1, Metropolitan Coal will assess the progress of the stream remediation against the performance indicators detailed in Section 6.2.2 to 6.2.4. It is noted that more than one remedial effort may be required at an individual pool/rock bar.

It is anticipated that a minimum of fifteen dry spells in the pre-impact and post-remediation data sets (i.e. periods with a minimum of five days when the maximum recorded daily rainfall is 0.5 mm) and at least two of these lasting ten days will be required to demonstrate the rehabilitation objective has been met.

The assessment of remediation success will be based on utilising a weight of evidence approach to enable a determination of whether surface flows and pool holding capacity has been restored. While the methodologies described in Sections 6.2.2 to 6.2.4 will be followed, it does not exclude other investigations from being undertaken to establish or support Metropolitan Coal's assessment of stream remediation success. For example, where there is sufficient, accurate data a Mann-Whitney null hypothesis test or stochastic modelling may also be conducted to inform the assessment of remediation success. Metropolitan Coal will also seek an independent expert review to support any analysis/conclusions.

The rehabilitation objective will be considered to have been met if surface flow and pool holding capacity has been restored in the impacted pool. Metropolitan Coal will provide the DPIE, Resources Regulator, WaterNSW and BCD with a detailed report on the assessment of remediation success for each pool (Figure 3).

The possible outcomes of the assessment and potential actions are summarised in Table 9.

Table 9
Remediation Assessment Outcomes and Actions

Assessment Outcome	Potential Actions
1. The weight of evidence supports the conclusion that surface flow and pool holding capacity have been effectively fully restored.	DPIE confirms in writing that the rehabilitation objective has been achieved.
2. Insufficient evidence to support the conclusion that surface flow and pool holding capacity as determined by DPIE and an independent expert.	Metropolitan Coal collects further data for re-analysis and consideration by DPIE.
3. The evidence suggests remediation efforts have not satisfied the rehabilitation objective.	Metropolitan Coal provide a plan for further remediation works. Following completion of further remediation, Metropolitan Coal collect further data for re-analysis and consideration by DPIE. Offsets could be considered if further remediation is not feasible (refer Section 8).

All evidence would be completed to the satisfaction of DPIE to enable a determination of whether surface flows and pool holding capacity have been restored.

8 OFFSETS

Metropolitan Coal exceeded the Eastern Tributary watercourse performance measure during the mining of Longwalls 23-27. This Stream Remediation Plan includes stream remediation activities for pools between the full supply level of the Woronora Reservoir and the maingate of Longwall 26.

In accordance with Condition 6, Schedule 6 of the Project Approval, if the stream remediation activities fail to remediate the impact, Metropolitan Coal will provide a suitable offset to compensate for the impact to the satisfaction of the Director-General (now Secretary) of the DPIE.

9 REFERENCES

Australian Drinking Water Guidelines (2011) *Australian Drinking Water Guidelines – National Water Quality Management Strategy*. The National Health and Medical Research Council Canberra.

Bangalay Botanical Surveys (2008) *Metropolitan Coal Project Baseline Flora Survey – Proposed Longwall Mining Area.* Report prepared for Helensburgh Coal Pty Ltd.

Eco Logical Australia (2016) *Longwalls 301-303 Upland Swamp Vegetation Mapping and Proposed Monitoring Program*. Report prepared for Metropolitan Coal. August 2016.

Eco Logical Australia (2018) *Revised Longwalls 304-310 Upland Swamp Vegetation Mapping*. Report prepared for Metropolitan Coal.

Helensburgh Coal Pty Ltd (2008a) *Waratah Rivulet Remediation Trial Activities - Completion Report*.

Helensburgh Coal Pty Ltd (2008b) *Metropolitan Coal Project Environmental Assessment*.

Hydro Engineering & Consulting (2018a) *Metropolitan Coal Surface Water Review 1 July to 31 December 2017.* Report prepared for Metropolitan Coal.

Hydro Engineering & Consulting (2018b) *Stream Remediation Assessment Method 1.* Report prepared for Metropolitan Coal.

Hydro Engineering & Consulting (2018c) *Stream Remediation Assessment Method 2.* Report prepared for Metropolitan Coal.

Hydro Engineering & Consulting (2018d) *Stream Remediation Assessment Method 3.* Report prepared for Metropolitan Coal.

McMahon, T.A. (2018) *Review of Null Hypothesis Testing whether Remediation of Pools Impacted by Longwall Mining is Effective.* Report prepared for Metropolitan Coal.

McMahon, T.A. (2019) *Time-series Intervention Analysis.* Report prepared for Metropolitan Coal.

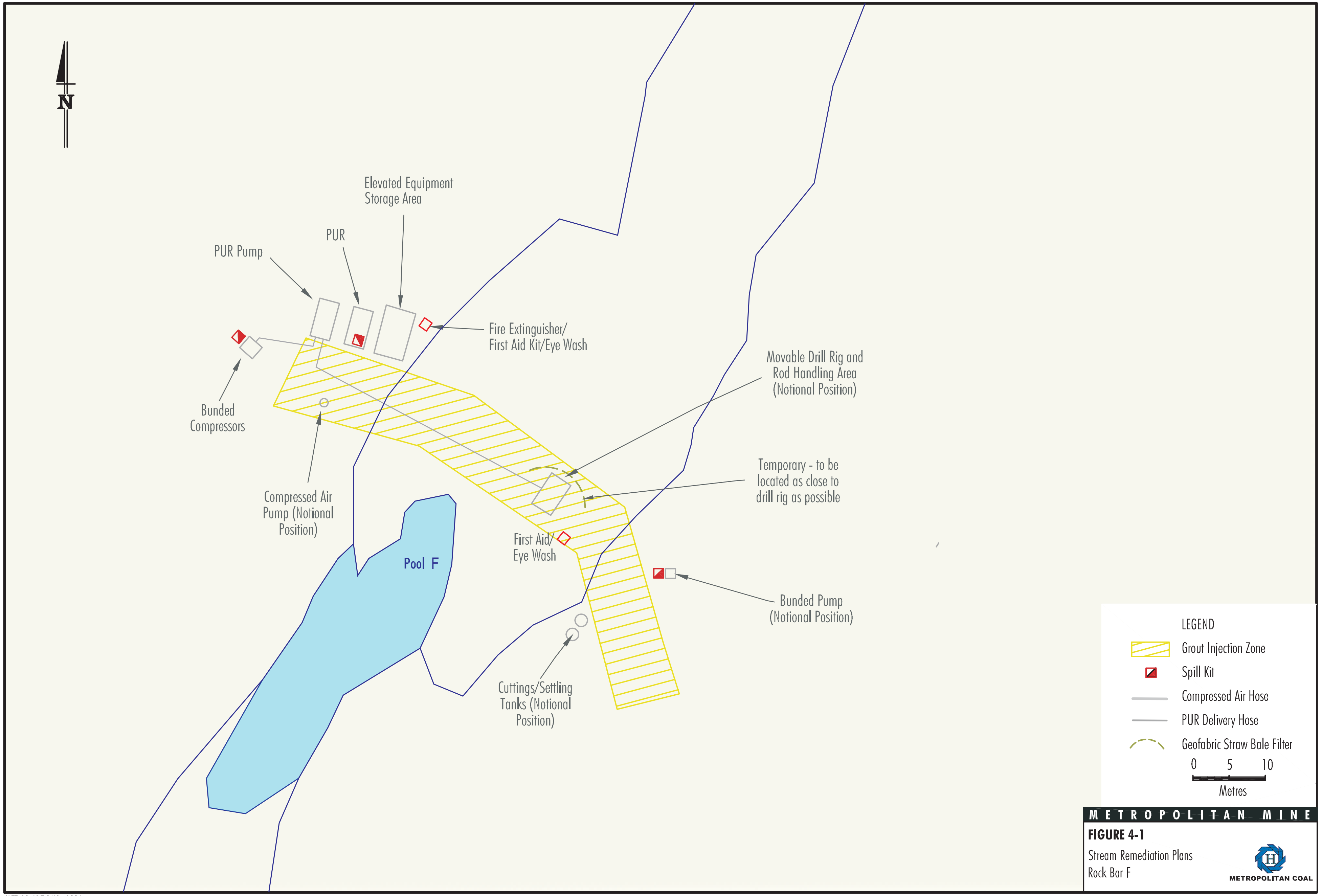
The University of Queensland (2018) *Assessment against Water Quality Performance Measure.* Report prepared for Metropolitan Coal.

WaterNSW and Office of Environment & Heritage (2015) *Special Areas Strategic Plan of Management 2015*.

Yee, N., Shaw, S., Benning, L.G. and Nguyen, T.N. (2006) The rate of ferrihydrite transformation to goethite via the Fe (II) pathway. *American Mineralogist* 91: 92-96.

ATTACHMENT 1

STREAM REMEDIATION PLANS

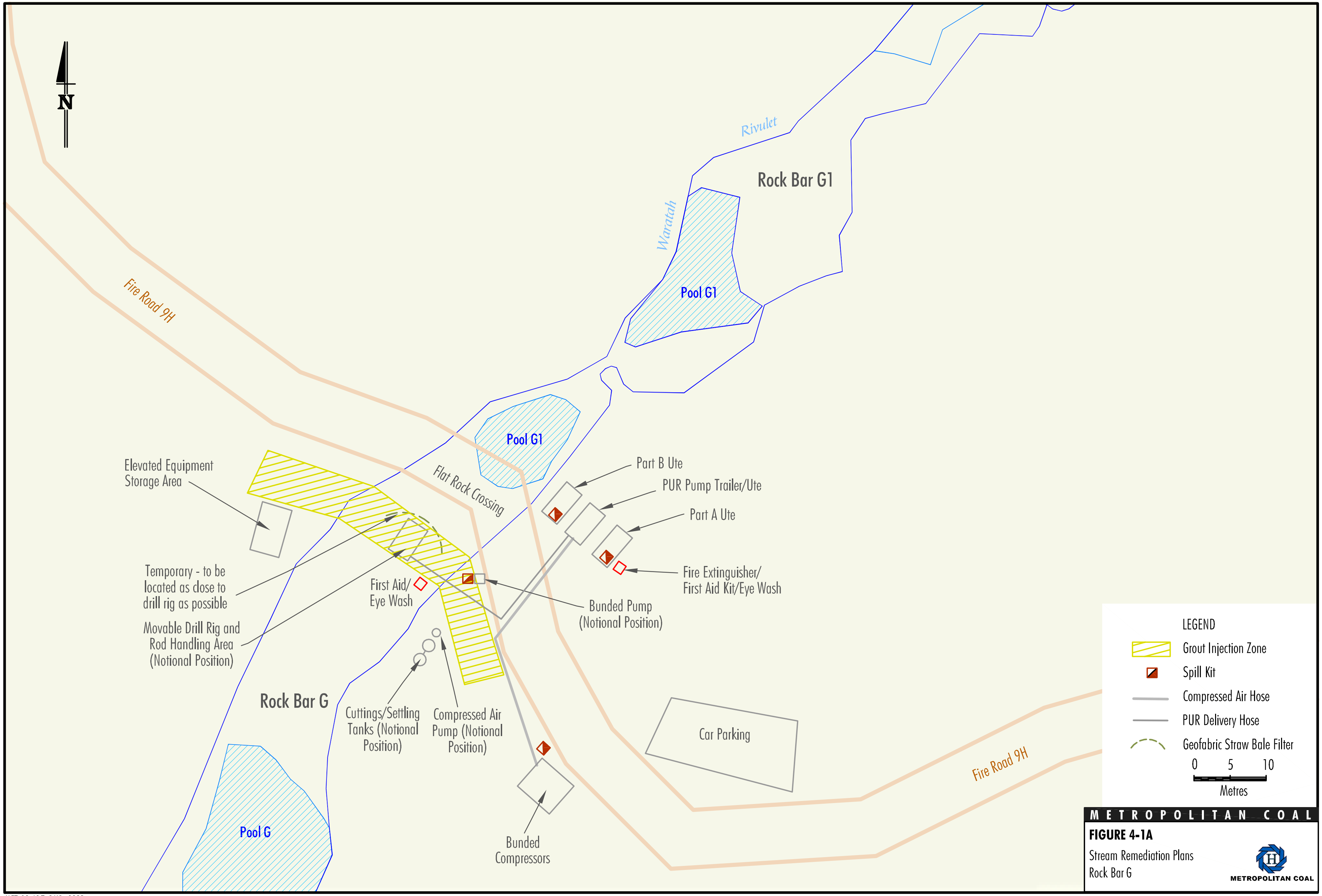


METROPOLITAN MINE

FIGURE 4-1

Stream Remediation Plans
Rock Bar F

MET-08-AD7 RMP_111A



METROPOLITAN COAL

FIGURE 4-1A

Stream Remediation Plans

Rock Bar G

METROPOLITAN COAL

MET-08-AD7 RMP_111B

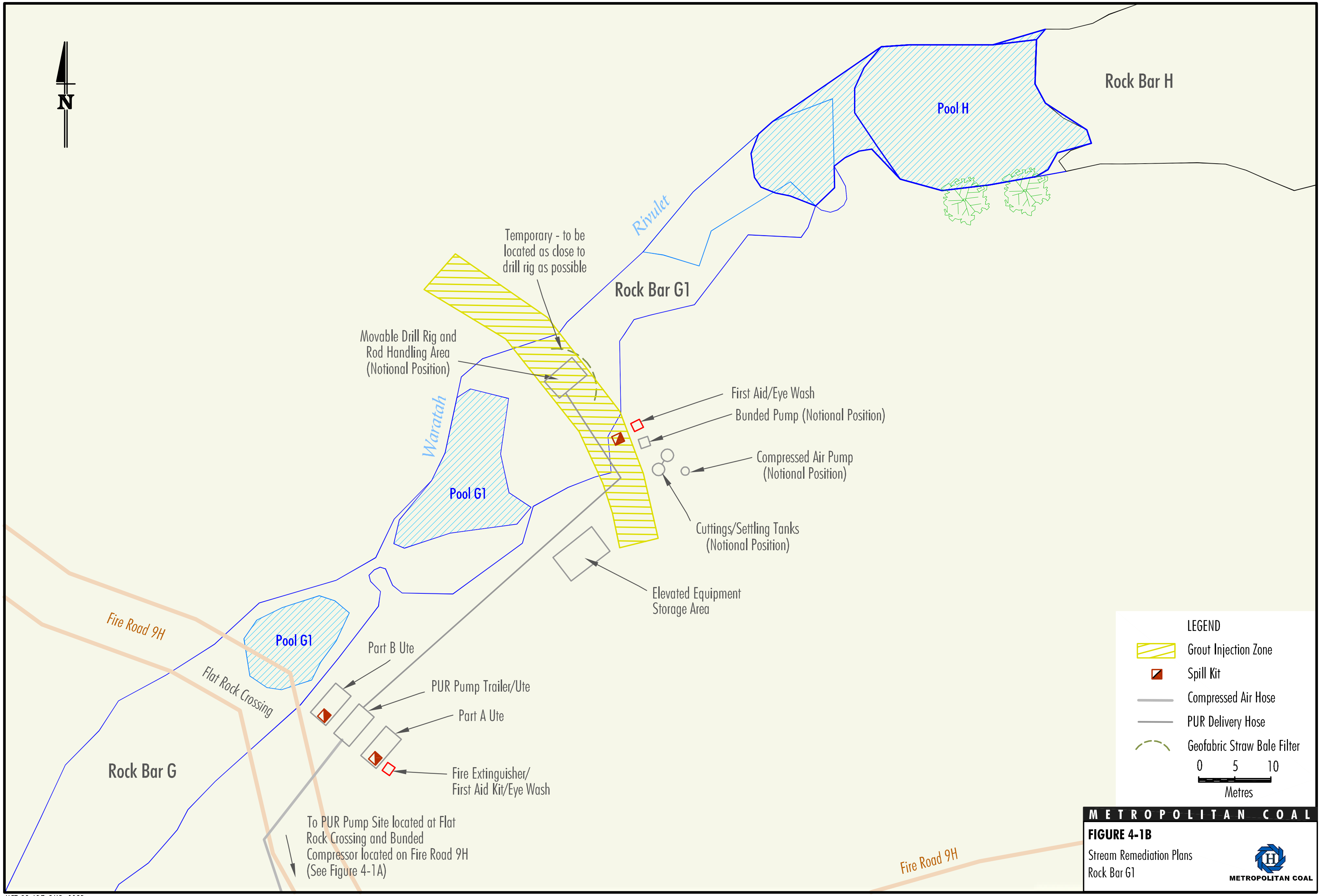
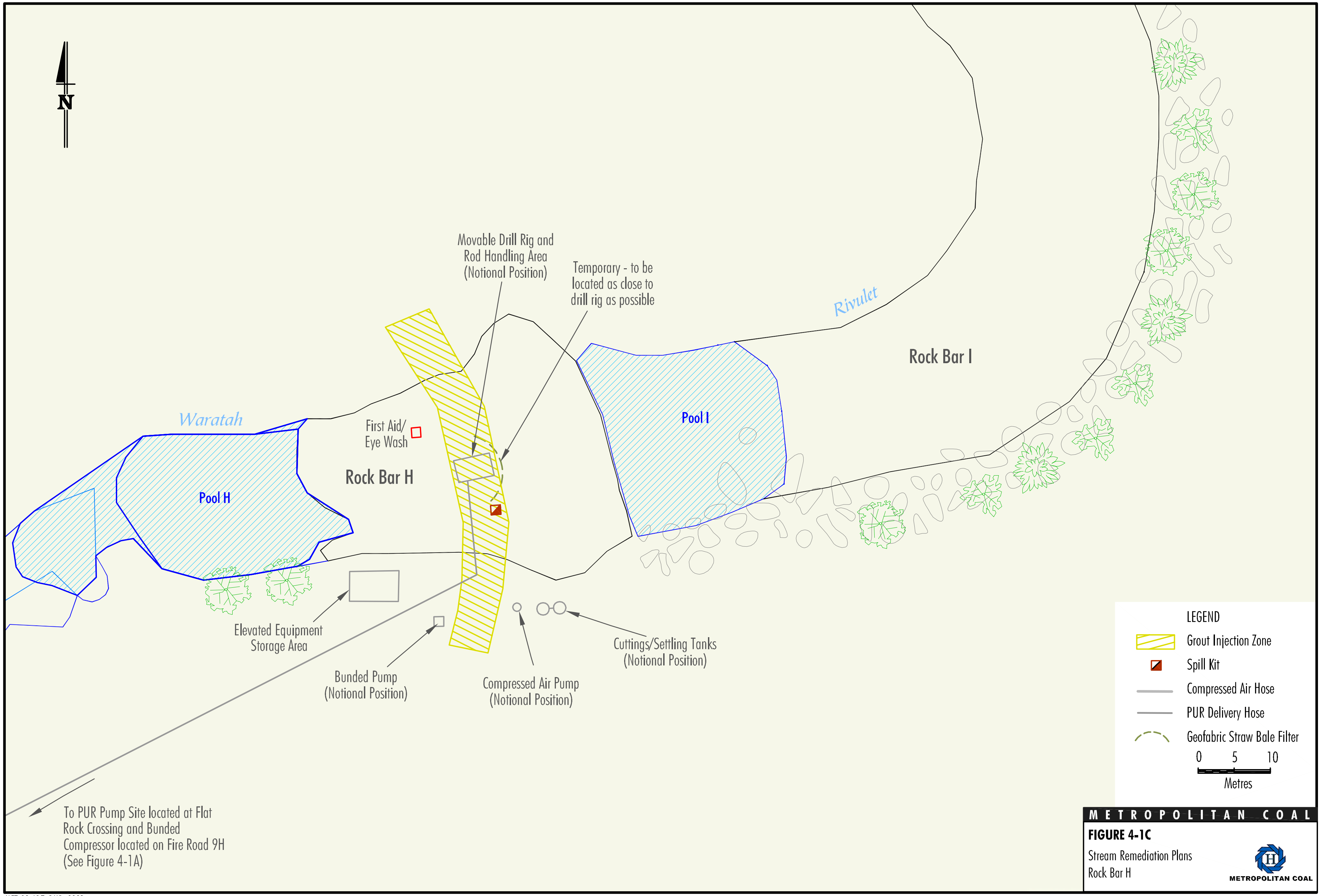


FIGURE 4-1B
Stream Remediation Plans
Rock Bar G1

MET-08-AD7 RMP_112B



METROPOLITAN COAL

FIGURE 4-1C

Stream Remediation Plans
Rock Bar H

METROPOLITAN COAL

MET-08-AD7 RMP_113B

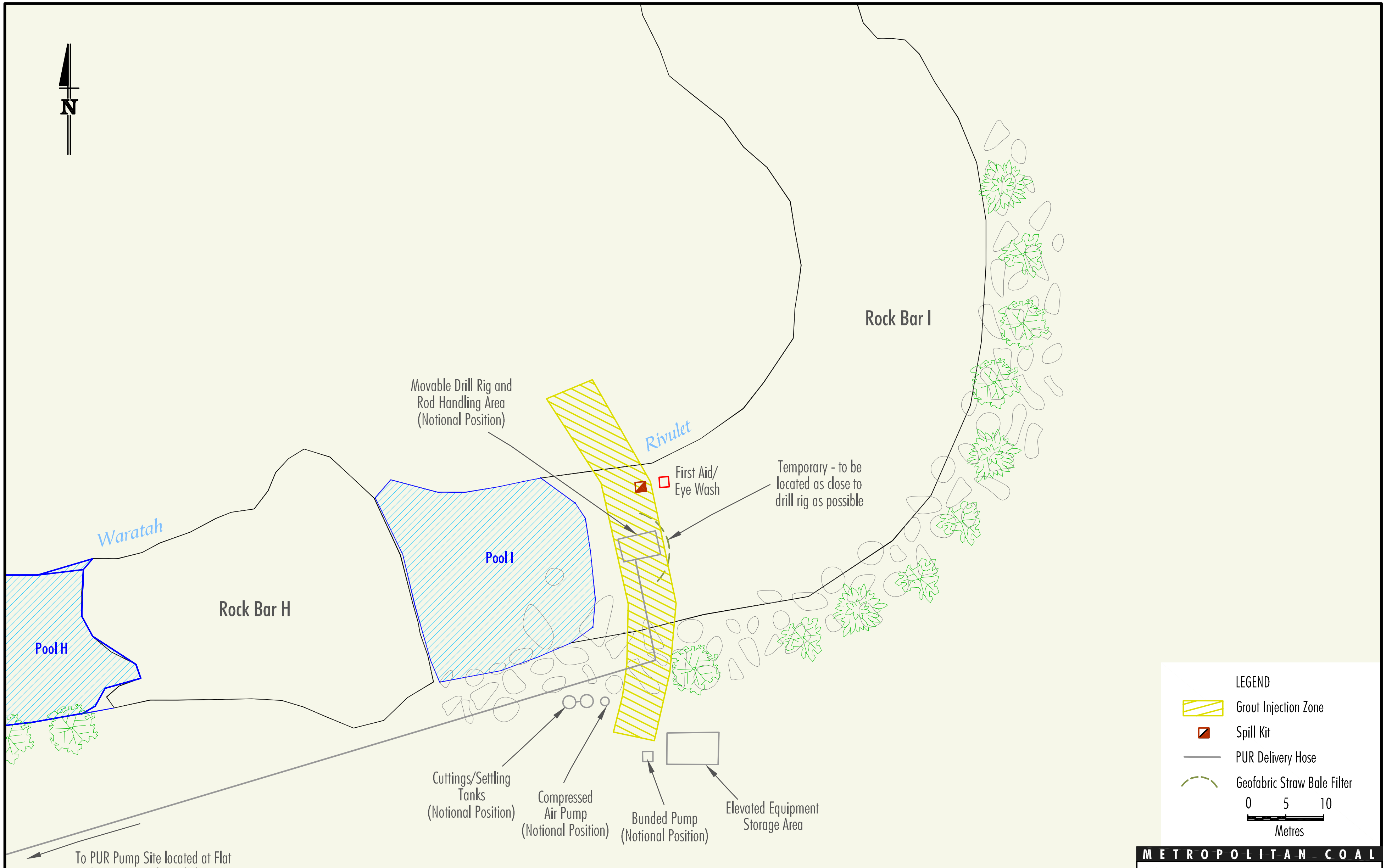


FIGURE 4-1D

Stream Remediation Plans
Rock Bar I (Site A)

MET-08-AD7 RMP_114B

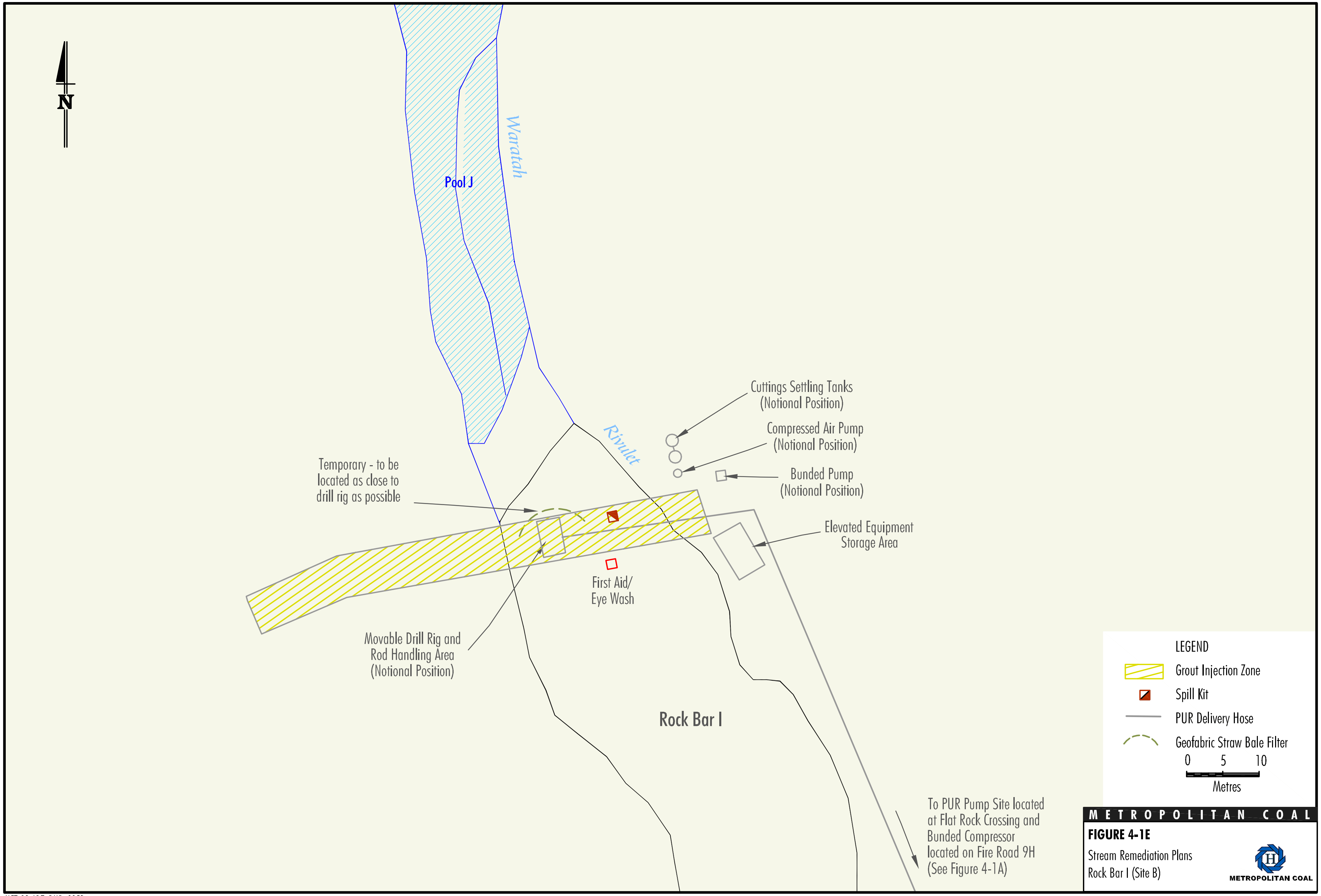
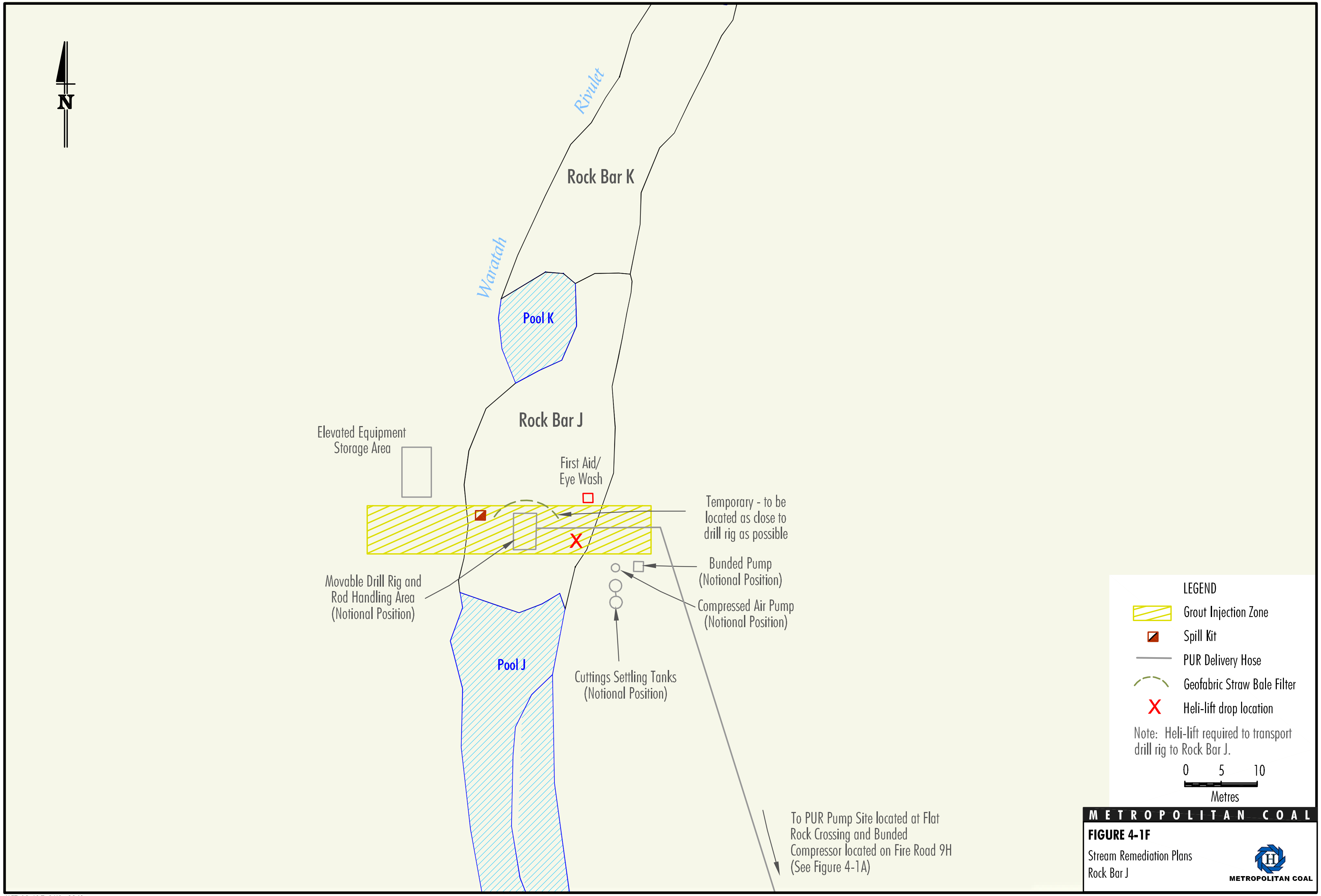


FIGURE 4-1E

Stream Remediation Plans
Rock Bar I (Site B)

MET-08-AD7 RMP_115B



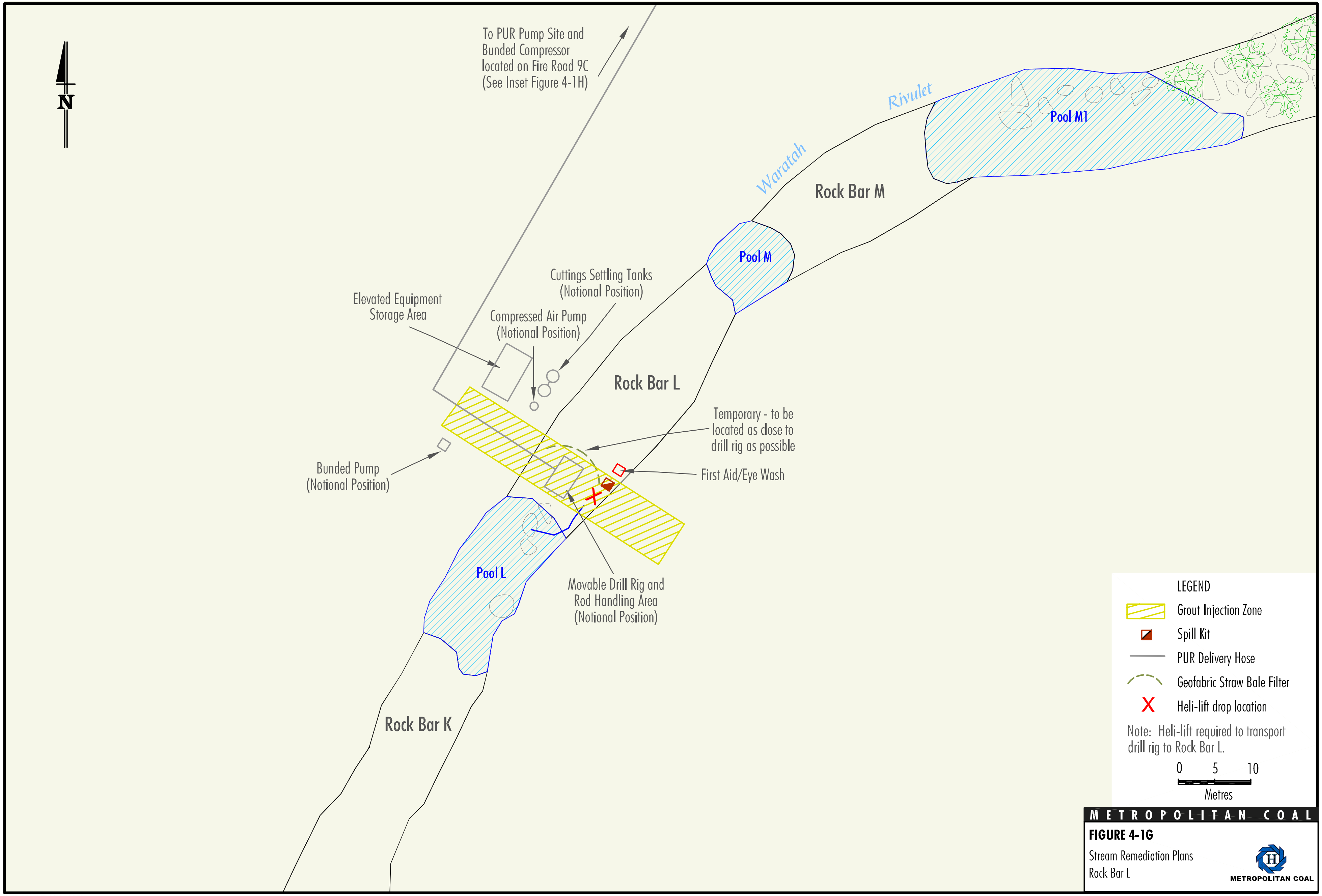
METROPOLITAN COAL

FIGURE 4-1F

Stream Remediation Plans
Rock Bar J

METROPOLITAN COAL

MET-08-AD7 RMP_116B



METROPOLITAN COAL

FIGURE 4-1G

Stream Remediation Plans
Rock Bar L

METROPOLITAN COAL

MET-08-AD7 RMP_117B

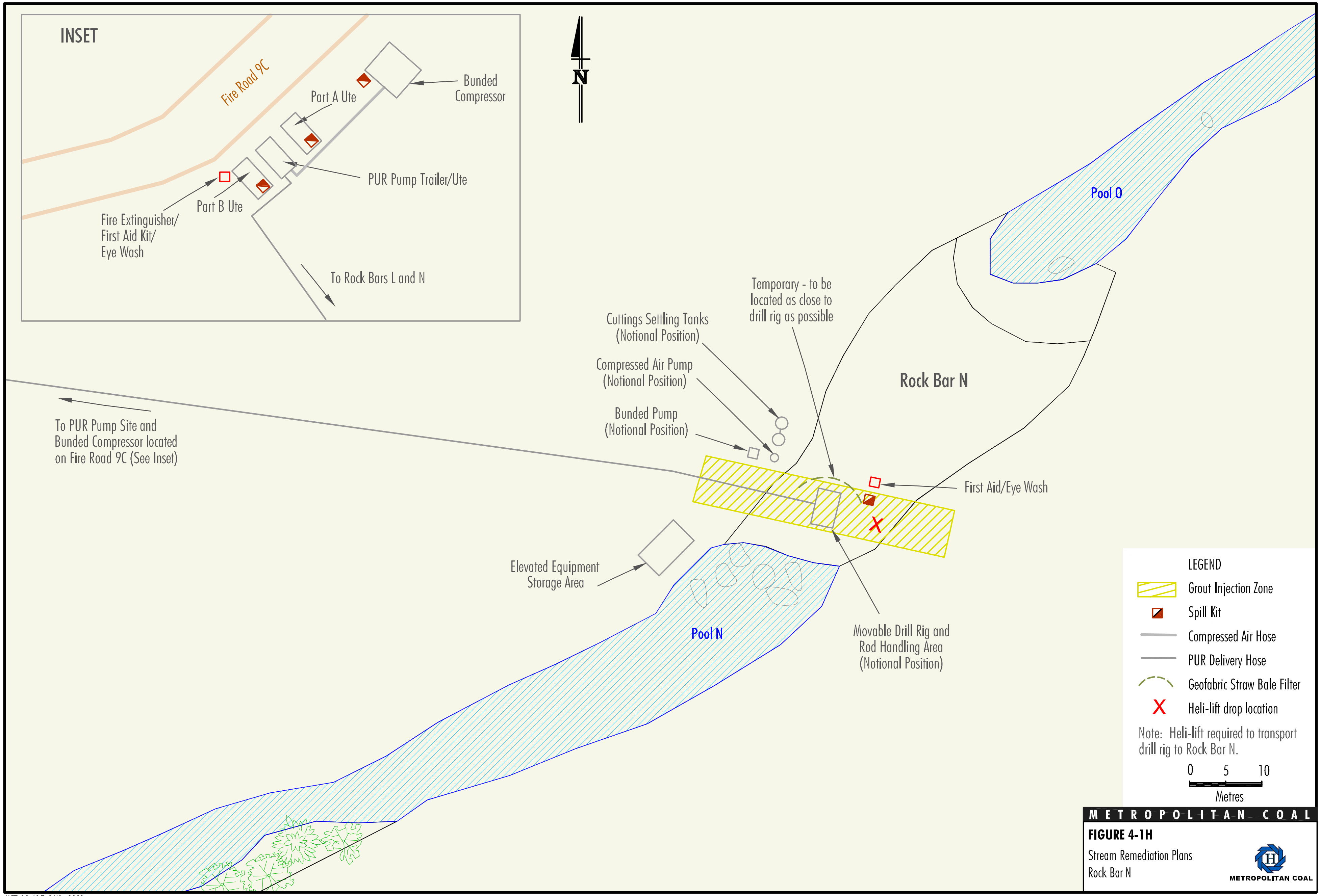
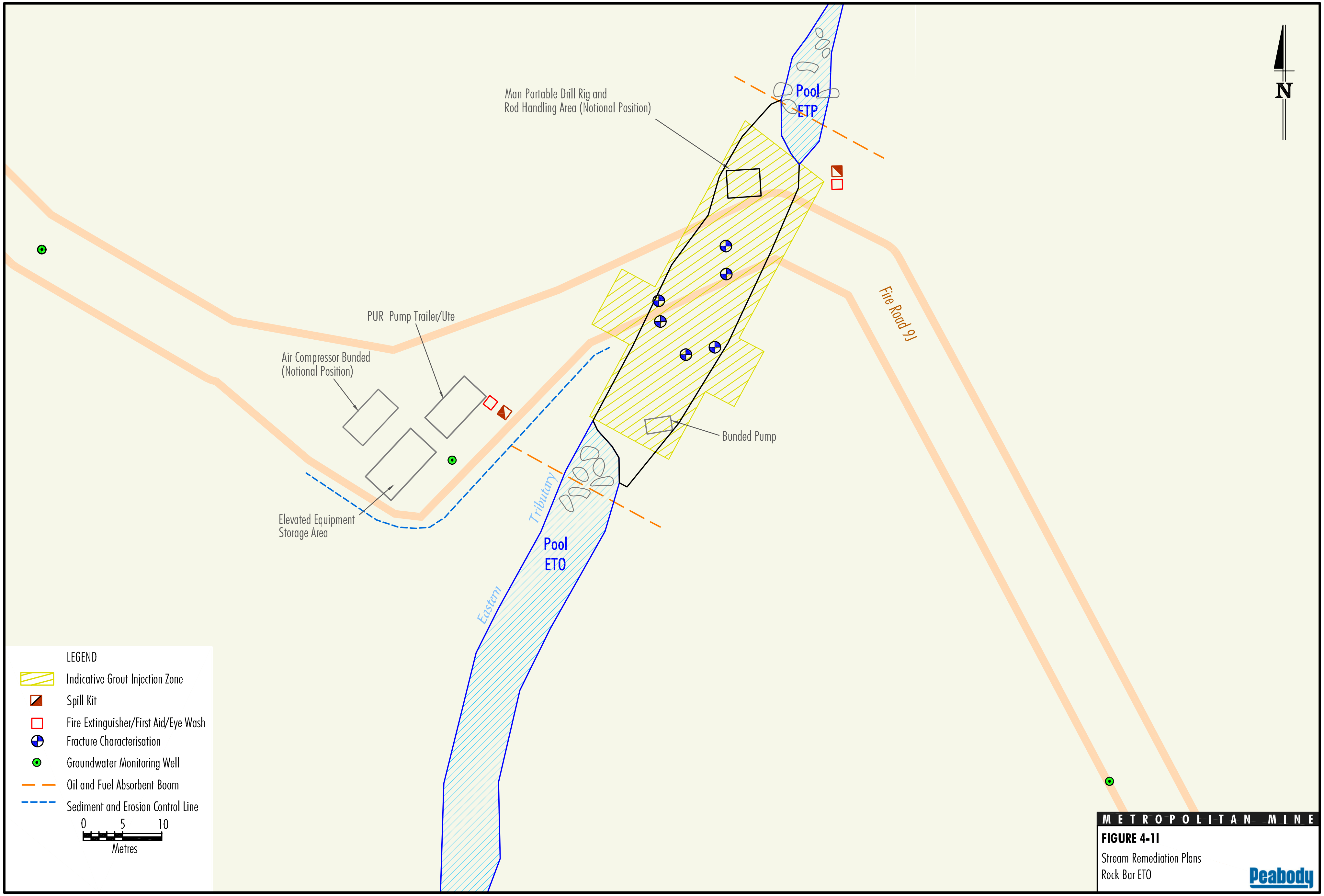


FIGURE 4-1H

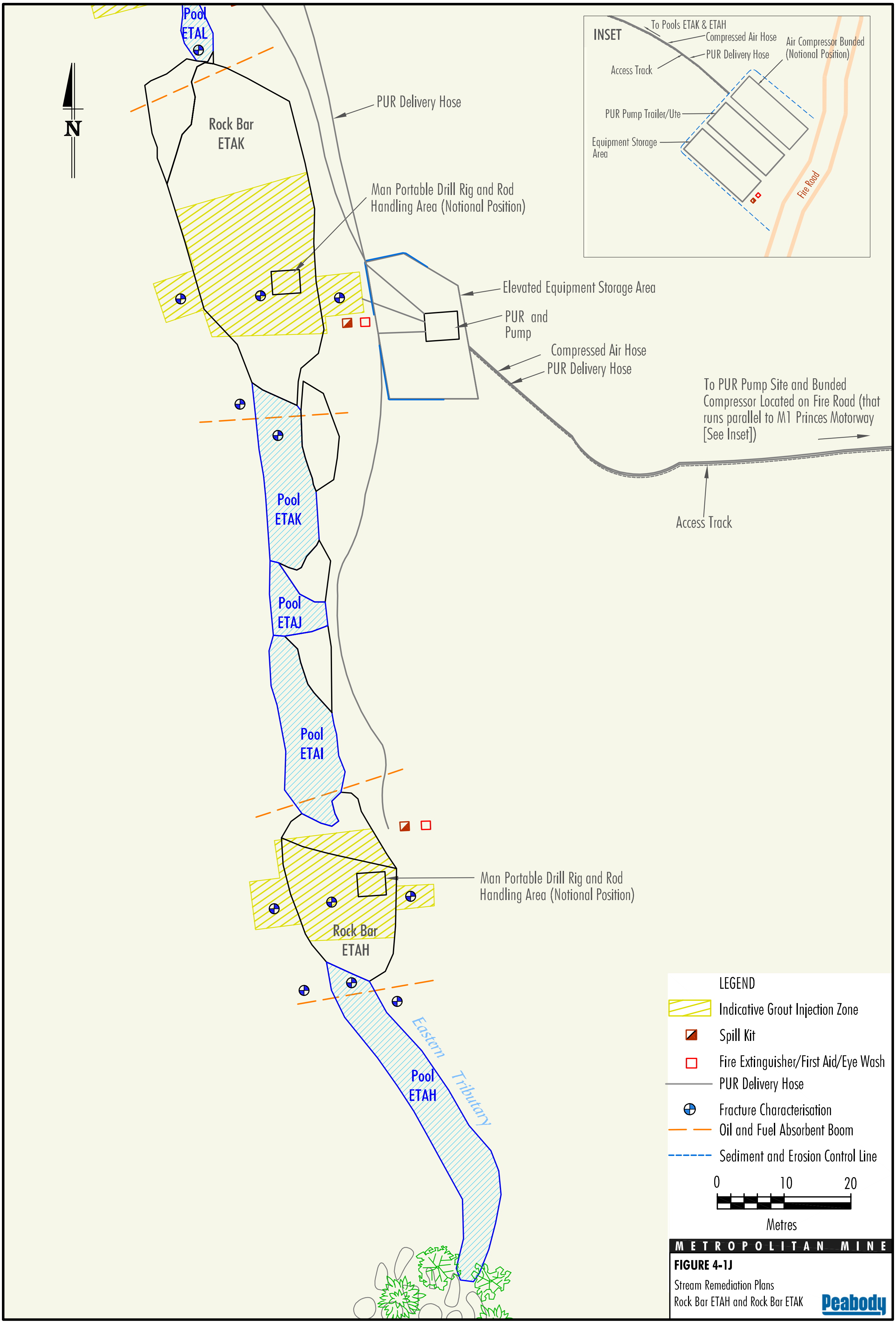
Stream Remediation Plans
Rock Bar N

METROPOLITAN COAL

MET-08-AD7 RMP_118B



MET-15-10 SRP 2021_101D



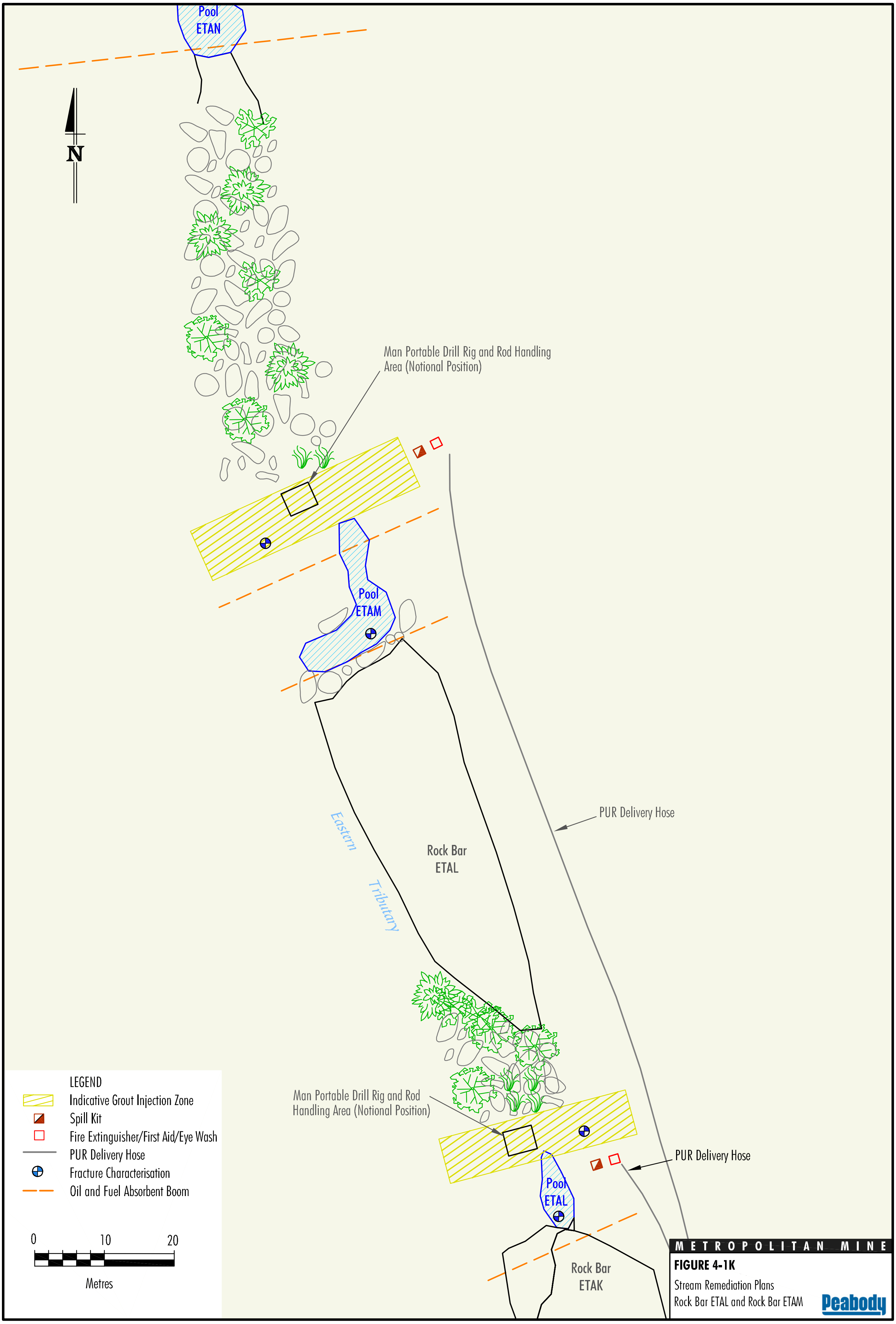
METROPOLITAN MINE

FIGURE 4-1J

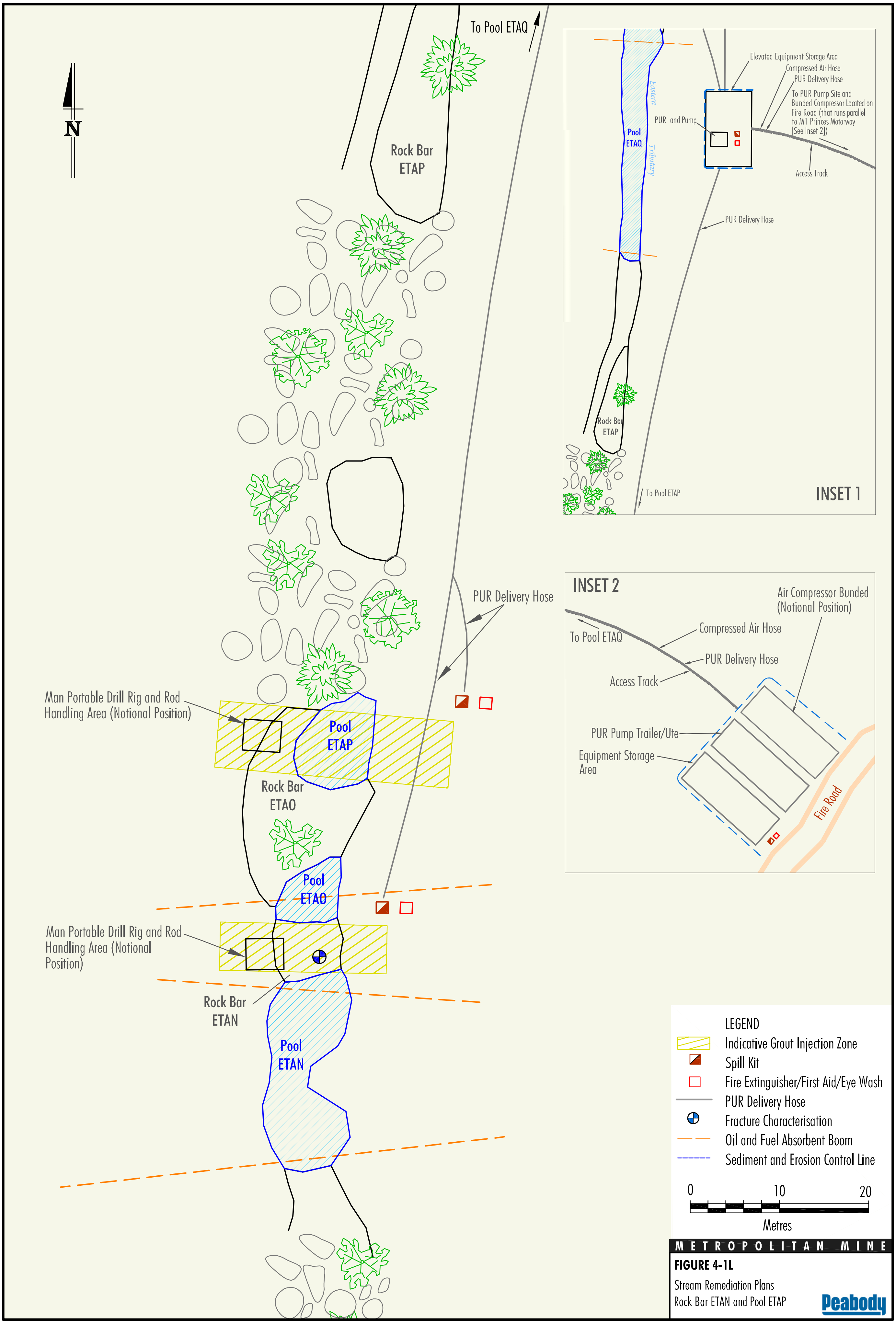
Stream Remediation Plans
Rock Bar ETAH and Rock Bar ETAK

Peabody

MET-15-10 SRP 2021_101D



MET-15-10 SRP 2021_101D



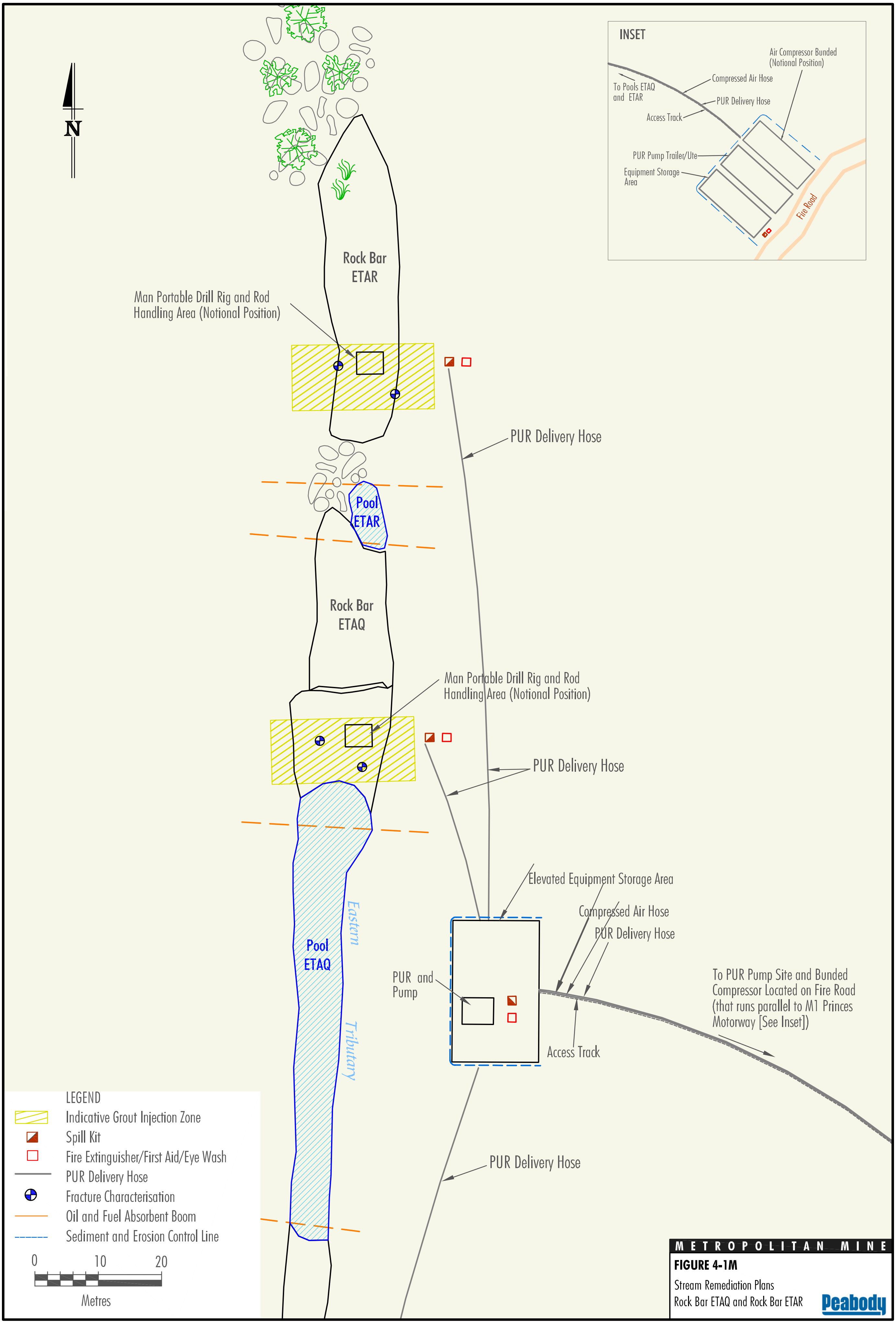
METROPOLITAN MINE

FIGURE 4-1L

Stream Remediation Plans
Rock Bar ETAN and Pool ETAP

Peabody

MET-15-10 SRP 2021_101D



MET-15-10 SRP 2021_101D

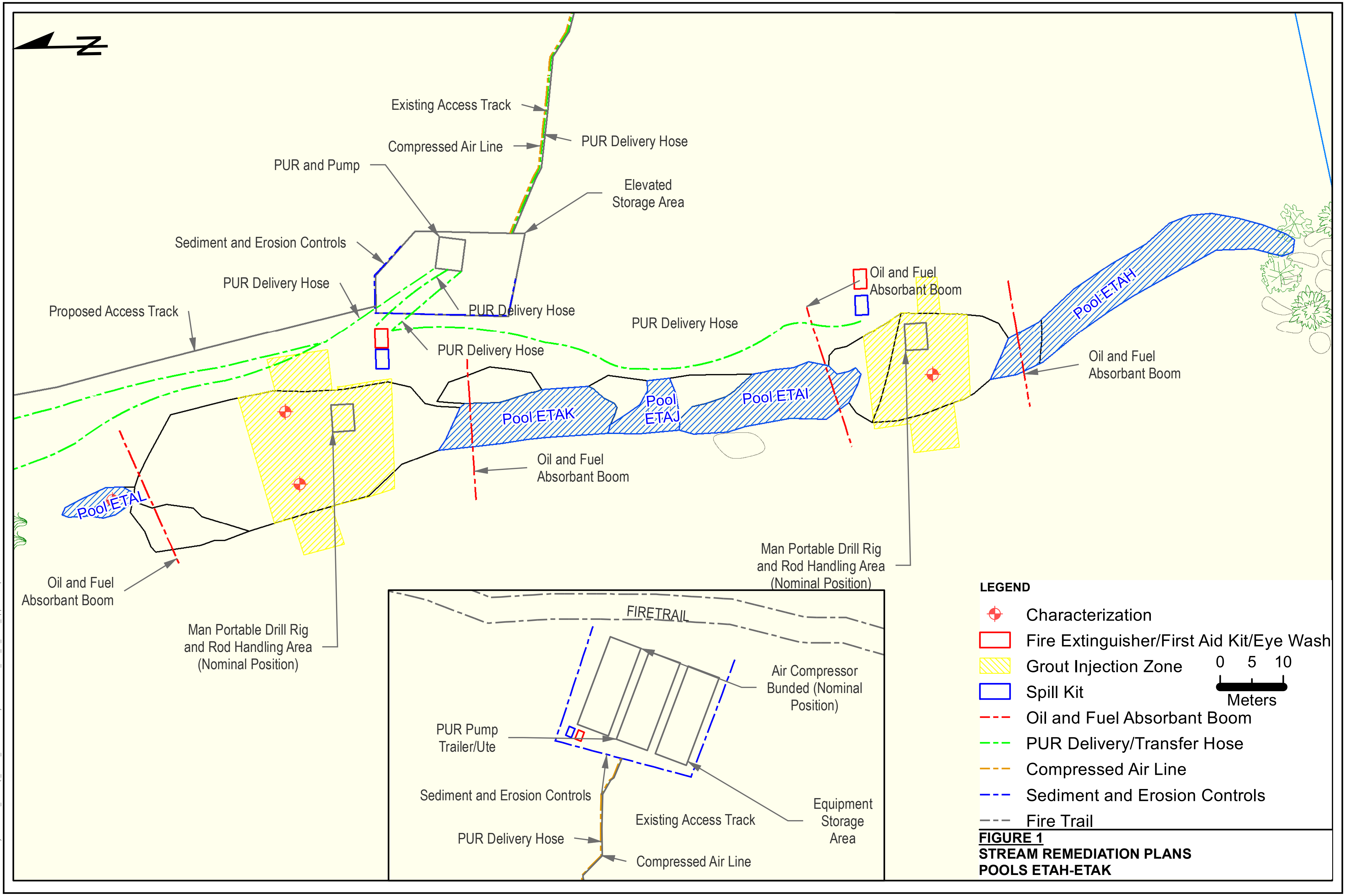


FIGURE 1
STREAM REMEDIATION PLANS
POOLS ETAH-ETAK

PATH: V:\Peabody\20139555_EastTrip_ETAH_ETAK\GIS\Project\20139555_005_M_RevB_ApprovalMaps.mxd PRINTED ON: 2021-06-01 AT: 2:13:23 PM

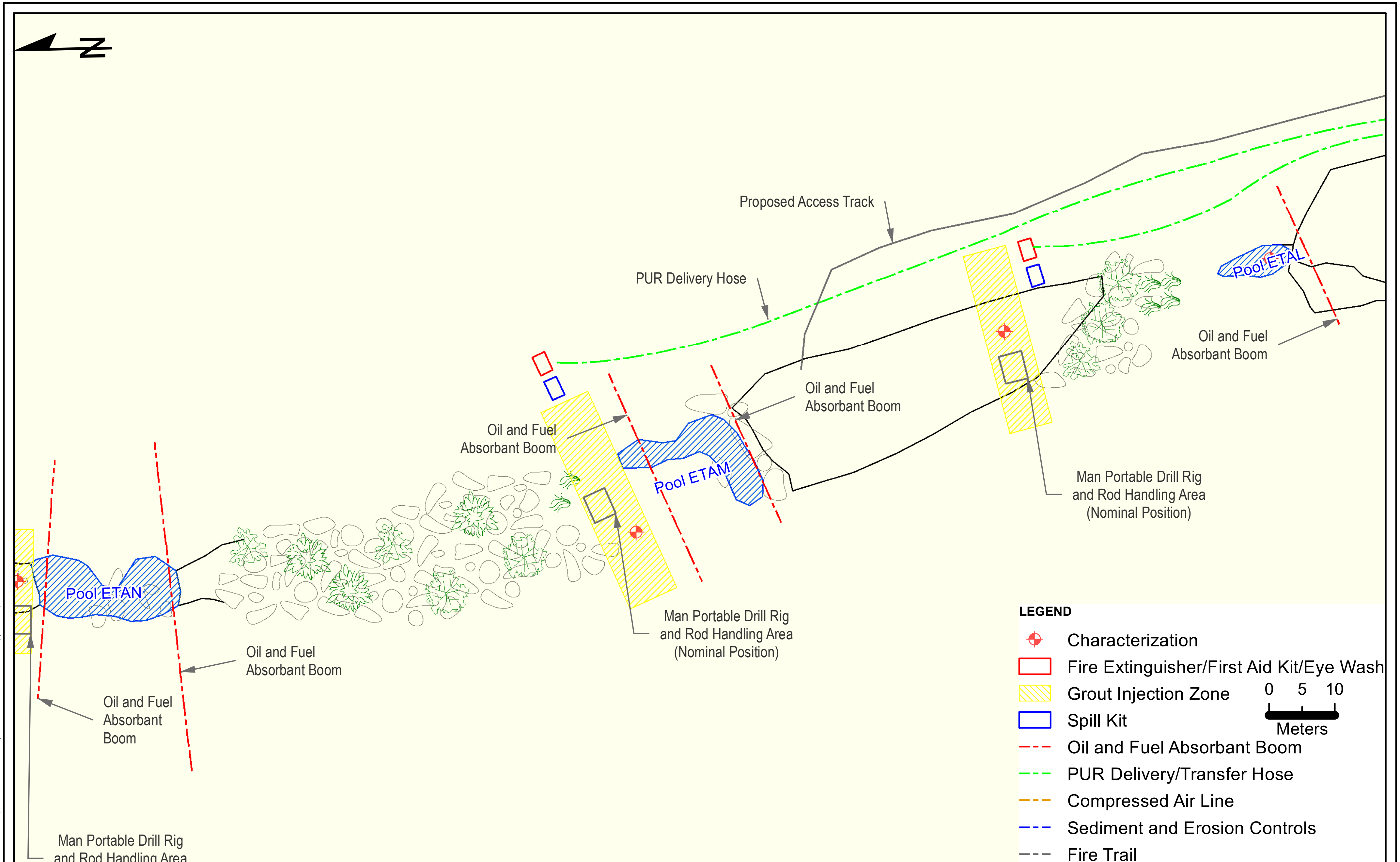
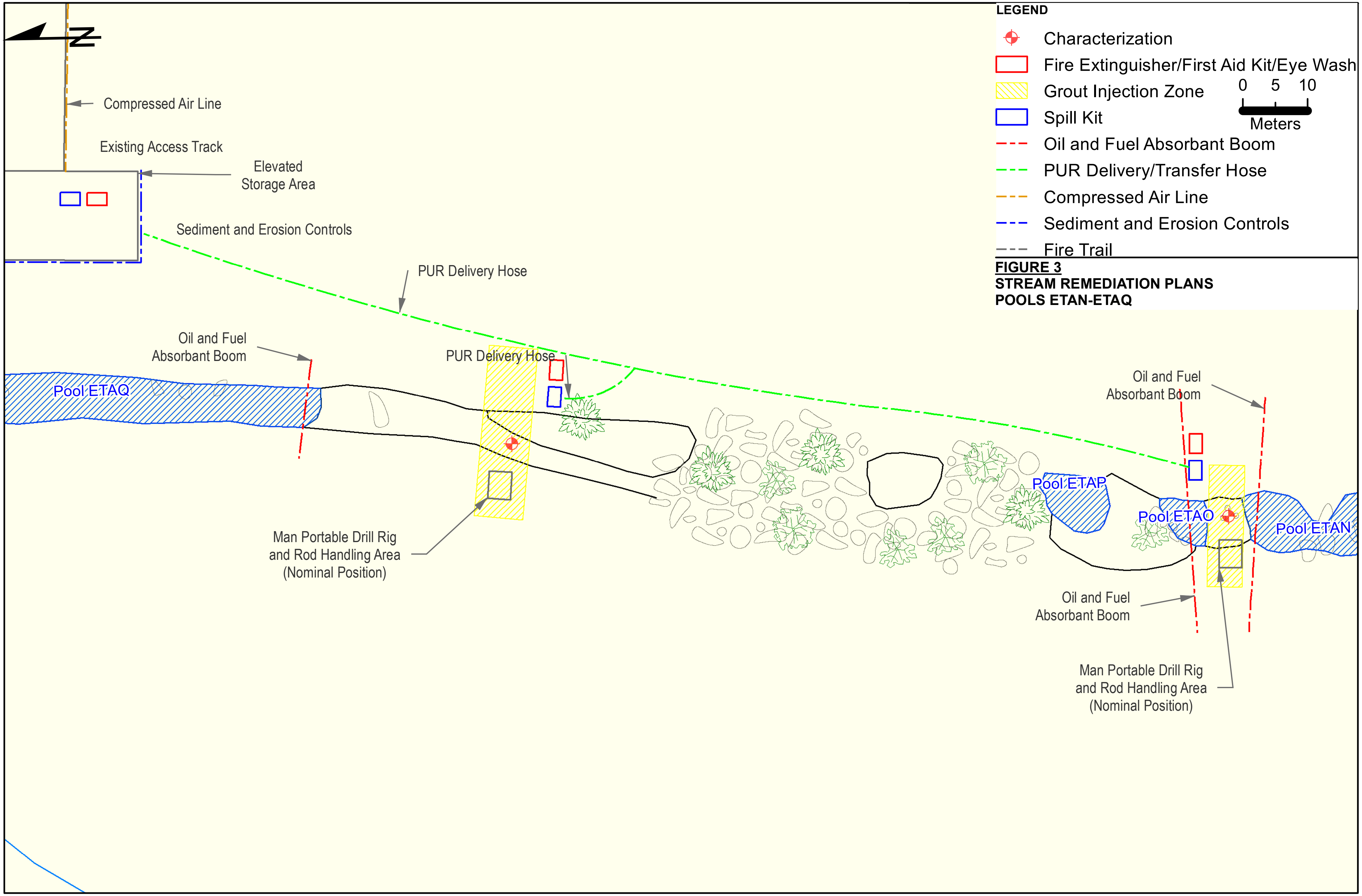


FIGURE 2
STREAM REMEDIATION PLANS
POOLS ETAL-ETAN

PATH: V:\Peabody\20139555_EastTrip_ETAH_ETAK\GIS\Project\20139555_005_M_RevB_ApprovalMaps.mxd PRINTED ON: 2021-06-01 AT: 2:15:23 PM



LEGEND

- Characterization
- Fire Extinguisher/First Aid Kit/Eye Wash
- Grout Injection Zone
- Spill Kit
- Oil and Fuel Absorbant Boom
- PUR Delivery/Transfer Hose
- Compressed Air Line
- Sediment and Erosion Controls
- Fire Trail

FIGURE 3
STREAM REMEDIATION PLANS
POOLS ETAN-ETAQ

PATH: V:\Peabody\20139555_EastTrip_ETAH_ETAK\GIS\Project\20139555_005_M_RevB_ApprovalMaps_F003.mxd PRINTED ON: 2021-06-01 AT: 2:18:05 PM

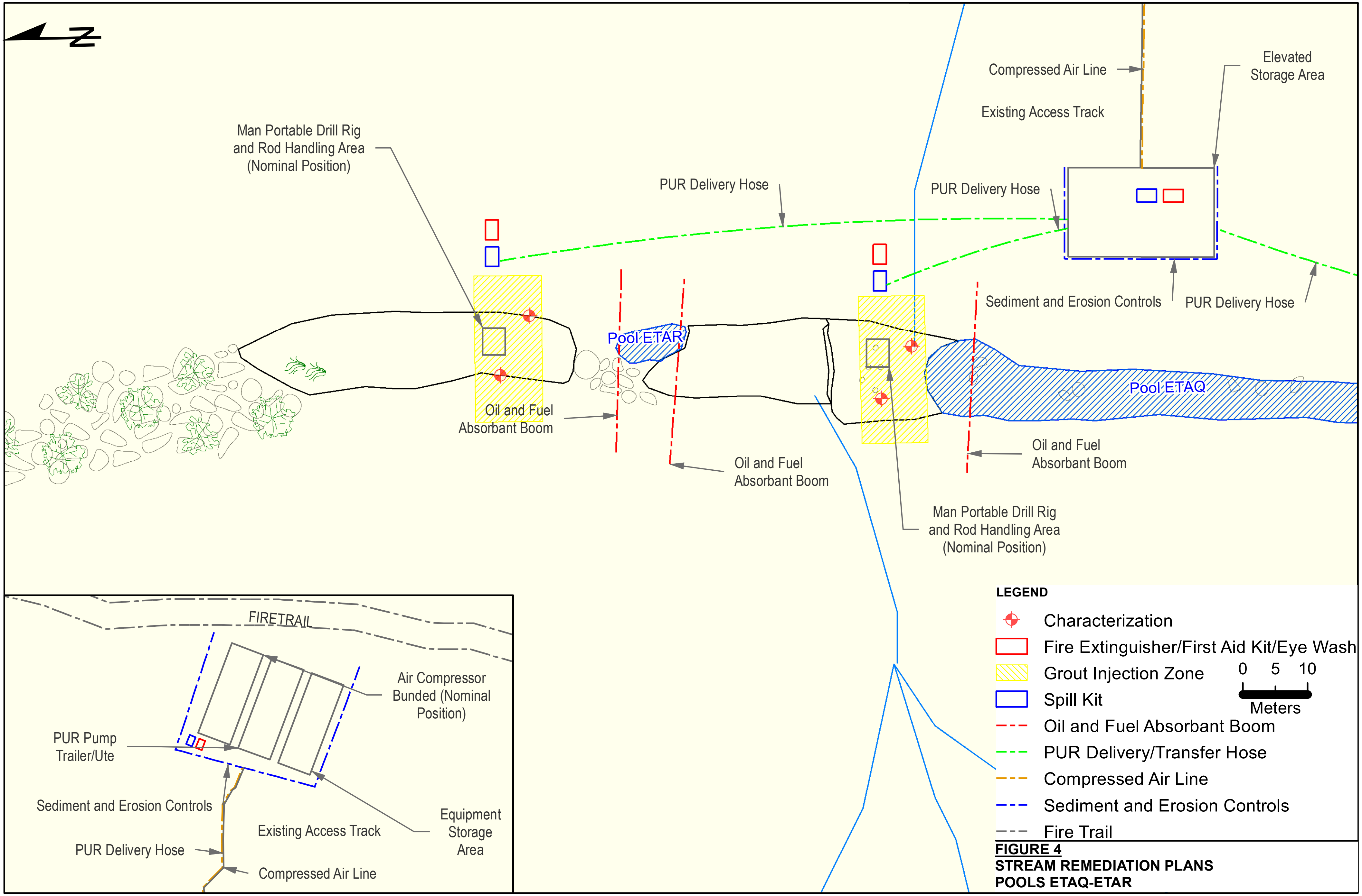


FIGURE 4
STREAM REMEDIATION PLANS
POOLS ETAQ-ETAR

PATH: V:\Peabody\20139555_EastTrip_ETAH_ETAK\GIS\Project\20139555_005_M_RevB_ApprovalMaps.mxd PRINTED ON: 2021-06-01 AT: 2:25:48 PM

ATTACHMENT 2

DESK TOP RISK ASSESSMENT OF A POLYURETHANE INJECTION RESIN PRODUCT SPETEC H100 FOR WARATAH RIVULET REMEDIATION AT THE METROPOLITAN COLLIERY

Desk Top Risk Assessment of a Polyurethane Injection Resin Product Spetec H100 for Waratah Rivulet Remediation at the Metropolitan Colliery

Report
By
Barry Noller

Principal Research Fellow
Centre for Mined Land Rehabilitation
The University of Queensland
QLD 4072

14 January 2014

For

Golders Associates Pty. Ltd.
124 Pacific Highway
St Leonards NSW 2065
Australia

SMI CMLR
Centre for Mined Land Rehabilitation

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

SMI CMLR
Centre for Mined Land Rehabilitation

Correspondence in relation to this report contact
Associate Professor Barry Noller
Centre for Mined Land Rehabilitation
Sustainable Minerals Institute
The University of Queensland, QLD 4072
Australia
Tel: 073346 4050 ; Fax: 07 3346 4056 ;
Mobile 0418 793 063
Email: b.noller@uq.edu.au

For other business enquiries contact
Ms Tracey Gregg
Centre Manager – Centre For Mined Land Rehabilitation
Sustainable Minerals Institute
The University of Queensland, QLD 4072 Australia
Tel: 07 3346 4039; Fax: 07 3346 4064
Email t.gregg@uq.edu.au

SMI CMLR
Centre for Mined Land Rehabilitation

Centre for Mined Land Rehabilitation (CMLR)

CMLR (www.cmlr.uq.edu.au)

At the forefront of research, education and technical expertise, the Centre for Mined Land Rehabilitation (CMLR) is leading the way we think about mining environmental management.

CMLR is involved in a broad range of research and training projects with mining companies, industry bodies and government departments from across Australia and the world.

As a part of one of the largest universities in the world, the CMLR has a team of highly skilled professionals focusing on the key issues facing modern mining and minerals processing industries.

A member of the Sustainable Minerals Institute (previously the Sir James Foots Institute of Mineral Resources), the Centre was established at The University of Queensland in 1993 and has built on more than twenty years involvement with the mining and minerals industries.

CMLR and the Sustainable Minerals Institute (www.smi.uq.edu.au)

The Sustainable Minerals Institute (SMI) was established in 2001 as a joint initiative between the Queensland Government, The University of Queensland and the Minerals Industry. The proposed development was to build upon the existing expertise within the various centres and departments and provide and over-arching framework for progressing Minerals Industry Research, Education and Training activities.

The CMLR is the sole provider of environmental mining management within the University and has established for itself and the SMI a reputation of national and international significance.

Our Location

The CMLR is situated on the 5th floor of the Sir James Foots Building (No 47A) at the University of Queensland, St Lucia campus (www.uq.edu.au).

Table of Contents

1. Scope of Work

CMLR was commissioned by Golders Associates Pty Ltd to undertake a desk top risk assessment of a polyurethane injection resin product for remediation activities on Waratah Rivulet at the Metropolitan Colliery, NSW. The details of the consultant are given in Appendix 1.

This report gives a summary of the review of information undertaken on the polyurethane injection resin product Spetec H100 using a risk-based approach. The desk-top risk assessment takes into account potential concerns that injection products may affect the Waratah Rivulet with respect to: (i) water supply; and (ii) ecological health. The report also makes comparison with the polyurethane injection resin product previously used at Waratah Rivulet.

2.0 Background

2.1 Metropolitan Colliery

Metropolitan is a coal mine with extensive underground workings and is located 31 km north of Wollongong, New South Wales, Australia. The Metropolitan mine is operated by Peabody Energy Australia Pty Ltd.

An artifact of the underground coal mining has been subsidence of creek beds that are located within or proximal to the mining area (NSWDP 2007). These impacts may affect the hydrology of creeks (e.g. sub-surface flow and water quality) and subsequently the ecology. Techniques to repair cracks in creek beds were investigated and trials undertaken (Noller 2007a; Noller 2007b; Noller and Edraki 2008). An alternative polyurethane injection resin product, Spetec H100, is now being considered and compared with the previously used products.

2.2 Review Objectives

This report considers the risks associated with use of Spetec H100 polyurethane injection resin product for grouting application to seal cracks generated by subsidence from underground mining.

The use of the polyurethane injection resin product needs to be undertaken in a manner which precludes or minimises deleterious effects on the environment and human health during application and from their long term placement.

2.3 Risk-based Approach

The risk assessment procedure, which is generally adopted (eNHealth 2012), considers the following steps:

- Hazard identification
- Dose response assessment
- Exposure assessment

Risk characterisation then enables the estimation of any adverse effect to be identified and to provide a means of devising risk management if appropriate. Risk management can then be applied on the basis of the assessments given below.

Risk assessment is a process that enables management and communication tools to be developed to aid controlling any adverse effects of chemical applications (Ricci 2006). It comprises the discrete steps of identification of source and hazard, dose response, exposure and calculation of risk (ISO 2009). There are acceptable risk management concepts that will apply to public health and the environment arising from exposure to grouting materials when applied under controlled conditions as pure or mixed formulations.

In the risk assessment process, exposure studies of biota may need to take into account formulation of the grouting compounds and their bioavailabilities. The risks to the environment need to take into account effects on: (i) terrestrial species; and (ii) aquatic species (ANZECC/ARMCANZ 2000; Suter II 1995). Other key areas at Waratah Rivulet include exposure assessment from drinking water as this creek system lies within a water supply catchment of the Sydney Catchment Authority. Assessment of drinking water quality is undertaken by following the procedures outlined by the Australian Drinking Water Guidelines (ADWG 2011).

The currently accepted procedures in Australia of the Department of Health and Aged Care for human health (eNHealth 2012) and the USEPA of ecological health (USEPA 1998) enable the formalized approach of risk assessment to be applied when required. Calculation of dose, if applicable, enables recommendations to be made regarding safe criteria for public health and the environment. The understanding of risk assessment and implementation and management are two sequential steps where assessment is first undertaken followed by development of the management tool based on identified risks. In many cases a complete risk assessment may not be undertaken for practical reasons. For this reason decision making tools are developed to provide a risk-based approach that acts as a framework. The first step of risk assessment is hazard identification.

At Waratah Rivulet the important end points from any grouting application are considered to be the effects on the ecosystem health and to the downstream drinking water catchment area. Lower aquatic life forms such as macro-invertebrate species, algae, lichens and microbial species are likely to be most significant in Waratah Rivulet because species such as fish are relatively few.

The desk-top assessment takes into account potential concerns that grouting materials may affect the Waratah Rivulet with respect to: (i) water supply; and (ii) ecological health.

3.0 Review of Product Information

Resiplast NV (RP Industries) is a Belgium company located at Gulkenrodestraat 3,2160, Wommelgem, Belgium. Since its inception in 1963 RP Industries has developed a large number of resin systems for various industrial applications. With more than 40 years' experience and brand names including Spetec®, RP Industries is an established global market leader in the manufacture and development of synthetic resins and in special techniques for industry.

The polyurethane injection resin product manufactured by RP Industries and the subject of this desk top assessment is Spetec® H100.

3.1 Spetec H100

3.1.1 Composition and properties

Spetec H100 is a 'single component' universal PUR H100 which uses PU H100 and PU H100 ACC mixed *in-situ* to give a solvent-free polyurethane pre-polymer for single-shot injection for water cut-off in geological and other structures and filling of water bearing cavities (Appendix 2). Spetec H100 is specifically designed for rapid water stopping and ground stabilisation. This resin is designed for control of high volume water ingress, stabilisation of fractured rock, sands and gravels and land-fill materials, void filling and repair of concrete structures. The end product polyurethane that is harmless to the environment and resistant to biological attack; i.e. it is biologically inert.

Spetec H100 is comprised of two parts, PU H100 (Appendix 3), uncured and PU H100 ACC (Appendix 4), which are mixed in an injection pump that can pump the mixture into an appropriate single-shot injection system. Spetec PU H100, uncured and PU H100 ACC, accelerator for PU 100 are very hygroscopic and are packed under a dry atmosphere. They are stored at 20^0C in their original unopened containers with a suggested shelf-life of at least 12 months. Before using PU H100 ACC is always shaken well to make sure the mixture is homogenous in the chosen ratio (from 2% - 10%). Once opened containers should be used as soon as possible.

Spetec PU H100 is a liquid with <50% of 4,4'-dimethylmethanediisocyanate which is appears to be the same as 4,4'-diphenylmethanediisocyanate (MDI) as both names are used (Appendix 3); it is a brown in colour with a viscosity of 150-250 mPas and density of 1.05-1.15 kg/m^3 at 20^0C. The MDI is considered to be harmful by inhalation, irritating to eyes, respiratory system and skin. The MDI has limited effect on aquatic and terrestrial biota in the environment (European Communities 2005, World Health Organisation [WHO] 2001) because of MDI's virtual insolubility in water (< 0.02 mg/L) and its high reactivity in water (lifetime less than 1 minute) (European Communities 2005, WHO 2001). The mixed polyurethane resin penetrates the structure to be sealed and the major part of water is displaced due to the hydrophobicity and the viscosity of the resin. Traces of water make the resin foam. The cured resin is resistant against many acids, alkalis, salt brines as well as organic solvents and 1 year of storage in air, water, sulfuric acid and sodium hydroxide solution showed no swelling nor shrinking.

Spetec PU H100 ACC is a pale yellow liquid with >20% of 1-dodecamin-N,N'-dimethyl and an odour of ammonia; it has a viscosity of 10-15 mPas at 25^0C, a density of 0.95 kg/m^3 at 20^0C and is not soluble in water (Appendix 4). PU H100 ACC is an accelerator for PU H100 and should be handled in a well-ventilated area. The product can penetrate the skin and if not removed at once will cause local burns after its removal. Contact with the eye may cause severe damage if not treated at once. The acute effect of ingestion is mainly due to the corrosive properties of the product. Long-term and continuous exposure may cause sensibility by skin contact.

3.1.2 Effect on water supply

Leaching experiments with cold water on the resin were undertaken by Hygiene-Institut des Ruhrgebiets (1998) (Appendix 5). Test plates coated with Spetec LH/H100 polyurethane resin were brought in contact with cold water according to the UBA (Umweltbundesamt - German Federal Environment Agency) - guideline for the hygienic assessment of organic coatings in contact with drinking water and met all requirements (Hygiene-Institut des Ruhrgebiets 1998). Test plates coated with Spetec LH/H100 resin in contact with water at 20^0C showed maximum total organic carbon (TOC) (12 mg/m^2xd) and free chlorine (15 mg/m^2xd) removals following Days 1-3 and were at similar levels following Days 7-9 (Hygiene-Institut des Ruhrgebiets 1998). The value for organic migrations on 3 samples had a value of 0.01 mg/m^2xd. Formaldehyde, phenol and primary aromatic amine all showed removals at detection limits (Hygiene-Institut des Ruhrgebiets 1998) and were insignificant in the context of hazards in drinking water.

The test water samples were examined according to the following parameters: appearance (colour, transparency, odour, taste and tendency to foam) and total organic carbon (TOC) (Hygiene-Institut des Ruhrgebiets 1998).

Additional tests were undertaken on Spetec H100 test polyurethane material leaching in water (Universiteit Gent, 2003; Appendix 6) for odour (nil), taste (nil), colour (nil) turbidity (0 FNU), COD (after 72 hours was <10 mg O_2/L the norm) and global migration of organic compounds (3.82 mg/dm^2 and < norm of 10 mg/dm^2).

The results indicate:

- Examination of the leachate showed that odour was nil to slight.
- Colour, transparency, turbidity and tendency of the test water samples to foam were unaffected.

- The release of organic compounds determined as TOC was still evident at Days 7-9 and may have reflected a background level of TOC in the test water. COD and global migration of organic compounds on more recent testing were less than the norm values.
- The test water was additionally checked for aromatic amines and were not detected.
- The lack of any apparent leaching indicates that the current approach recommended by the *Australian Drinking Water Guidelines* (ADWG, 2011), based on the identification of hazards and having barriers in place to minimise dispersion, is unlikely to cause any risks from grouting application with application of Spetec H100 in the Waratah Rivulet, provided proper application procedures are followed.

3.1.3 Ecological effects

The influence of Spetec H100 polyurethane resin in water was evaluated for ecological effects by the response of coliforms (Universiteit Gent, 2003). The material did not control the stimulation of bacteriological growth.

The aquatic toxicity of Spetec H100 to both bacterial (EC50) and fish (LC50) are reported to be >300 mg/L (Appendix 3).

The results for the available aquatic toxicity test date for Spetec H100 is similar to earlier studies (Noller 2007a) and implies that the lower life forms in the Waratah Rivulet will be most significant with respect to any toxicity effects if Spetec H100 resin is to be used for grouting purposes.

For an average flow of 210 L/sec and depth of 250 mm in Waratah Rivulet contact with the surface of a typical grout (10mX300mm) will require a volume of 840 L to achieve the safe dilution of 1:4 found for aquatic test species (Noller 2007a). This volume compares with 2500 L needed to dissolve the MDI from a 1mm thickness of the grout and indicates that the actual dilution in creek water required is low (Noller 2007a). Flowing stream conditions favour degradation of leached grout constituents by bacterial degradation and are clearly different to those for laboratory tests.

3.1.4 Hazards associated with application

Reference should be made to the Material Safety Data Sheets (Appendices 3 and 4) for safety measures. Avoid contact with skin and eyes by using the required personal protective equipment, such as overalls, gloves and eye goggles. If contact with skin occurs, wash thoroughly using soap and water. If contact with eyes occurs, rinse thoroughly with running water and seek medical advice. The cured products are harmless. Uncured products should be prevented from entering local drainage system and water courses. Spillage must be collected using absorbent materials such as sawdust and sand, and dispose of in accordance with local regulations.

Because of the potential occupational health hazard of handling Spetec PU H100, suitable protective clothing, gloves and eye/face protection must be worn. Medical advice must be sought in case of an accident. Before processing the product should be stored at the temperature of the site of application. Storage, shelf life is at least 6 months from the date of delivery. Liquid residues should be disposed of properly.

4.0 Discussion

The test results for the Spetec H100 polyurethane injection resin product indicate that some initial ecotoxicity exists. However the toxicity is not considered to be a major response. It appears that the toxicity is arising from other additives than the 4,4'-diphenylmethane diisocyanate (MDI) in the formulation, as the isocyanate component has a short lifetime in water as indicated in Section 3.1.

Comparison of the test results for the previously used grouting materials (Noller 2007a) with those for the Spetec H100 polyurethane injection resin product shows little difference.

Estimations of the dilutions achieved from leaching of grouts, typically 10mX300mm, by average creek flow of 210 L/sec show that volumes of 640-840 L, depending on the product used, will achieve safe dilution. In the absence of creek flow there is no downstream impact.

Once cured, the polyurethane resins and filling foam are very inert and are considered to be useful materials.

5.0 Conclusions

The desk-top assessment of the Spetec H100 polyurethane injection resin product, proposed for sealing cracks in Waratah Rivulet at the Metropolitan Colliery, NSW, concludes that the use of this material requires adherence to its specific handling procedures in order that it can be applied properly. Spetec H100 polyurethane injection resin product gives similar test results to the grouting material previously used at Waratah Rivulet.

An impact on downstream water supply from polyisocyanate compounds is unlikely as these compounds break down rapidly. The impact of creek waters passing over grouts on downstream aquatic biota is also unlikely as sufficient dilution is achieved by average creek flow exceeding the dilutions necessary to avoid toxic responses.

6.0 Limitations

CMLR has prepared this report for the use of Golders Associates Pty Ltd. It is prepared in accordance with the scope of work.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

The methodology adopted and sources of information used by CMLR are outlined in this report. Our conclusions are based upon the analytical data presented in this report and our experience. Opinions and recommendations presented herein apply to the information available at the time of our investigation and cannot necessarily apply to matters of which CMLR is not aware and has not had the opportunity to evaluate.

7.0 References

ADWG (2011) *Australian Drinking Water Guidelines - National Water Quality Management Strategy.* The National Health and Medical Research Council Canberra.

ANZECC/ARMCANZ (2000) *Australian Water Quality Guidelines for Fresh and Marine Water Quality.* Australian and New Zealand Environment and conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

eNHealth (2012) *Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards.* Department of Health and Aged Care and eNHealth Council: Canberra, 2012.

European Communities (2005*) Methylenediphenyl Diisocyanate (MDI)* Volume 59 European Union Risk Assessment Report. Office for Official Publications of the European Communities, Luxembourg.

Hygiene-Institut des Ruhrgebiets (1998) *Spetec LH/H100 auf Polyurethan-Basis.* PRUFBERICHT gemass KTW-Empfehlung der Arbeitsgruppe "Trinkwasserbelange" der Kunststoff-Kommission des Bundesgesundheitsamtes. Gelsenkirchen Germany. pp 1-3.

ISO (2009). *ISO 31000:2009, Risk Management - Principles and Guidelines*.ISO.

Noller, B.N. (2007a) *Risk Assessment of Potential Products for Waratah Rivulet Remediation at the Metropolitan Colliery.* Report for Helensburgh Coal Pty Ltd 16 March 2007. pp 1 – 22 + appendices.

Noller, B. (2007b) Leaching of CarboPUR WFA and WF by Waratah Rivulet creek water. Report prepared for Helensburgh Coal Pty Ltd. 8 September 2007. pp 1 - 29.

Noller, B.N. and Edraki, M. (2008) 40 Day Testing of PUR Grouting product. Report for Helensburgh Coal Pty Ltd 25 October 2008. pp 1 – 30.

Ricci, P. F., (2006) *Environmental and health risk assessment and management: principles and practices*. Springer: Dordrecht, NL.

NSWDP (2007). *Submission to Independent Expert Panel - Inquiry into NSW Southern Coalfield*. Available at http://www.planning.nsw.gov.au/planningsystem/pdf/southerncoalfieldinquiry_helensburgh_coal.pdf

Suter II, G. W., (1995) In *Fundamentals of Aquatic Toxicology*, 2 Ed, 803-816.

Universiteit Gent (2003) *Report of Analysis*. Laboratium voor levensmiddelentechnolgie en –proceskunde. Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen. Universiteit Gent, Belgium. pp 1-3.

USEPA (1998) *Guidelines for ecological risk assessment*; U.S. Environmental Protection Agency: Washington, DC, pp 188.

WHO (2001) *Diphenylmethane Diisocyanate (MDI)* Concise International Chemical Assessment Document 27 World Health Organization, Geneva.

8.0 Appendices

Appendix 1 Experience of Consultant

Associate Professor Noller has a PhD (1978) in Environmental Chemistry from the University of Tasmania. He worked as a Research Fellow at the Australian National University (1978-1980), Senior Research Scientist at the newly created Alligator Rivers Region Research Institute, Jabiru, Northern Territory (1980-1990) and then as Principal Environmental Chemist for the Department of Mines and Energy, Darwin Northern Territory (1990-1998). From 1998-2006 Professor Noller has been Deputy Director of the National Research Centre for Environmental Toxicology (ENTOX) – The University of Queensland, Coopers Plains, Qld. ENTOX has a strong involvement with the utilisation of the risk assessment process to deal with toxicological hazards, including in environmental systems. Since November 2006 Professor Noller has been appointed as Honorary Consultant and Associate Professor at the Centre of Mined Land Rehabilitation (CMLR) a centre of the University of Queensland based at St Lucia. The CMLR is part of the Sustainable Minerals Institute.

Professor Noller has been working and publishing in the field of environmental chemistry and industrial toxicology for the past 40 years and has presented 350 conference papers and published 170 papers. His professional activities undertaken at 4 different centres have covered processes and fates of trace substances in the environment, particularly in tropical environmental systems with special reference to risk management associated with their application and studies of the bioavailability of toxic elements in mine wastes, including waters. He has undertaken a number of consulting activities in Queensland, Tasmania, New South Wales, Western Australia and the Northern Territory and has undertaken a number of investigations at the Metropolitan Colliery since 2007. He was appointed in 2007 as Lead Author of the Australian Government Leading Practice Sustainable Development Program for the Mining Industry Handbook on Cyanide Management and was Project Leader for the Lead Pathways Study conducted at Mount Isa on behalf of Glencore Xstrata 2007-2013.

Appendix 2 Spetec Single component universal PUR H100

SINGLE COMPONENT UNIVERSAL PUR H100
water cut-off grout –cavity filling

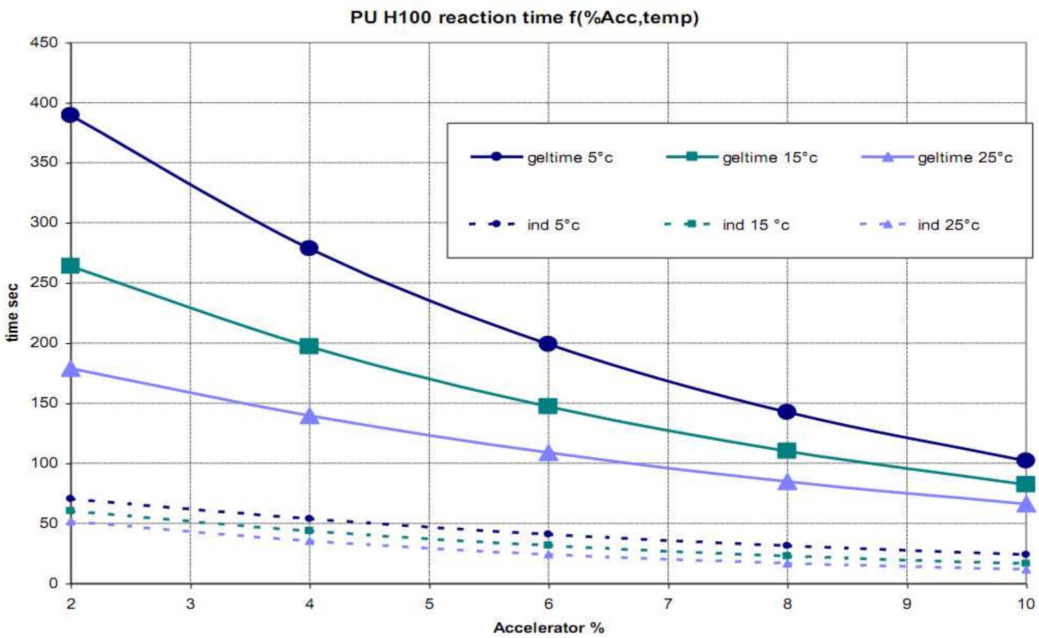
DESCRIPTION

- Solvent-free Polyurethane prepolymer for single-shot injection.

APPLICATIONS

- Injection resin for water cut-off in concrete, masonry structures and sandy soils, even when strong seepage or gushing water is encountered.
- Filling of water bearing cavities rapidly.
- Adaptable reaction velocity by varying accelerator content from 2% to 10%.
- Reaction with water results in formation of a rigid polyurethane foam that forms, with the substrate, a hydrophobic and chemically resistant conglomerate.
- Good compression strengths are obtained in a very short time without neither shrinking nor swelling.
- Solvent-free system: the end product is harmless to the environment and resistant to biological attack.

REACTION TIME VS TEMPERATURE



RESIPLAST N.V.
Gulkenrodestraat 3
B-2160 Wommelgem
☎ +32 (0)3 320 02 03
+32 (0)3 322 63 80
www.spetec.com
E-mail: info@spetec.com

PROPERTIES

PU H100, uncured			
Appearance		brown liquid	
Viscosity at 25°C	ASTM D4878-98	160 ± 20	mPa.s
Flashpoint	ASTM D1310-86	>150	°C
Relative Density at 25°C	ASTM D3505-96(2000)	1.08 ±0.005	

PU H100 ACC, Accelerator for PU H100			
Appearance		yellow clear liquid	
Viscosity at 25°C	ASTM D4878-98	15 ± 5	mPa.s
Flashpoint	ASTM D1310-86	>150	°C
Relative Density at 25°C	ASTM D3505-96(2000)	0.995 ± 0.003	

PU H100 + Accelerator cured			
Compressive Strength (confined)	ASTM D4219-93a	6,5	MPa
Tensile Strength	ASTM D1623-78	>2	MPa
Density (confined)	ASTM D-3574	1	Kg/dm³

AVAILABILITY

PU H100 and PU H100 ACC are very hygroscopic, therefore they are packed under dry atmosphere.
Stored at 20 °C in the original unopened containers, shelf life is at least 12 months.
Once opened, containers should be used as soon as possible.
PU H100 comes packed in either 200-kg steel drums or 20-kg metal pails.
PU H100 ACC comes packed in either 20-kg metal pails or 2-kg polyethylene bottles.

PROCEDURE

Before using PU H100 ACC always shake well to make sure the mixture is homogeneous.
Mix PU H100 and PU H100 ACC in the chosen ratio (from 2% to 10%).
Normal injection pumps can pump the mixture into an appropriate single-shot injection system.

SAFETY PRECAUTIONS

Avoid any contact with skin or eyes.
Follow safety precautions as indicated on our separate "Safety Data Sheet".
REACH complaint

ISO 9001 REGISTERED FIRM

The information in this data sheet has been given in good faith but without warranty. The application, use and processing of the products are beyond our control and therefore entirely your responsibility. Should, in spite of this, liability be established for any damages, it would be limited to the value of the foods delivered by us and used by you. We will of course provide products of consistent quality.
Date: 31/01/2013

RESIPLAST N.V.
Gulkenrodestraat 3
B-2160 Wommelgem
☎ +32 (0)3 320 02 03
Fax +32 (0)3 322 63 80
www.spetec.com
E-mail: info@spetec.com

Appendix 3 Spetec PU H100 Safety Data Sheet

SPETEC PU H100

1 Identification of substance and manufacturer/Supplier

a. Product details

Trade name : **SPETEC PU H100**

Application of the substance/preparation : *Polyurethane Resin*

b. Manufacturer/Supplier :

RESIPLAST N.V.
Gulkenrodestraat 3
2160 Wommelgem (Belgium)

Tel : + 32-(0)3 320 02 03
Fax : + 32-(0)3 322 63 80
http : www.spetec.com

c. Information : see chapter 16

d. Emergency telephone number : **+ 32-(0)3 320 02 04**

2 Hazards identification

Hazard designation X_n Harmful

Information pertaining to particular dangers for man and environment :

Harmful by inhalation	(R48/20)
Irritating to eyes, respiratory system and skin.	(R36/37/38)
Limited evidence of carcinogenic effect.	(R40)
May cause sensisation by inhalation and skin contact.	(R42/43)
Contains isocyanates, consult information presented by the manufacturer.	(R84)

3 Composition/Data on components

Chemical characterization :

a. Designation : Polyurethane prepolymer for crack injection.

b. Hazardous ingredients :

CASnr	EINECS	Omschrijving	%	Symbool	R-zinnen
101-68-8	202-966-0	4,4'-dimethylmethanediisocyanate	<50	Xn	48/20-36/37/38-40-42/43-84

(Relevant H-phrases : see chapter n° 16)

4 First aid measures :

a. Symptomes and effects :
Headache, dizziness, nausea, vomiting, irritation of skin and respiratory ystem.

b. General information :
Take affected person out of danger area and instruct to lie down. Instantly remove any clothing soiled by the product.
Seek medical help in all cases of doubt or if the sympthoms are persistent.

c. After inhalation :
Supply fresh air (or remove to fresh air), keep patient warm and at rest until any symptoms of respiratory irritation distress have disappeared. If rapid recovery does not occur obtain medical attention. If breathing has stopped or is laboured, give assisted respiration (e.g. mouth to mouth). Supplemental oxygen may be indicated.
Assure mucus does not obstruct airway. Turn victims head to the side.
In case of unconsciousness bring patient in a stable position for transport.

d. After skin contact :
Remove any contaminated clothing immediately. Remove the substance mechanically. Do no use solvent or thinner.
Immediately following skin contact, all affected areas should be washed thoroughly with soap and water (rinse thoroughly).

e. After eye contact :
Remove contact lenses. Rinse immediately with plenty of running water for at least 15 minutes. Eyelids should be held away from the eyeball to ensure thorough rinsing. Seek medical advice if there is any suspicion of eye damage or persistent irritation.

f. After ingestion :
DON'T INDUCE VOMITING.
Keep patient at rest. Seek medical advice immediately and show the label or the packaging.
Never give anything by mouth to an unconscious person.

g. Information for medical personnel :
Treat symptomatically.

5 Fire-fighting measures

a. Suitable extinguishing media :
CO2 , dry chemical powder. Larger fire with alcohol resistant foam.
b. For safety reasons unsuitable extinguishing agents :
Water jet (reacts with MDI)..
c.Special exposure hazards and combustion products :
May generate carbon monoxide (CO) and Nitrogenoxides (Nox).
Under certain fire conditions, traces of other toxic gases cannot be excluded.
d. Special fire-fighting procedures :
Wear full protective suit and a self-contained breathing apparatus.
e.Additional information:
Retain expended liquids from fire fighting for later disposal. Prevent spilled product from entering streams, drinking water supplies or drains. Dispose of fire debris and contaminated fire fighting water in accordance with official regulations.

6 Accidental release meassures

a. Person related safety precautions :
Wear protective equipment. (see chapter 8)
All personnel remain upwind of the spill. Keep unprotected persons away.
Avoid contact with eyes and skin. Ensure sufficient ventilation.
b. Measures for environmental protection :
Do not allow to enter drainage system, surface or ground water. Inform the local authorities if the product has entered the sewage system.
Try pumping the product in an open barrel.
c. Methods for cleaning/collecting :
Provide sufficient ventilation.
Absorb with liquid-binding material (sand, earth, diatomite, silica gel, universal binder).
Avoid using solvents. Place in metal containers for recovery or disposal. Place leaking containers in a marked drum.
Scrub the contaminated surface with a diluted soap solution. Consider the cleaning water as contaminated waste.
Take care of large quantities by damming and pumping.
Contaminated materials should be removed as waste, according to item 13.

7 Handling and storage

HANDLING
Handling below 50°C.
a. Information for safe handling :
Use this product in a well ventilated area.
Take notice of the MAC values while working.
b. Information concerning fire and explosion hazards :
Keep away from ignition sources. Don't smoke.
STORAGE
a. Demands concerning storage rooms and tanks :
Sufficient ventilation in the storage rooms and working areas. Prevent contact with water and strong alcalines or acids.
b. Information about storage in a common storage facility :
May produce violent reactions with bases and numerous organic substances specially amines.
c. Further information about storage conditions :
Protect containers against physical damage. Store in a cool, dry and well ventilated place, in tightly closed container.
Do not store in full sun nor near sources of heat. At these conditions shelflife is 6 months.

8 Exposure controls /personel protection

a. Additional information about design of technical systems :
Do not spray
b. Substances with exposure limits :

CAS-No.	Substance	MAC	MAC (TRGS 900)
101-68-8	4,4'-dimethylmethanediisocyanate	0,2 mg/m³	0,1 mg/m³

SPETEC PU H100

PERSONAL PROTECTIVE EQUIPMENT :

a. Breathing Do not inhale dust or spray.
If necessay wear appropriate dust filter mask.

b. Hands Rubber (butyl caoutchouc, nitril) or plastic gloves (with cufffs to prevent spread of material to area above the wrists) should be worn whenever the possibility of skin contact arises.

c. Eyes Tightly sealed safety glasses.

d.Body Wear suitable, long sleeved protective work clothing.
Under normal conditions, cotton overalls or working suits of cotton/synthetic fibre are suitable.
Heavy duty rubber or plastic-covered aprons can be worn.

Wear impermeable shoes.

e. Personal hygiene Remove all contaminated clothing immediately.
Keep working clothing away from food and drinks.
Wash hands before breaks and at the end of the work.
Use a skin protecting onguent as preventive measure.
Handle in accordance with good industrial hygiene and safetey practice.

f. In general Avoid breathing of vapours, gases and aërosols.

9 Physical and chemical properties

Appearance	:	liquid	
Colour	:	brown	
Odour	:	weak musky	
Melting point	:	<-20°C	
Boiling point	:	>200°C	
Flashpoint	:	>150°C	DIN 51758
Ignation temperature	:	>200°C	
Decomposition temp.	:	not determinated	
Explosion limits	:	n.a.	
Vapour pressure	:	0,00001 mbar bij 25°C	
Density	:	1,05 -1,15 g/cm³ @20°C	DIN 52217-02
Solubility in water	:	not soluble	
PH-value	:	neutral	DIN 16916
Viscosity	:	150-250 mPas @ 25°C	DIN 53015
Vapor density	:	8,5 @ 20°C (air=1)	

10 Stability and reactivity

a. Thermal decomposition conditions to avoid :
No decomposition if used according to specifications. Keep away from strong alcalines.

b. Dangerous reactions :
May produce violent reactions with bases and numerous organic substances including amines.
Exothermic polymerisation.

c. Dangerous products of decomposition :
Corrosive gases/vapours, carbonmonoxide, nitrogenoxide

11 Toxicological information

a. Acute toxicity :

LD50/LC50-values that are relevant for classification :

Components	oral LD50	dermal LD50	inhalation LC50/4h
4,4'-diphenylmethanediisocyanate	>8000 mg/kg rat	>5000 mg/kg rabbit	>490 mg/m3 aerosol rabbit

b. Primary irritant effect :
On the skin : Irritant to the skin and the mucous membrane.
On the eye : Irritant effect.
After ingestion : May cause irritation.
Sensibility : Long term and continuous exposure may cause sensibility by skin contact.
c. Additional toxicological information :
The product shows the following dangers according to the calculation method of the General EC.
Classification Guidelines for Preparations as issued in the latest version.
Harmful
d. Chronical irritant effect:
Long term and continuous exposure may cause sensibility by skin contact.

12 Ecological information

Biological degradability : Not easy biodegradable - formation of insoluble solids.
Aquatic toxicity: Fish toxicity (LC50) > 300 mg/l
Bacterial toxicity (EC50) :

General information:
Product reacts with water to form insoluble polyurethanes.

13 Disposal considerations

a. Product :
Recommendation: remove according to local authority recommendations, e.g. convey to a suitable incinerator.
b.Uncleaned packagings :
Recommendation: disposal must be made according to official regulations..
c. European waste catalogue :
The waste code classification is to be carried out according to the European waste catalogue (EWC) specifically for each branch of industry and each type of process.

14 Transport information

a. Land transport ADR/RID (transboundary)

ADR class	Not classified
UN number	
Packaging group	
Classification code	
Hazard index number	
Proper shipping name	Diphenylmethane-4,4'-diisocyanate

b. Maritume transport IMDG :

IMDG class	Not classified
UN number	
Packaging group	
Classification code	
Hazard index number	
Proper shipping name	Diphenylmethane-4,4'-diisocyanate

c. Air transport IATA :

IATA class	Not classefied
UN number	
Packaging group	
Classification code	
Hazard index number	
Proper shipping name	Diphenylmethane-4,4'-diisocyanate

15 Regulatory information

a. Code. letter and hazard designation of product :

Xn : Harmful

b. Hazardous ingredients :
Diphenylmethane-4,4'-diisocyanate

c. R-phrases :

R 48/20	Harmful: danger of serious damage to health by prolonged exposure through inhalation.
R 36/37/38	Irritating to eyes, respiratory system and skin.
R 40	Limited evidence of a carcinogenic effect.
R 42/43	May cause sensitization by inhalation and skin contact.
R 84	Contains isocyanates, consult information presented by the manufacturer.

d. S-zinnen :

S 36/37/39	Wear suitable protective clothing, gloves and eye/face protection.
S 26	In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.
S 45	In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).
S 23.3	Do not breath gas/vapour/aerosol.

f. Additional regulations :
Document of APME: " Polyurethane resins and curing agents (Toxicology, health, safety and evironmental aspects)"

16 Other information

This information considers above mentioned product alone and is not necessarily valid if used in combination with other products or in a process. This data is based on our present state of knowledge and is provided in good faith, however without guarantee. It remains the responsibility of the user to ensure himself that this information is appropriate and complete for his special use. It shall not constitute a guarantee for any specific product features and shall not establish a legally valid contractual relationship.

*** Relevant R-phrases :**

H317	May cause an allergic skin reaction.
H319	Causes serious eye irritation.
H332	Harmful if inhaled.
H334	May cause allergy or asthma symptoms or breathing difficulties if inhaled.
H335	May cause respiratory irritation.
H351	Suspected of causing cancer.
H373	May cause damage to organs through prolonged or repeated exposure.

*** Telephone number by distress :' 0032(0)3 320 02 04**

Prepared by: Felix Verstraeten

For more information visite our website : http://www.spetec.com

Appendix 4 Spetec ACC H100 Safety Data Sheet

Spetec

SPETEC ACC H100

1 Identification of substance and of the company/entreprise

a. Product details

Trade name : ***SPETEC ACC H100***

Application of the substance/preparation : *Accelerator for PU H100*

b. Manufacturer/supplier :

RESIPLAST N.V.
Gulkenrodestraat 3
2160 Wommelgem (Belgium

Tel : + 32-(0)3 320 02 03
Fax : + 32-(0)3 322 63 80
http : www.spetec.com

c. Information : see chapter 16

d. Emergency telephone numer : **+ 32-(0)3 320 02 04**

2 Hazards identification

Hazard designation : **C** Corrosive; **N** dangerous for the environment

Information pertaining to particular dangers for man and environment :

Harmful if swallowed. (R22)
Causes burnes. (R34)
Very toxic to aquatic organismes (R50)

3 Composition/Data on components

Chemical characterization:

a. Designation : Accelerator for polyurethane crack injection system

b. Hazardous ingredients :

CASnr	EINECS	Definition	%	Symbol	R-phrases
61788-93-0	263-020-0	1-dodecamin-N,N'-dimethyl	>20	C	20 - 36/37/38 - 42/43

(Relevant H-phrases : see chapter 16)

4 First aid measures :

a. Symptoms and effects :
Dizziness, nausea, vomiting, irritation of skin and respiratory system.
b. General information :
Take affected person out of danger area and instruct to lie down. Instantly remove any clothing soiled by the product. Seek medical help in all cases of doubt or if the symptoms are persistent.
c. After inhalation :
Supply fresh air (or remove to fresh air), keep patient warm and at rest until any symptoms of respiratory irritation distress have disappeared. If rapid recovery does not occur obtain medical attention. If breathing has stopped or is laboured, give assisted respiration (e.G. mouth to mouth). Supplemental oxygen may be indicated.
Assure mucus does not obstruct airway. Turn victims head to the side.
In case of unconsciousness bring patient in a stable position for transport.
d. After skin contact :
Remove any contaminated clothing immediately. DO NOT use solvent or thinner.
Immediately following skin contact, all affected areas should be washed thoroughly with soap and water (rinse thoroughly).
Seek medical advice.
e. After eye contact :
Remove contact lenses. Rinse immediately with plenty of running water for at least 15 minutes.
Eyelids should be held away from the eyeball to ensure thoroughly rinsing. Seek medical advice.
f. After ingestion :
Do not induce vomiting.
Rinse out mouth and nose and give plenty of water to drink with small sips (dilution effect). Keep patient at rest.
Never give anything by mouth to an uncunscious person. Seek medical advice immediately and show label of the packaging.
g. Information for medical personnel :
Treat symptomatically with mild corticosteroids.

5 Fire-fighting measures

a. Suitable extinguishing media :
Water, CO2, dry chemical powder. Larger fire with alcohol resistant foam.
b. For safety reasons unsuitable extinguishing agents:
Strong water jet.
c. Special exposure hazards and combustion products:
May generate carbon monoxide (CO) and Nitrogenoxides (Nox).
Under certain fire conditions, traces of other toxic gases cannot be excluded.
d. Special fire-fighting procedures:
Wear full protective suit and a self-contained breathing apparatus.
e. Additional information:
Retain expended liquids from fire fighting for later disposal. Prevent spilled product from entering streams, drinking water suppli or drains. Dispose of fire debris and contaminated fire fighting water in accordance with official regulations.

6 Accidental release measures

a. Person related safety precautions :
Wear protective equipmet. (see chapter 8). All personnel remain upwind of the spill. Keep unprotected persons away.
Avoid contact with eyes and skin.
Ensure sufficient ventilation.
b. Measures for environmental protection :
Do not allow to enter drainage system, surface or ground water.
Inform the local authorities if the product has entered the sewage system.
Try pumping the product in an open barrel.
c. Methods for cleaning/collecting :
Provide sufficient ventilation.
Absorb with liquid-binding material (sand, earth, diatomite, silica gel, universal binder).
Avoid using solvents. Place in metal containers for recovery or disposal. Place leaking containers in a marked drum.
Scrub the contaminated surface with a diluted soap solution. Consider the cleaning water as contaminated waste.
Take care of large quantities by damming and pumping.
Contaminated materials should be removed as waste, according to item 13.

7 Handling and storage

HANDLING

a. Information for safe handling :
Use this product in a well ventilated area.
Take notice of the MAC-values while working.
b. Information concerning fire and explosion hazards :
Keep away from ignition sources. Don't smoke.
STORAGE
a. Demands concerning storage rooms and tanks :
Sufficient ventilation in the storage rooms and working areas.
Prevent contact with copper, aluminium and zinc or their amalgamates.
b. Information about storage in a common storage facility :
May produce violent reactions with acids
c. Further information about storage conditions :
Protect containers against physical damage. Store in a cool, dry and well ventilated place, in tightly closed containers.

8 EXPOSURE CONTROL/PERSONAL PROTECTION

a. Additional information about design of technical systems :

Keep a solution of 0,5% acetic acid at hand on the job location.

b. Substances with exposure limits :

CAS-No	substance	MAC	MAC (TRGS 900)
61788-93-0	1-dodecamin-N,N'-dimethyl	n.a.	n.a.

PERSONAL PROTECTIVE EQUIPMENT :

a. Breathing Do not inhale dust or spray.
If necessary wear gas mask - filter K (green, ammonia).

b. Hands Rubber (butyl caoutchoux, nitril latex) or plastic gloves (with cuffs to prevent spread of material to area above the wrists) should be worn whenever the possibility of skin contact arises.

c. Eyes Tightly sealed safety glasses.

d. Body Wear suitable, long sleeved protective work clothing.
Under normal conditions, cotton overalls or working suits of cotton/synthetic fibre are suitable.
Heavy duty rubber or plastic-covered aprons can also be worn.

Wear impermeable shoes.

e. Personal hygiene Remove all contaminated clothing immediately.
Keep working clothing away from food and drinks.
Use a skin protecting onguent as preventive measure.
Handle in acoordance with good industrial hygiene and safety practice.

f. In general Avoid breathing of dust and aërosols.

9 Physical and chemical properties

Appearance	:	liquid	
Colour	:	pale yellow	
Odous	:	ammonia	
Melting point	:	-10°C	
Boiling point	:	>200°C	
Flashpoint	:	135°C	DIN 51758
Ignition temperature	:	>200°C	
Decomposition temp.	:	n.a.	
Explosion limits	:	n.a.	
Vapour pressure	:	n.a.	
Density	:	0,95 g/cm³ @ 20°C	DIN 52217-02
Solubility in water	:	not soluble	
pH-value	:	14	DIN 16916
Viscocity	:	10-15 mPas @ 25°C	DIN 53015
Vapour density	:	>1 @ 20°C (air)	

10 Stabilitty and reactivity

a. Thermal decomposition/conditions to avoid :
Stable under normal conditions.
No decomposition if used according to specifications. Keep away from strong acids.
b. Dangerous reactions:
May produce violent reactions with acids.
Exothermic polymerisation.
c. Dangerous products of decomposition :
Corrosive gases/vapours, carbonmonoxide, nitrogenoxide.

11 Toxicological information

a. Acute toxicity:
LD50/LC50-values that are relevant for classification

Components	oral LD50	dermal LD50	inhalation LC50/4h
1-dodecamin-N,N'-dimethyl	>2000 mg/kg rat	n.a.	n.a.

b. Primary irritant effect :

On the skin : The product penetrates the skin.
If not removed at once, local burns may develop after removal of the produc

On the eye : Contact with the eyes may cause severe damage if not treated at once.

After ingestion : The acute effect of ingestion is mainly due to the corrosive properties of the product.

Sensibility : Long term and continuous exposure may cause sensibility by skin contact.

c. Chronical irritant effect : Long term and continuous exposure may cause sensibility by skin contact.

12 Ecological information

Biological degradability : Biodegradable - formation of insoluble solids.

Aquatic toxicity : Toxic for aquatic organisms.

General information :
Avoid release to the environment.

13 Disposal considerations

a. Product :
vuilverbrandingsinstallatie vervoeren.
b. Uncleaned packagings:
Recommendation: disposal must be made according to official regulations.
c. European waste catalogue :
The waste code classification is to be carried out according to the European waste Catalogue (EWC) specifically for each branch of industry and each type of process.

14 Transport information

a. Land transport ADR/RID (transboundary)

ADR class	8
UN number	2735
Packaging group	III
Classification code	C7
Hazard index number	80
Proper shipping name	Amines, liquid, corrosive, n.o.s. (1-dodecamin-N,N'-dimethyl)

b. Maritime transport IMDG :

IMDG class	8
UN number	2735
Packaging group	III
Classification code	C7
	53,c
Proper shipping name	Amines, liquid, corrosive, n.o.s. (1-dodecamin-N,N'-dimethyl)

c. Air transport ICAO- TI and IATA- DGR :

IATA class	8
UN number	2735
Packaging group	III
Classification code	C7
Hazard index number	Page 8103
Proper shipping name	Amines, liquid, corrosive, n.o.s. (1-dodecamin-N,N'-dimethyl)

15 Regulatory information

a. Code, letter and hazard designation :

C : Corrosive

N : Dangerous to the environment

b. Hazard ingredients :
1-dodecamin-N,N'-dimethyl

c. R-phrases :

R 22	Harmful if swallowed.
R 34	Causes severe burns.
R 50	Very toxic to aquatic organisms.

d. S-zinnen :

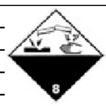
S 36/37/39	Wear suitable protective clothing, gloves and eye/face protection.
S 26	In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.
S 45	In case of accident or if you feel unwell, seek medical advice immediately. (show the label where possible)
S 57	Use appropriate container to avoid environment contamination.
S 60	This material and its container must be disposed of as hazardous waste.

f. Additional information :

b. Maritime transport IMDG :

IMDG class	8
UN number	2735
Packaging group	III
Classification code	C7
	53,c
Proper shipping name	Amines, liquid, corrosive, n.o.s. (1-dodecamin-N,N'-dimethyl)

c. Air transport ICAO- TI and IATA- DGR :



IATA class	8
UN number	2735
Packaging group	III
Classification code	C7
Hazard index number	Page 8103
Proper shipping name	Amines, liquid, corrosive, n.o.s. (1-dodecamin-N,N'-dimethyl)

15 Regulatory information

a. Code, letter and hazard designation :

C : Corrosive

N : Dangerous to the environment

b. Hazard ingredients :

1-dodecamin-N,N'-dimethyl

c. R-phrases :

R 22	Harmful if swallowed.
R 34	Causes severe burns.
R 50	Very toxic to aquatic organisms.

d. S-zinnen :

S 36/37/39	Wear suitable protective clothing, gloves and eye/face protection.
S 26	In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.
S 45	In case of accident or if you feel unwell, seek medical advice immediately. (show the label where possible)
S 57	Use appropriate container to avoid environment contamination.
S 60	This material and its container must be disposed of as hazardous waste.

f. Additional information :

16 Other information

This information considers above mentioned product along and is not necessarily valid if used in combination with other products or in a process. This data is based on our present state of knowledge and is provided in good faith, however without guarantee. It remains the responsibility of the user to ensure himself that this informations is appropriate and complete for his special use. It shall not constitute a guarantee for any specific product features and shall not establish a legally valid contractual relationship.

*** Relevant H-phrases :**

H302	Harmful if swallowed
H314	Causes severe burns and eye damage.
H400	Very toxic to aquatic life.

*** telephone number by distress : '0032(0)3 320 02 04**

Prepared by: Felix Verstraeten

Visit our website for additional information : http://www.spetec.com

Appendix 5 Hygiene – Institut des Ruhrgebeits, Gelsenkirchen

Hygiëne Institut Gelsenkirchen 05/09/2013

Rough translation of the report of the Workgroup "Potable water department of Institut

Submitted: Tecinvest NV
Contents: Cold water test
Product: Spetec LH/H100
Sample: plate of 200 mm x 200 mm x 5 mm
Start leaching/emission test: 03.02.1998

Research

Sample plates coated with Spetec LH/H100 have been tested by the division "Potable water " of the Plastics commission of the health department following their testing method.

Cold water test

The coated sample plates are washed for 24 hours at 20 °C with water and another 2 hours with potable water.
For the migration (leaching) tests demineralised water was used at 20°C.
For determining the Chloride evaporation Cl, demineralised water (Cl content of 0,6 mg/l free Cl) at 20°C is used.

The test results are in enclosed table (see table in German certificate).

The test water was checked for colour, clarity ,foaming, smell and taste. No effect was measured (test method for sealant with large surface area).

The emission of organic products(TOC) on 3 samples after 7-9 days gives 12 mg/m² x day (maximum allowed for large surface sealants is 60 mg/m² x day)

The Cl vaporation-emission shows an diminishing value. This for 3 samples (7-9 days) with value of 13 mg/m² x day free Cl (maximum allowed for large sealant surface is 75 mg/m² x day).

The value for organic migrations on 3 samples has a value of 0,01 mg/m² x day. The value is primary aromatic amines and they are clearly under the allowable value. Formaldehyd and Phenols are not detected.

Signed by the director of the Institute.

Testreport of 18,03,1998 Hygiene-Insitute des Ruhrgebiets, Gelsenkircen
Dir.Tgb,-Nr: C436/98/st

Test results

requested by : Tecinvest NV, Belgium

Product: Spetec LH/100

Test sample surface: migration test: 3320 cm² Chloride test: 210 cm²
Test water volume: migration test: 3080 ml Chloride test: 3630 ml

Test in cold water, as for large en small surface seals, like glues (O/V = 1:25)

	1-3 days	4-6 days	7-9 days	7-9 days (large size seals)
color	colorless	colorless	colorless	v,d,n,e
transparency	clear	clear	clear	v,d,n,e
foaming	no	no	no	v,d,n,e
odor treshold 20°C	1	1	1	< 2
taste treshold 20°C	nt	nt	1	<2
organic bonded Carbons (TOC)				
mg/m² x day	12	9	12	< 60
free Cl2				
mg/m² x day	15	12	13	< 75
Phenol				
mg/m² x day	<0,02	<0,02	<0,02	<6,25
Aromatic Amine				
mg/m² x day	0.002	0.001	0.001	<0,12
Formaldehyd				
mg/m² x day	< 1	< 1	< 1	< 25
Organotin				
mg/m² x day	0.06	0.02	1	*

v,d,n,e, = value does not effect
nt = not tested

Gelsenkirchen 18-03-2013 Director of the Insitute

Hygiene-Institut
des Ruhrgebiets, Gelsenkirchen

Institut für Umwelthygiene und Umweltmedizin
Direktor: Dr. rer. nat. E. Schrammeck

Gelsenkirchen

Hygiene-Institut Postfach 10 12 55 · 45812 Gelsenkirchen

Rotthauser Straße 19
45879 Gelsenkirchen
Telefon (0209) 9242-0
Telefon Durchwahl (0209) 9242- 210 / 211
Telefax (0209) 9242- 212

45879 Gelsenkirchen, 18.03.1998
Dir.Tgb.-Nr.: C 436/98/st
Sachbearbeiterin: Frau Stefanski
Durchwahl: 270/271

PRÜFBERICHT

gemäß KTW-Empfehlung der Arbeitsgruppe "Trinkwasserbelange" der Kunststoff-Kommission des Bundesgesundheitsamtes

Antragsteller:	TECINVEST NV Neteweg 4 B-2850 Boom BELGIEN
Auftrag vom:	08.10.1997 (eingegangen am: 05.11.1997)
Inhalt des Prüfauftrages:	Kaltwasserprüfung großflächige Dichtungen (Kategorie D1) kleinflächige Dichtungen und Klebstoffe (Kategorie D2)
Art und Bezeichnung der Proben:	SPETEC LH/H100 auf Polyurethan-Basis
Prüfkörper:	Prüfplatten der Abmessungen: 200 mm x 200 mm x 5 mm
Probenehmer:	überbrachte Proben

Probeneingang: 05.11.1997

Beginn der Migrations-prüfung: 03.02.1998

Durch die DAP Deutsches Akkreditierungssystem Prüfwesen GmbH akkreditiertes Prüflaboratorium Die Akkreditierung gilt für die in der Urkunde aufgeführten Prüfverfahren.	Deutscher AkkreditierungsRat **DAR** DAP-P-02.548-00-93-11

Untersuchungsmethoden:
Prüfplatten, beschichtet mit SPETEC LH/100 wurden nach dem von der Arbeitsgruppe "Trinkwasserbelange" der Kunststoff-Kommission des Bundesgesundheitsamtes veröffentlichten Verfahren untersucht ("Gesundheitliche Beurteilung von Kunststoffen und anderen nichtmetallischen Werkstoffen im Rahmen des Lebensmittel- und Bedarfsgegenständegesetzes für den Trinkwasserbereich", Bundesgesundheitsblatt 20. Jahrg., 1977, S. 124 ff.).

Kaltwasserprüfung:
Als Vorbehandlung wurden die Prüfkörper 24 Stunden bei 20°C vorgewässert und 2 Stunden mit Trinkwasser gespült.
Für den Migrationsversuch wurde als Prüfwasser entmineralisiertes Wasser verwendet; die Prüftemperatur betrug 20°C.
Die Bestimmung der Chlorzehrung wurde mit gechlortem, entmineralisiertem Wasser (Chlorgehalt 0,6 mg/l freies Chlor) bei 20°C durchgeführt.
Die Prüfergebnisse sind in der Anlage tabellarisch zusammengestellt.

Die äußere Beschaffenheit der Prüfwässer hinsichtlich Farbe, Klarheit, Neigung zur Schaumbildung, Geruch und Geschmack wird in der dritten Versuchsstufe bei dem für die Prüfung von großflächigen Dichtungen festgelegten O/V-Verhältnis von 1:25 nicht nennenswert beeinflußt.
Die Abgabe organisch-chemischer Verbindungen, erfaßt durch den Summenparameter "organisch gebundener Kohlenstoff" (TOC), wurde in der maßgeblichen 3. Versuchsstufe (7.-9. Tag) mit 12 mg/m² x Tag bestimmt (Grenzwert für großflächige Dichtungen: 60 mg/m² x Tag). Die Chlorzehrung zeigt einen abnehmenden Verlauf; der Materialflächenwert hierfür erreicht in der zur Beurteilung maßgeblichen 3. Versuchsstufe (7.-9. Tag) einen Wert von 13 mg/m² x Tag freies Chlor (Grenzwert für großflächige Dichtungen: 75 mg/m² x Tag).

Die Abgabe von Organozinn liegt in der 3. Migrationsstufe bei 0,01 mg/m² x Tag. Die Abgabe von primären aromatischen Aminen liegt deutlich unter dem Grenzwert. Formaldehyd und Phenole werden nicht an das Prüfwasser abgegeben.

Der Direktor des Instituts
i.A.

(Dr.rer.nat. H. Schössner)

1 Anlage

HYGIENE-INSTITUT DES RUHRGEBIETS
Institut für Umwelthygiene und Umweltmedizin
Gelsenkirchen

- Untersuchungsergebnisse -

Antragsteller: TECINVEST NV
Neteweg 4

B-2850 Boom
BELGIEN

Erzeugnis: SPETEC LH/100

Rezeptur: (wurde uns bekanntgegeben)

Prüfkörperoberfläche: Migrationstest: 3320 cm²; Chlorzehrungstest: 210 cm²

Prüfwasservolumen: Migrationstest: 3080 ml; Chlorzehrungstest: 3630 ml

Prüfergebnisse im Kaltwasserbereich, Einsatzbereich "groß- und kleinflächige Dichtungen sowie Klebstoffe" (O/V = 1:25)

Art der Prüfung	1.-3. Tag	4.-6. Tag	7.-9. Tag	Anforderungen an "großflächige Dichtungen" 3. Extraktion (7.-9. Tag)
Farbe	farblos	farblos	farblos	n.n.b.
Trübung	klar	klar	klar	n.n.b.
Neigung zur Schaumbildung	keine	keine	keine	n.n.b.
Geruchsschwellenwert (20°C)	1	1	1	< 2
Geschmacksschwellenwert (20°C)	n.u.	n.u.	1	< 2
organisch gebundener Kohlenstoff (TOC) mg/m² x d	12	9	12	≤ 60
Chlorzehrung (freies Cl_2) mg/m² x d	15	12	13	≤ 75
Phenole mg/m² x d	<0,02	<0,02	<0,02	≤ 6,25
aromatische Amine mg/m² x d	0,002	0,001	0,001	≤ 0,12
Formaldehyd mg/m² x d	<1	<1	<1	≤ 25
Organozinn mg/m² x d	0,06	0,02	0,01	-

n.n.b. = nicht nennenswert beeinflußt
n.u. = nicht untersucht

HYGIENE-INSTITUT DES RUHRGEBIETS Institut für Umwelthygiene und Umweltmedizin

Der Direktor des Instituts
i.A.
[signature]
(Dr.rer.nat. H. Schössner)

Gelsenkirchen, 18.03.1998

Appendix 6 Laboratium voor levensmiddelentechnolgie en – proceskunde. Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen. Universiteit Gent, Belgium

UNIVERSITEIT GENT

FACULTEIT LANDBOUWKUNDIGE EN TOEGEPASTE BIOLOGISCHE WETENSCHAPPEN

VAKGROEP LEVENSMIDDELENTECHNOLOGIE– EN VOEDING
LABORATORIUM VOOR LEVENSMIDDELENTECHNOLOGIE EN -PROCESKUNDE
PROF. DR. IR. KOEN DEWETTINCK

Tecinvest
Gulkenrodestraat 3

2160 Wommelgem

Date
16th December 2003

REPORT OF ANALYSIS

Identification code: MS 7478/1			
Type sample	Polyurethane	**Date delivery**	27/08/03
Sampling by	Tecinvest	**Date start Analysis**	01/09/03
Delivered by	Tecinvest	**Type packaging**	plastic
Requested analysis	NBN S29-001		
Remarks			

RESULTS

1. Organoleptic analysis and analysis of the migration of organic compounds

Analysis & units	Our ref.	MS 7478/1
	Your ref.	SPETEC H100
Odour		No odour
Taste		No taste
Colour		No colour
Turbiditity (FNU)		0
COD (mg O_2/l) after 72 hours		< 10

Both of the materials are conform the norm.

Coupure Links 653, B-9000 Gent Belgium
tel. +32 (0)9 264 61 67 fax +32 (0)9 264 62 18 e-mail : An.Witters@UGent.be
UNIVERSITEIT GENT

2. **Global migration**

Analysis & units	Our ref.	MS 7478/1
	Your ref.	SPETEC H100
Global migration (mg/dm²)		3,82

The global migration is below the norm (10 mg/dm²).

3. **Control of the stimulation of microbiological growth.**

Analysis & units	Our ref.	blanco	MS 7478/1
	Your ref.		SPETEC H100
Start			
Coliforms (/100 ml) at 37°C		9,3	
Total plate count (/ml) at 21°C		$1,7.10^3$	
Total plate count (/ml) at 37°C		$1,6.10^3$	
After 3,5 days			
Coliforms (/100 ml) at 37°C		2,3	2,3
Total plate count (/ml) at 21°C		$2,6.10^4$	$9,8.10^4$
Total plate count (/ml) at 37°C		$4,1.10^4$	$1,4.10^5$
After 7 days			
Coliforms (/100 ml) at 37°C		Absent	Absent
Total plate count (/ml) at 21°C		$1,2.10^6$	$1,9.10^5$
Total plate count (/ml) at 37°C		$1,8.10^5$	$7,6.10^4$
After 10,5 days			
Coliforms (/100 ml) at 37°C		Absent	Absent
Total plate count (/ml) at 21°C		$5,1.10^4$	$1,3.10^4$
Total plate count (/ml) at 37°C		$6,6.10^4$	$1,2.10^4$
After 14 days			
Coliforms (/100 ml) at 37°C		Absent	Absent
Total plate count (/ml) at 21°C		$3,5.10^4$	$1,1.10^4$
Total plate count (/ml) at 37°C		$2,2.10^4$	$1,4.10^4$
After 17,5 days			
Coliforms (/100 ml) at 37°C		Absent	Absent
Total plate count (/ml) at 21°C		$2,3.10^4$	$9,8.10^3$
Total plate count (/ml) at 37°C		$1,2.10^4$	$1,1.10^4$

Coupure Links 653, B-9000 Gent Belgium
tel. +32 (0)9 264 61 67 fax +32 (0)9 264 62 18 e-mail : An.Witters@UGent.be
UNIVERSITEIT GENT

Analysis & units	Our ref.	blanco	MS 7478/1
	Your ref.	.	SPETEC H100
After 21 days			
Coliforms (/100 ml) at 37°C		Absent	Absent
Total plate count (/ml) at 21°C		1,2.10^4	1,9.10^4
Total plate count (/ml) at 37°C		1,8.10^4	3,6.10^3
After 24,5 days			
Coliforms (/100 ml) at 37°C		Absent	Absent
Total plate count (/ml) at 21°C		1,1.10^4	7,9.10^3
Total plate count (/ml) at 37°C		9,8.10^3	1,2.10^3
After 28 days			
Coliforms (/100 ml) at 37°C		Absent	Absent
Total plate count (/ml) at 21°C		1,8.10^3	8,2.10^3
Total plate count (/ml) at 37°C		1,5.10^3	9,6.10^2
After 31,5 days			
Coliforms (/100 ml) at 37°C		Absent	Absent
Total plate count (/ml) at 21°C		1,4.10^3	4,9.10^3
Total plate count (/ml) at 37°C		1,7.10^3	7,5.10^2
After 35 days			
Coliforms (/100 ml) at 37°C		Absent	Absent
Total plate count (/ml) at 21°C		1,7.10^3	2,4.10^3
Total plate count (/ml) at 37°C		1,5.10^3	9,9.10^2
After 38,5 days			
Coliforms (/100 ml) at 37°C		Absent	Absent
Total plate count (/ml) at 21°C		1,2.10^3	1,9.10^3
Total plate count (/ml) at 37°C		1,1.10^3	7,6.10^2

The material does not stimulate bacteriological growth.

Prof. dr. ir. K. Dewettinck
Technical Manager

i.o.
ing. A. Witters
Technical responsible

Coupure Links 653, B-9000 Gent Belgium
tel. +32 (0)9 264 61 67 fax +32 (0)9 264 62 18 e-mail : An.Witters@UGent.be
UNIVERSITEIT GENT

ATTACHMENT 3

EXAMPLE ACTIVITY CHECKLISTS, DUTY CARDS AND FORMS

PUR TRANSPORT CHECKLIST

Check List to be completed whenever transporting product

Date: ________	Date: ________	Date: ________	Date: ________	Date: ________	
{ }	{ }	{ }	{ }	{ }	1. Check vehicle for fuel/oil leak.
{ }	{ }	{ }	{ }	{ }	2. Check bund for water/materials affecting storage capacity.
{ }	{ }	{ }	{ }	{ }	3. Secure IBC, hoses and pump(s) for transportation.
{ }	{ }	{ }	{ }	{ }	4. Secure all tools, transfer hose and other equipment.
{ }	{ }	{ }	{ }	{ }	5. Check rubber matting in Ute is intact and positioned appropriately.
{ }	{ }	{ }	{ }	{ }	6. Ensure product storage containers are placed in bund on Ute/trailer.
{ }	{ }	{ }	{ }	{ }	7. Test to ensure drum security and tailgate/sides are up and secure.
{ }	{ }	{ }	{ }	{ }	8. Sight spill kit.
{ }	{ }	{ }	{ }	{ }	10. Sight product MSDS.
{ }	{ }	{ }	{ }	{ }	11. Sight WaterNSW gate key.
{ }	{ }	{ }	{ }	{ }	12. Lock each WaterNSW gate after passing through.
{ }	{ }	{ }	{ }	{ }	13. Engage 4WD at entrance gate.

Golder Operator Signature: …………………………………….

LAYDOWN, TRANSFER AND BATCHING CHECKLIST

ENSURE HOSE PRESSURE HAS BEEN RELIEVED PRIOR TO DISCONNECTING ANY GROUT OR COMPRESSED AIR LINES

Date	Date	Date	Date	Date	
Laydown Tasks					
					1. Establish radio channel communication.
					2. Has the air compressor been fuelled & inspected?
					3. Check hoses to ensure connections are securely fitted.
					4. Fit discharge hose to the transfer pump and suction hose from IBC.
					5. Connect grout transfer lines and air hoses w/ pins and whip checks.
					6. Connect & purge all required compressed air lines.
					Golder Operator Initials
					Golder Supervisor Initials
Transfer Tasks					
					1. Walk length of grout transfer and air lines to ensure connections are secure with pins and whip checks.
					2. Inspect ends of grout transfer hoses for cured product.
					3. Confirm grout transfer line valve positions & connection to plant IBC.
					4. Once pump operation is confirmed, transfer product to batch plant
					5. Walk entire length of grout transfer line to reinspect for leaks.
					6. If leaks discovered, stop pumping, relieve pressure & repair leaks.
					Golder Operator Initials
					Golder Supervisor Initials

Batching Tasks					
					Inspect batching & injection site, bunding, valves & hose connections.
					Place apron of absorbent material around hole and adjacent holes (if necessary) to catch any spills.
					Position waste containers/drums, where required, at injection site.
					Complete packer inspection & pumping test prior to installation.
					Add required accelerator to PUR mix in batching plant.
					Obtain & test PUR sample to confirm set time.
					Test grout pump to confirm operation through packer.
					Open supply valves on grout line & commence injection operations.
					Closely monitor rivulet during injection for grout leaks back to the ground surface.
					If leaks are discovered, stop pumping, clean-up / contain PUR.
					Golder Operator Initials
					Golder Supervisor Initials

SITE SUPERVISOR & CLEAN UP CHECKLIST

Date	Date	Date	Date	Date	
Supervisor Tasks					
					1. Has daily toolbox meeting been completed?
					2. Is the site safe & secure?
					3. Do site workers have adequate PPE for daily activities?
					4. Are appropriate environmental controls are in place?
					5. Is adequate spill containment material on site and accessible?
					6. Are all joint connectors secure with safety clips & whip checks?
					7. Have hoses been checked for damage and leaks at joiners?
					8. Are pressure gauges, shut-off valves, FRLs & manifolds functioning?
					9. Is grout transfer pump functioning properly?
					10. Are drill rig guards in place?
					11. Have daily checklists been completed?
					12. Are all first-aid, spill kits & fire extinguishers stocked & inspected?
Cleanup Tasks					
					1. Remove excess grouting materials from site.
					2. Seal all fluid ports with caps or plugs.
					3. Place grouting & equipment hoses in designated storage areas.
					4. Place transfer hose ends in bunds.
					5. Clear site of any unnecessary flammable materials.
					6. Remove rubbish and leave site in tidy condition.
					7. Place tarp over spill containment bunds.

					Golder Operator Initials
					Golder Supervisor Initials

GOLDER

ENVIRONMENT CHECKLIST

Date

____/_____/____

Pre-Shift at Metropolitan Mine Site

{ } 1. Check if more than 10 mm rain in last 24 hours.

{ } 2. Check weather forecast for heavy rain or bushfires. Check NSW Rural Fire Service Fire Danger Ratings and Bush Fire Alerts.

{ } 3. Check if Total Fire Ban has been issued.

{ } 4. Check that all personnel have received a copy and understand the Fire Evacuation Plan and Bushfire Preparedness Plan and have been instructed in the requirements for Hot Work.

{ } 5. Check all personnel have conducted a dry-run of the second means of bushfire escape.

{ } 6. Check emergency numbers have been provided to all personnel on a telephone list, including the WaterNSW Fire Incident number (1800 061 069).

{ } 7. Any hot work planned today (Y/N)? If "Y", ensure WaterNSW Hot Work Permit has been obtained.

{ } 8. Check water testing kit adequately stocked.

{ } 9. Instruct all personnel to use chemical toilet situated on a nearby fire road.

GOLDER

ENVIRONMENT CHECKLIST

Date

____/_____/____

Pre-Shift at Site Works

Site Layout and Set-Up

{ } 10. Check all vehicles are parked in designated areas along adjacent fire roads.

{ } 11. Are steel ramps/sandbags in place to facilitate access to the drill/injection site, where required?

Soil and Vegetation Management

{ } 12. Check if lopping of branches is required for the mobilisation, placement or operation of equipment. Approx. number of branches: ____________

{ } 13. If lopping required, check that lopped branches are left on the ground in random pattern.

{ } 14. Check if slashing of vegetation is required for the mobilisation, placement or operation of equipment. Approx. area to be slashed: ______________

{ } 15. If slashing required, check that slashing is undertaken by cutting the vegetation at ground level and leaving the lower stem and roots intact.

{ } 16. Check if rubber lattice matting in place in high traffic areas to minimise vegetation disturbance.

Erosion and Sediment Control

{ } 17. Check erosion and sediment controls are in place consistent with the Erosion and Sediment Control Plan.

GOLDER

ENVIRONMENT CHECKLIST

Date
____/_____/____

Pre-Shift at Site Works (Cont.)

Stream Flow Diversion

{ } 18. Check pumps established in relevant pools and/or existing boreholes.

{ } 19. Check bunding established for all pumps or compressors.

{ } 20. Check that pump hoses are appropriately situated so that water will be conveyed downstream of the site sediment controls (back into Waratah Rivulet or Eastern Tributary).

{ } 21. Check presence of stand-by pumps in the elevated equipment storage area.

{ } 22. Are stream flows above intended injection site (Y/N)? If "Y", cease grouting activities until a suitable flow regime can be established.

Fuel and Spill Management

{ } 23. Inspect all hoses/couplings.

{ } 24. Check compressors, pumps and drill rig for leaks of oil/fuel/coolant.

{ } 25. Check for spills evident inside bunded areas and arrange clean-up if required.

{ } 26. Any spills outside bunded areas (Y/N)? If "Y", what remedial actions undertaken

____

GOLDER

ENVIRONMENT CHECKLIST

Date

____/_____/____

During Shift

Erosion and Sediment Control

{ } 27. Complete integrity and effectiveness checks of all erosion and sediment controls.

{ } 28. Complete regular inspections of water clarity of downstream pools.

Water Quality Monitoring

{ } 29. Complete water quality sampling for field analysis.

{ } 30. Complete data analysis of field sampling results. Are any downstream water quality results outside previously recorded water quality data (Y/N)?

{ } 31. If "Y", are any downstream water quality results also above (outside) values obtained from testing at upstream sites on that day (Y/N)? If "Y", cease drilling/injection activities and send samples to the laboratory for analysis.

{ } 32. If laboratory testing confirms the downstream results are outside previously recorded water quality data and the results for the upstream sites, trigger investigation and notify WaterNSW.

End-Shift

{ } 33. Ensure all fuel containers accounted for.

{ } 34. Check sign in/sign out board completed by all personnel.

Site Supervisor: ………..…………… Signature: …………………Date: …../…../…..

GOLDER PUR TRANSPORT DRIVER
DUTY CARD

Date

_____/_____/_____

Responsible for: Transportation of Grout Products

Responsible to: Golder Site Supervisor

Responsibilities:

1	Receive inductions for MCPL, WaterNSW & Golder
2	Understand the bunding requirements for grout product transport & storage
3	Understand the transport rules in the catchment
4	Understand the site parking and Spill procedures
5	Obtain SCA gate key and sign key register
6	Attend pre-shift meetings
7	Assist with set-up, start-up, grout injection and clean-up operations

Complete Checklists/Forms

1	Sign-on/Sign Off Daily Toolbox
2	PUR Transport Checklist – to be completed whenever transporting product
3	Laydown, Transfer & Batching Checklist
4	Clean Up Checklist

At all times in the catchment

1	**SAFETY FIRST**
2	Strictly 40km/hr maximum speed
3	Report spills immediately to site supervisor

Name: ______________________________

Signed: _______________________________ Date: _________

GOLDER PUR GROUTING PERSONNEL
DUTY CARD

Date

_____/_____/_____

Responsible for: PUR Pump Operator

Responsible to: Golder Site Supervisor

Responsibilities:

1	Receive inductions for MCPL, WaterNSW & Golder
2	Understand communication protocols
3	Obtain telephone list(s)
4	Attend pre-shift meetings
5	Administer Breath Testing Equipment, daily Log In & Out
6	Assist with set-up, start-up, grout injection and clean-up operations

Complete checklists/forms

1	Sign-on/Sign Off Daily toolbox
2	PUR Transport Checklist
3	Laydown Transfer & Batching Checklist
4	Clean Up Checklist
5	Daily Report to project team

At all times in the catchment

1	**Safety First**
2	Strictly 40km/hr maximum speed
3	Report spills immediately to Site Supervisor

Name: ______________________________

Signed: ______________________________ Date: _________

GOLDER SITE SUPERVISOR
DUTY CARD

Date
_____/_____/_____

Responsible for: Coordinate PUR remediation activities.

Responsible to: Golder Project Manager

Responsibilities:

1	Liaise with MCPL Project Manager and Environmental Coordinator
2	Receive MCPL induction
3	Understand project objectives and coordinate daily activity
4	Ensure all site personnel receive inductions from MCPL, WaterNSW & Golder
5	Ensure that PUR Transport Driver, and PUR Grouting Personnel understand and sign duty cards.
6	Assist with Job Safety Analysis
7	Facilitate pre-shift meeting at Golder Storage Yard Site
8	Determine the shifts grout injection requirements; Volumes & Pmax

Complete check-lists/forms

1	Tool Box Talk
2	Update LEM records
3	Laydown, Transfer & Batching Checklist
4	Site Supervisor & Clean Up Checklist
5	Daily Grouting Report

At all times in the catchment

1	**Safety First**
2	Strictly 40km/hr maximum speed
3	Report spills immediately to MCPL Project Manager and Environmental Coordinator

Name: ______________________________

Signed: _______________________________ Date: _________

SITE SUPERVISOR:

PROJECT:

METROPOLITAN COLLIERIES PTY LTD

CHEMCIAL GROUTING LOG

GOLDER

Date: ____________________

Location:

Crew: ____________________________________

Page: ___ of ___

Shift: Day ☐ Night ☐

Updated Aug 27 GSP

HOLE ID	STAGE		TIME		MIX (% ACC)	PRESSURE (psi)			VOLUME (L)		LEAKS	TERMINATION	COMMENTS
	From	To	From	To		Allowed	Line	Actual	Allowed	Actual	(Y/N)	P, V, C or Other	

GOLDER

JOB SAFETY & ENVIRONMENT ANALYSIS

Date: **Time:**

Project:

Site:

Site Supervisor:

1 STOP

TAKE 5 MINUTES AND 5 STEPS BACK:	Y	N
Planning		
HaSEP communicated to workers?	√	√
Workers signed on to Work Method Statements?	√	√
Required Permits to Work issued?	√	√
Preparation		
Workers fit for duty and not showing signs of fatigue?	√	√
Work not expected to exceed the fatigue guidelines?	√	√
Required site inductions completed?	√	√
Workers hold the necessary competencies?	√	√
Workers have the required PPE?	√	√
Plant / tools in good repair (incl. guarding & E stop)?	√	√
Site Establishment		
GPS coordinates verified against technical instruction / map?	√	√
Service clearance completed?	√	√
Current hardcopy DBYD/BYD & other plans available on site?	√	√
Pre-work photographs taken?	√	√
Work area adequately delineated / protected?	√	√
Traffic control plan implemented (if applicable)?	√	√
Emergency response equipment accessible?	√	√
Environment & Heritage		
Equipment free of visible weeds and pests?	√	√
Waste / substances stored away from sensitive receptors?	√	√
Secondary containment for substances / liquid waste?	√	√
Erosion and sediment controls installed?	√	√
Sensitive flora protected from damage / disturbance?	√	√
Heritage items / artefacts protected from disturbance?	√	√
Plant inspected for evidence of fluid leaks & excess exhaust?	√	√

Notes:

2 THINK

DISCUSS THE TASK AND THE WORK ENVIRONMENT:

- Weather Forecast
- Site Conditions
- Daily Tasking
- Equipment, Material & Logistical Issues
- Interfacing Works

NO JOB IS SO URGENT THAT WE CANNOT MEET OUR HSSE RESPONSIBILITIES.

You have the authority and the responsibility to stop a task if you:

- Believe a HSSE risk is not adequately controlled or mitigated.
- Are unsure of the way to manage risk.
- Do not hold the necessary competency to manage the risk.

3 IDENTIFY

ARE ANY **FATAL RISK CONTROLS** INVOLVED?	Y	N
Powered Mobile Equipment - Be visible, identify a safe spot and maintain positive communications - Do not enter the operating zone until you have positive okay from the operator	√	√
Driving - Respect the road rules and drive at a speed appropriate to conditions - Do not use mobile phones or other distracting devices - Do not drive after 14 hours on duty	√	√
Acutely Hazardous Substances / Atmospheres - Know what you are working with. - Know the environments in which you are working. - Do not enter a confined and/or restricted space without understanding and following the required entry procedures.	√	√
Working At Heights - Where fall potential has been identified, use fall prevention measures. - Do not stand within 2 m of an open edge where there is the potential to fall greater than 1.8 m	√	√
Suspended Loads - Remain at a safe distance from a suspended load. - Do not pass under a suspended load.	√	√
Unstable Ground - Scan continuously for signs of ground instability - Do not enter an unsupported excavation greater than the waist height - Avoid entering areas of unsupported or unstable ground.	√	√

Record the controls for these and other hazards not already addressed in the HSSE Plan or WMS overleaf.

STOP

CONTACT THE HSSE TEAM FOR A PERMIT TO WORK IF WE ARE OVERSEEING THAT INVOLVES FATAL RISKS #3-6

4 PLAN – plan what needs to be done to manage the risk

Hazards List any hazards not already identified in WMS	**Risk Control Measures** List the control measures required to eliminate or minimise the risk arising from the identified hazards. If risks cannot be controlled STOP and notify your Project Manager. Update HaSEP or WMS if necessary.

Check out the HSSE Field Guide for guidance on managing key risks in the field

Attendee	Signature

Attendee	Signature

Attendee	Signature

5 PROCEED – communicate and implement risk controls

Site Closure Checklist

- Equipment and materials removed or secured? √
- Waste collected and removed or securely stored and labelled? √
- Site restored to original condition (unless otherwise required)? √
- Area free from hazards created by the works? √
- Photograph taken of site on completion of works? √

Site Supervisor: **Time:**

Learnings:

Ensure all Learnings are recorded in the Learnings Database as soon as possible.

ATTACHMENT 4

EXAMPLE EROSION AND SEDIMENT CONTROL PLAN

SITE SPECIFIC SEDIMENT CONTROL MEASURES

Appropriate sediment control measures will be applied to ensure that the TSS limits for surface water are reduced. The measures have been selected in accordance with the site specific conditions taking into account all relevant factors such as size of catchment, vegetative cover, soil conditions, gradient etc. Site specific sediment control measures that have been implemented are detailed below.

Sand Bags

Sand bags are biodegradable bags which are filled with soil. Sand bags are used to control erosion by channelling water flow thereby stabilising areas. The devices are used to slow the movement of water on slope surfaces by breaking up the slope length and trapping sediment. At the site the following use of sandbags will be implemented:

- Sandbags placed upstream of disturbed areas in rows semi perpendicular to the gradient to channel clean water away from the disturbed surface.
- Sandbags placed on the disturbed area in rows semi perpendicular to the gradient.
- The sandbag rows are to be placed at 10 m intervals (average) down the disturbed slope.
- The rows will direct the runoff towards the vegetative buffer zones described below.
- Sandbags are to be placed across areas of concentrated flow to limit flow velocities.

Sediment Fences

Sediment fences are geotextile barriers, which are installed at the toe of a disturbed slope to filter sediment runoff. Multiple sediment fences are used across the slope to reduce the catchment area, minimising the concentration of flow and flow exiting the ends of the silt fence or causing a 'blow out' of the fence resulting in rill or gulley erosion.

Sediment fences are to be installed on contours where practicable and in a manner consistent with that specified in Managing Urban Stormwater, Soils and Construction, 2004, SD 6-8. At the site the following use of sediment fences will be implemented:

- Sediment fences will intercept surface water flow from sandbag rows.
- Sediment fences will also be installed at locations where natural drainage transports surface water towards the vegetative buffer zones.

Vegetative Buffer Zone

Buffer zones are areas of existing vegetation around or adjacent to an identified waterway that have been maintained to provide a barrier between the waterway and construction activities. Buffer zones can also be effective in trapping soil particles being carried by sheet flow. The vegetation reduces water velocity and acts as a filter, removing sediments from the water. Buffer zones are clearly identified and demarcated on site to prevent their unauthorised removal.

Maintenance & Inspection of Sediment Controls

The site sediment control measures will be inspected on a daily basis by Golder's Site Manager and weekly inspections will be completed by the Metropolitan Mine Environmental Officer. Additional inspections will be conducted in case of rainfall exceeding 10 mm depth in 24 hours.

Maintenance of the sediment control measures will be undertaken as required during the period of the works to ensure compliance with this ESC Plan.

ATTACHMENT 5

SPILL RESPONSE PROCEDURE

INTENT

To ensure that suitable control measures have been identified and implemented for the safe clean up and disposal of any spilt products.

AIM

To maintain site-specific Environmental, Quality, Safety and manufacturer's requirements.

PROCEDURE

- Obtain spill disposal kit
- Open absorbent bag
- Ensure product is dammed and contained from entering waterway
- Don any necessary PPE
- Liberally sprinkle absorbent onto spill ensuring enough to encapsulate spill
- Shovel spilt product and absorbent using steel shovel
- Place product into plastic bags provided in spill kit
- Seal bags with zip ties
- Remove waste product from site for correct disposal

ATTACHMENT 6

EXAMPLE BUSHFIRE PREPAREDNESS PLAN

Peabody

PEABODY ENERGY
WORONORA SPECIAL AREA - ROCKBAR REMEDIATION
BUSHFIRE PREPAREDNESS PLAN

Contents

1 Purpose

1.1 Introduction

This Bushfire Preparedness Plan (BPP) has been prepared by Metropolitan Coal for all personnel involved in rehabilitation and or remediation activities within the Woronora Special Area.

1.2 Aim and Objectives

The Aim of this Bushfire Preparedness Plan (BPP) is to minimise the risk of adverse impact of bush fires on life, property and the environment.

The objectives of this BPP are to:

- Reduce personnel vulnerability to bush fires by improving preparedness
- Direct personnel to pertinent information sources for fire danger ratings, total fire bans and fire locations.
- Provide a clear and concise guide that can be to be used during a bush fire event.

1.3 Background

The Woronora Special Area is subject to the Illawarra Bush Fire Risk Management Plan (Illawarra BFRMP) 2015 to 2020 that has been prepared by the Illawarra Bush Fire Management Committee (2016). The Illawarra BFRMP is a strategic document that identifies community assets at risk and sets out a five-year program of coordinated multi-agency treatments to reduce the risk of bush fire to the assets.

The Illawarra BFRMP assessment of the bush fire risk for the Woronora Special Area is **Very High Risk** (major consequence and likely likelihood). Treatment of the bush fire risk was prioritised as Priority 2A and the treatment strategies are stated as:

- Preparedness Strategy: Catchment Authority (WaterNSW) shall maintain fire trails
- Hazard Reduction Strategy: Catchment Authority (WaterNSW) shall implement Strategic Fire Advantage Zones (SFAZ) mosaic burn program with assistance from National Park & Wildlife Service and Department of Primary Industries - Lands

2 Scope

2.1 Bushfire Prevention

2.1.1 Hot Work Policy

No 'Hot Work' shall be carried out in the Woronora Special Area without a 'Hot Work' permit issued via the designated Metropolitan Coal environmental coordinator.

'Hot Work' shall be conducted in accordance with the Metropolitan Coal and WaterNSW approved, Hot Work Permits

2.1.2 No Smoking

Strict policy of no smoking at any time within the Woronora Special Area.

2.1.3 Fuel Management

When re-fuelling or transporting fuel by hand to machinery:

- Ensure the machinery is turned off.
- Ensure that a fire extinguisher is located within easy reach.
- Ensure that a suitably sized funnel is used to reduce risk of spills and that oil absorbents are
- Clean up fuel spills (and report all spills)
- Ensure that portable fuel containers are accounted and removed from site at end of shift.

2.1.4 Housekeeping
Ensure that all rubbish is removed from site at the end of each shift.

2.1.5 Total Fire Ban
A total fire ban means no fires out in the open. A total fire ban helps limit the potential of fires developing. During a Total Fire Ban you cannot light, maintain or use a fire in the open, or to carry out any activity in the open that causes, or is likely to cause, a fire.

No general purpose hot works, such as welding or gas cutting can be done in the open.

During the Bush Fire Danger Period, the decision to issue a Total Fire Ban is usually made in the afternoon for the following day. A Total Fire Ban may be issued on the actual day if weather conditions get worse. A Total Fire Ban usually starts at midnight and lasts for 24 hours.

2.2 Emergency Procedures for Work Site Fires
In case of fire breaking out within the Works Area the following will be undertaken (in this order):

1. Notify site personnel either shout or radio "Fire, Fire, Fire, Location (describe location)";
2. Plant and equipment must be switched off (if safe to do so) and the area made safe;
3. The area will be vacated and all staff will retire to the emergency assembly area;
4. The fire should be fought with fire extinguishers or water pumps - ONLY IF SAFE TO DO SO;
5. Pending status of fire the Site Supervisor must immediately contact:
    a. Metropolitan Coal control room (4294 7333); and/or
    b. Emergency Services (000 or 112);
6. The incident must be reported.

Appendix A contains a decision tree flowchart to assist personnel with the emergency procedure for work site fires.

2.3 Bushfire Preparedness
2.3.1 Check and Monitor Conditions
Working within the Woronora Special Area you could be affected by a fire especially during the bush fire season. Bush and grass fires often cross roads and highways. Smoke can reduce visibility and roads may also be closed without warning.

At each daily work pre-start meeting the following checks must be made:

- NSW Rural Fire Service (RFS) Fire Danger Ratings and Bush Fire Alerts at or on the Fires Near Me smartphone application or website http://www.rfs.nsw.gov.au/fire-information
- Whether a Total Fire Ban is in place.
- Weather conditions on the Bureau of Meteorology website (http://www.bom.gov.au/)

Throughout the working day conditions must be monitored for any changes and RFS notifications checked during periods of high fire danger.

2.3.2 Fire Danger Ratings
The Bush Fire Danger Ratings give you an indication of the possible consequences of a fire, if one was to start. Bush Fire Danger Ratings are based on predicted conditions such as temperature, humidity, wind and the dryness of the landscape.

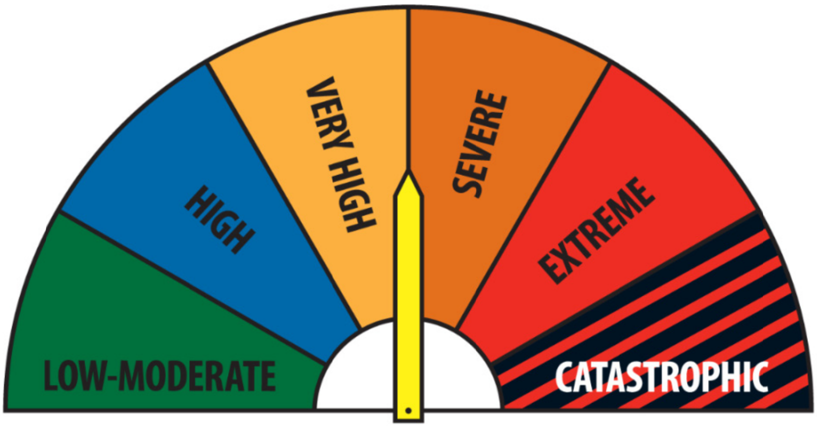
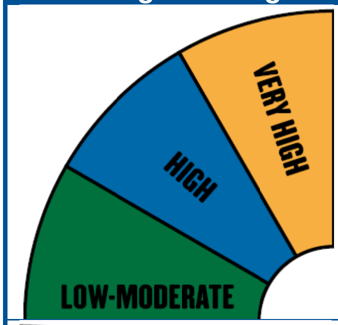
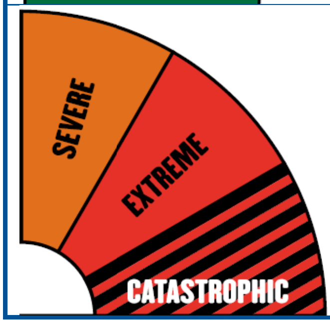


Figure 1 RFS Fire Danger Ratings

The higher the fire danger rating, the more dangerous the conditions.

Fire Danger Rating	Action Required
	**Very High and High** Keep yourself informed and monitor conditions. Be ready to act if necessary
	**Severe, Extreme & Catastrophic** Leaving the area is the safest option for survival. WaterNSW will generally close the Woronora Special Area for Fire Danger ratings of Severe or greater.

2.3.3 Alert Levels

The RFS have adopted three levels of Bush Fire Alerts that are displayed on the RFS website or smart phone application. The Alert Levels are used to give you an indication of the level of threat from a fire.

Remember – don't wait for a warning. Some fires start and spread so quickly there may not be any time for a warning. If you get a Bush Fire Alert, you must take it seriously. Failure to take action can result in death or injury.

Alert Level	Alert Instructions
	**Advice** A fire has started. There is no immediate danger. Stay up to date in case the situation changes.

Alert Level	Alert Instructions
	**Watch And Act** There is a heightened level of threat. Conditions are changing and you need to start taking action now to protect yourself.
	**Emergency Warning** An Emergency Warning is the highest level of Bush Fire Alert. You may be in danger and need to take action immediately. Any delay now puts your life at risk.

2.4 Bushfire Survival Plan

A Bushfire Survival Plan has the following key considerations in its preparation:

- **Prepare:** You must make important decisions before a fire starts
- **Act:** The higher the fire danger rating the more dangerous the conditions
- **Survive:** fires may threaten without warning so you need to know what you will do to survive.

In the event of a bush fire leaving early is the safest choice.

A site specific Bushfire Survival Plan must be prepared for each site using the RFS guide and shall include the following decisions and agreed actions.

When will we leave? What will be your sign to leave? It could be smoke in your area, or as soon as you find out there's a fire near you.

Where will we go? Where's a meeting place that's safe and away from a fire area?

How will we get there? What road will you take? What's your backup plan in case the road is blocked?

What will we take? Make a list of what you'll take in the event of a fire.

Who will we call to tell that we're leaving and that we have arrived safely?

What is our backup plan? What if things don't go to plan? Identify a safer location nearby that is well prepared, or a place of last resort.

Appendix B contains the template for the Bush Fire Site Specific Survival Plan.

2.5 Fire Evacuation Routes

Evacuation routes for nominated work sites are described in detail for each work area and depicted in Appendix C - Bush Fire Evacuation Route Plan. All personnel shall have a copy of the BPP containing the Fire Evacuation Plan in site vehicles. Newly inducted personnel must complete a dry run of the alternative evacuation routes.

In the event of a bush fire personnel are to assess the location(s) of the fire(s) and prevailing weather conditions to determine which fire evacuation route should be used. If the fire's location is unknown call the WaterNSW Incident Line (1800 061 069) and ask for direction of fire.

If you are caught in a fire

1. Call Triple Zero 000 or 112
2. Park off the road in a clear area away from trees, scrub and tall grass
3. Face the front of your car towards the fire
4. Stay in the car below the windows to protect yourself from radiant heat

5. Turn off the engine and turn on headlights and hazard lights
6. Close windows and air vents
7. Cover yourself with a woollen blanket
8. Drink plenty of water
9. Cover your mouth with a damp cloth
10. Stay down until the sound of the fire has passed, carefully leave the car (it will be hot)

2.5.1 Flat Rock Crossing

The Flat Rock Crossing area can be described either by:

- Coordinates (E309620, N6214190 MGA Zone 56).
- Flat Rock Crossing on Fire Road 9H, nearest cross street is Princes Hwy.

Evacuation Route	Route Description
Primary	Travel south on fire road 9H towards the Princess Highway as highlighted in Orange (this is the standard access route for the site)
Alternative	Travel west on Fire Road 9H towards Darkes Forrest Road as highlighted in Green 1. Cross the Waratah Rivulet and head up the hill 2. Drive west until T-intersection at Fire Road 9 3. Turn left onto Fire Road 9 4. At locked gate turn south (left) on Fire road 5. Continue on fire road to locked gate and onto Darkes Forest Road

2.5.2 Eastern Tributary Fire Trail 9J crossing

Eastern Tributary Fire Trail 9J Crossing area can be described either by:

- Coordinates (Easting: 311589 m E, Northing: 6214117 m N MGA Zone 56H)
- On Fire Road 9J, nearest cross St is Princess Highway

Evacuation Route	Route Description
Primary	Travel south east on Fire Road 9J towards the Princess Highway as highlighted in Orange (this is the standard access route for the site)
Alternative	Travel north-west on Fire Road 9J as highlighted in Green. 1. Turn left at the intersection of Fire Road 9J and Fire Road 9G. 2. Continue on Fire Road 9G to T-intersection at Fire Road 9H 3. Pending fire or weather conditions take primary or alternative routes listed for Flat Rock Crossing to either Princess Highway or Darkes Forest Road respectively.

2.5.3 Eastern Tributary Grouting Equipment Laydown Area

Eastern Tributary Fire Road Laydown Area can be described either by:

- Coordinates (Easting: 312625 m E, Northing: 6214862 m N MGA Zone 56H)

Evacuation Route	Route Description
Primary	Travel north on Fire Road towards the Princess Highway as highlighted in Orange (this is the standard access route for the site)
Alternative	Travel south on Fire Road as highlighted in Green. 1. At T-intersection of Fire Road 9J turn left. 2. Continue on Fire Road 9J to locked gate and then continue into the Princess Highway.

3 Emergency Contact Details

Contact	Contact Number
Emergency Services - Ambulance, Fire or Police	000 or 112
RFS Bush Fire Information Line	1800 679 737
Metropolitan Coal Control Room	4294 7333
Water NSW Incident Notifications	1800 061 069

4 Training

Mandatory personnel training requirements are:

- Provide First Aid (HLTAID003)

Relevant training that is strongly recommended for personnel are:

- Remote Area First Aid
- Fire Warden/Fighting Training

5 References & Supporting Documents

The following reference documents have been used in the preparation of this plan.

- Illawarra Bush Fire Risk Management Plan (Illawarra BFRMP) 2015 to 2020 prepared by the Illawarra Bush Fire Management Committee (2016). Accessed March 2018 at *http://www.rfs.nsw.gov.au/resources/publications/bush-fire-risk-management-plans*
- Rural Fire Service (*https://www.rfs.nsw.gov.au*)
  - Fire Near Me (*https://www.rfs.nsw.gov.au/fire-information/fires-near-me*)
  - Fire Danger Ratings and Total Fire Bans (*https://www.rfs.nsw.gov.au/fire-information/fdr-and-tobans*)
  - Hazard Reductions (*https://www.rfs.nsw.gov.au/fire-information/hazard-reductions*)

6 Abbreviations & Definitions

Term	Definition
BPP	Bushfire Preparedness Plan
RFS	Rural Fire Service
SFAZ	Strategic Fire Advantage Zones
TOBAN	Total Fire Ban
WaterNSW	State-Owned Corporation established under the WaterNSW Act that operates the Woronora Special Area

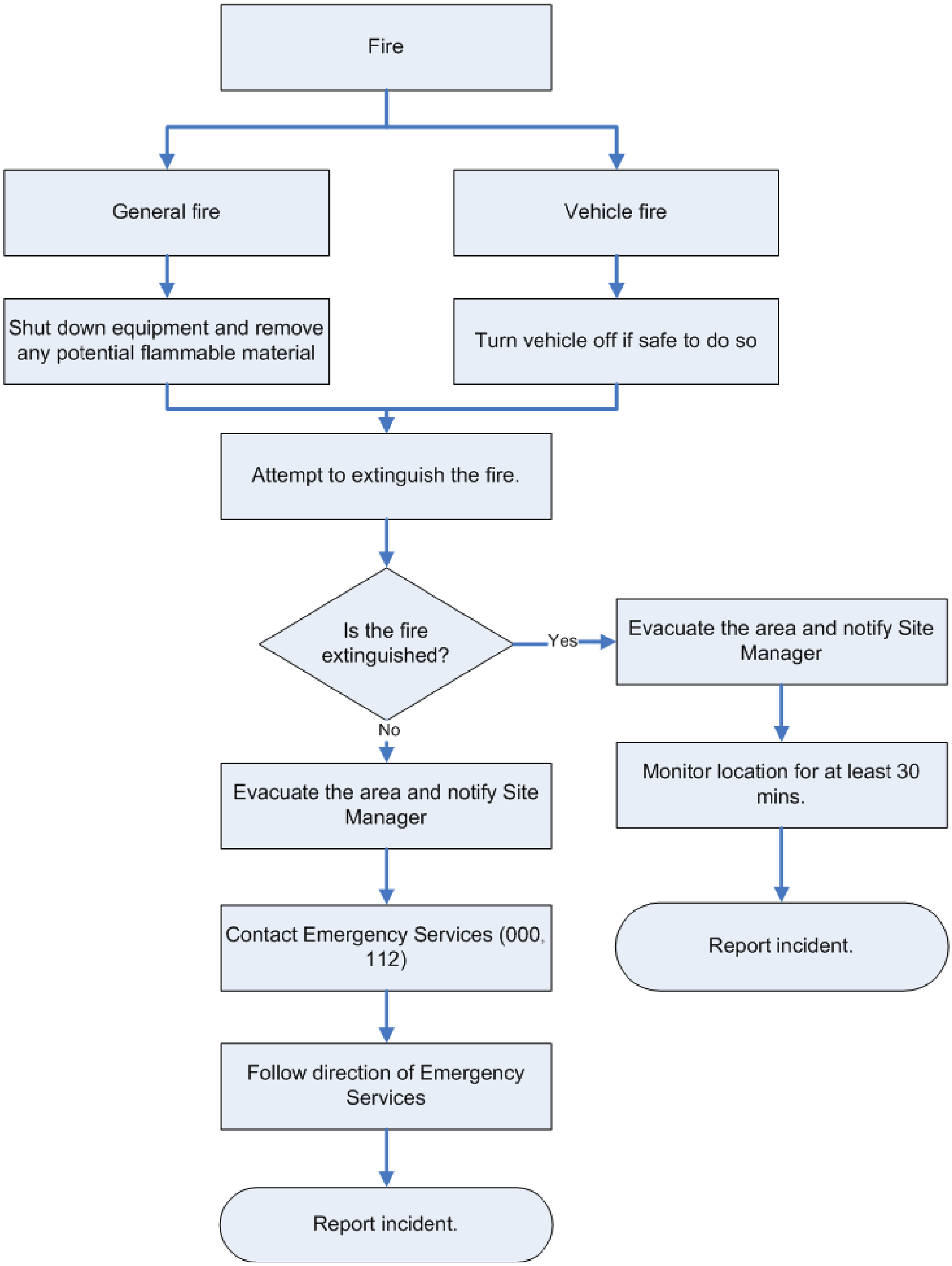
7 Appendices

Appendix A – Emergency Procedure for Fire

Appendix B – Bush Fire Site Specific Survival Plan

Appendix C – Bush Fire Evacuation Route Plan

Appendix A – Emergency Procedure for Fire



Appendix B – Bush Fire Site Specific Survival Plan

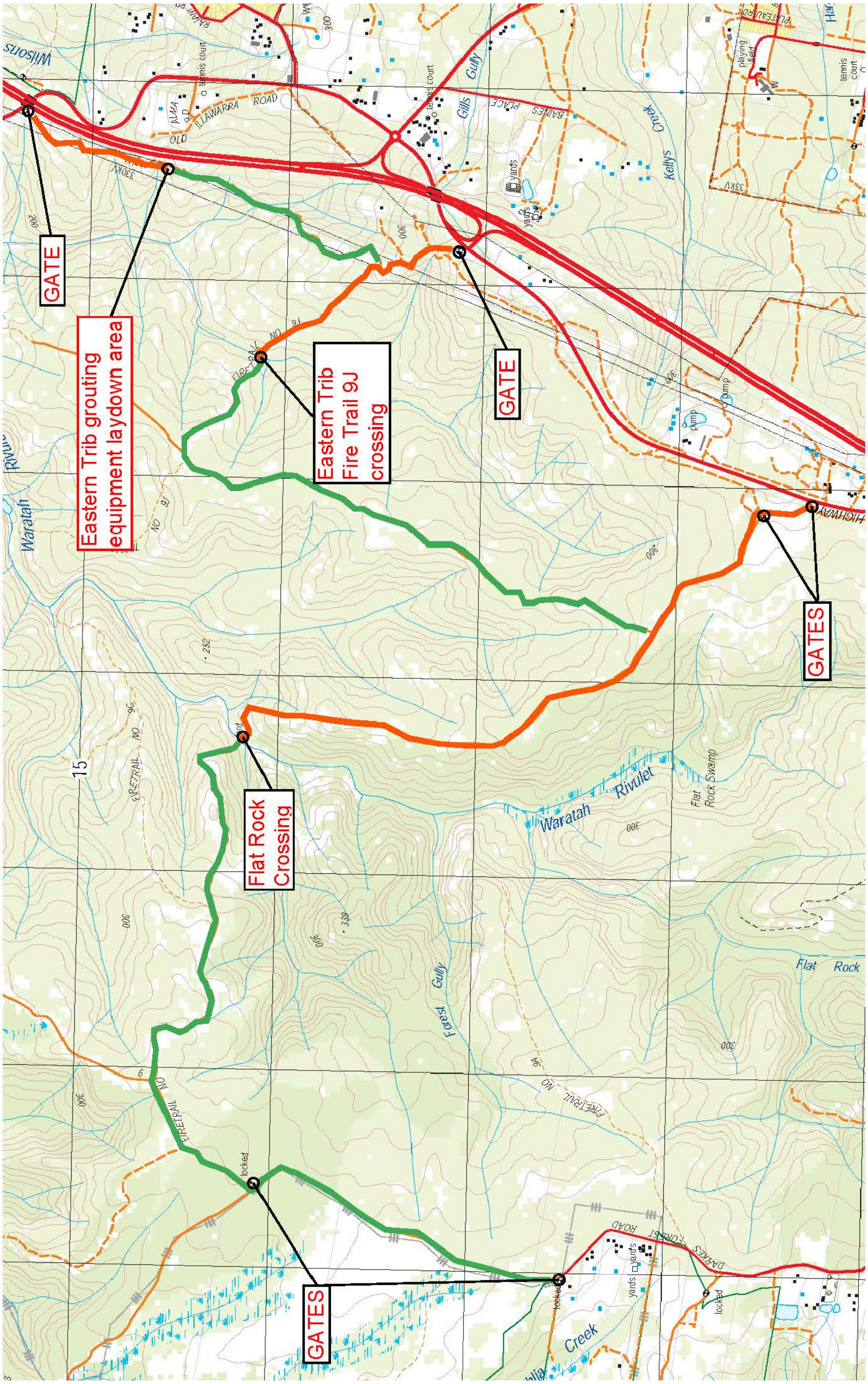
Site Location: Date:

Bush Fire Survival Plan Decisions	Agreed Actions
When will we leave? What will be your sign to leave? It could be smoke in your area, or as soon as you find out there's a fire near you.	
Where will we go? Where's a meeting place that's safe and away from a fire area?	
How will we get there? What road will you take? What's your backup plan in case the road is blocked?	
What will we take? Make a list of what you'll take in the event of a fire.	
Who will we call to tell that we're leaving and that we have arrived safely?	
What is our backup plan? What if things don't go to plan? Identify a safer location nearby that is well prepared, or a place of last resort.	

Assessment Completed by:

Name	Signature	Name	Signature

Appendix C – Bush Fire Evacuation Route Plan



ATTACHMENT 7

GROUTING PRODUCTS AND INJECTION ACTIVITIES MANAGEMENT

GROUTING PRODUCTS AND INJECTION ACTIVITIES MANAGEMENT

General

The PUR grouting products will be managed in accordance with the relevant product Material Safety Data Sheet (MSDS).

The equipment has been designed with features that assist in preventing or minimising potential impacts on the environment. These include:

- The hoses are designed to withstand four times the stall pressure of the pump to prevent rupturing.
- Hose joins and connections will be fitted with safety clips prior to filling the hoses with product.
- Hoses will be colour coded to minimise the risk of incorrect coupling.
- The accelerator and resin are mixed before entering the pump.
- The accelerator and resin are mixed before entering the pump. The pumping system is designed to withstand overpressure and in the event of a blockage, the pump is designed to automatically stall.
- The pump has a remote shut-off capability allowing pumping to be stopped remotely (e.g. at the injection site).
- Operators have the ability to manually stop grout injection by turning off the injection nozzle.

Equipment will be maintained and checked prior to use in accordance with the checklists to be developed for each stream remediation site. Example checklists are provided in Appendix 5.

In addition, prior to works commencing, the following actions will be conducted:

- Calibration of pumps.
- Proper function of all valves.
- Inspection of all hoses and fittings for any damage or obstructions.
- Proper function of shut-off valve to the high capacity pressure hose.

Hose couplings will be located within a notched plastic container containing absorbent material. The coupling will be wrapped in absorbent material and then wrapped in clear plastic to facilitate identification of any leaky couplings. Inspection of the hose couplings for leaks forms part of the checklist for two separate people.

Handling of Polyurethane Grouting Products

One container of Spetec H100 and one pallet of Accelerator ACC H100 will be transported to the Woronora Special Area, when required for injection, on a box trailer, ute tray, or truck. The box trailer, ute tray, or truck will be lined with a chemical resistant underlay. The containers of Spetec H100 and Accelerator ACC H100 will be bunded and sit on top of the underlay. That is, the bunded pallet will act as the primary containment mechanism, and the underlay as a secondary containment mechanism. The injection equipment will also be positioned on a bunded pallet in a box trailer, ute tray, or truck that has been lined with a chemical resistant underlay. The box trailers, ute trays, or truck will be positioned adjacent to the fire trail used to access the remediation site.

All of the above controls will be identified in the PUR Transport Driver's checklist which will be completed prior to leaving the Metropolitan Coal site and again prior to leaving the remediation site.

Set-Up

A set-up procedure checklist (example provided in Appendix 5) will be followed. The checklist includes the following major controls and management measures for safe handling and connection of product components:

- The connectors to and from the 205 L drums have special drip free chemical couplings.
- Accelerator ACC H100 is added to the single-component Spetec H100 in the drum, as required, determined on hole spacing, sequence of grout injection, discontinuity aperture etc.
- Product is transferred from the containers directly to the injection pump via braided delivery lines.
- The set-up checklist is countersigned by the Site Supervisor.

Injection

Start-up and pumping checklists will be completed (example provided in Appendix 5) and countersigned by the Site Supervisor. The checklists include the following major controls:

- Individual injection boreholes will be logged to detail hole injection pressure used and quantity injected. An injection record (example provided in Appendix 5) will be maintained to document the type of grout used and the quantity injected.
- Spill cleanup materials will be made available at both the pump site (spill kit in each PUR vehicle) and injection site. Should a spill occur, it will be reported immediately to the Site Supervisor, the Manager – Technical Services and/or the Environment & Community Superintendent, to WaterNSW via their Incident Management Number (1800 061 069) and to DRG. The Site Supervisor and Metropolitan Coal Technical Services Manager (or delegate) will investigate all spills and environmental incidents.
- The contents of the spill kits are listed in Section 7.2.8.5 and the spill response procedure is provided in Appendix 9.
- A pump operator will be present at the pump site and a PUR injection operator will be present at the injection site throughout the operations. In addition, a Site Supervisor will be present to oversee the drilling and grout injection activities.
- Walkie talkie communication between pump operator and injection site will be maintained at all times during the set-up and injection phases.

- At the end of each injection phase a brief (few seconds) flush using a single component is required to prevent PUR curing within the injection nozzle. The flushed component will be directed to a sealed drum which itself is bunded within a larger drum.
- The injection levers are located within a plastic tray which will act as a bund.
- Each injection hole will be covered with an apron of absorbent fabric to catch any spills during injection of that hole.

End-Shift

At the completion of daily grout injection activities, the hoses will be disconnected from the pump and injection sites and capped with purpose-built end caps. During hose disconnection, the hose will be located through a notched plastic container with absorbent material at its base, thereby absorbing any drips. The hoses will remain in place overnight (located at a distance from the stream bed and tied in places to suitable objects such as trees).

No PUR will be stored on site overnight (other than that remaining in the hoses).

Equipment malfunctions, failed or worn components, abnormalities or constraints to the system will be reported to enable modifications or amendments to be implemented.

The PUR Transport Driver and Site Supervisor each have a specific end of shift checklist (examples provided in Appendix 5) to ensure that all rubbish is removed, all PUR waste is removed, and the site is left in a tidy condition.

ATTACHMENT 8

REVIEW OF NULL HYPOTHESIS TESTING WHETHER REMEDIATION OF POOLS IMPACTED BY LONGWALL MINING IS EFFECTIVE

EMERITUS PROFESSOR THOMAS MCMAHON (2018)

Review of null hypothesis testing whether remediation of pools impacted by longwall mining is effective

TA McMahon
22 November 2018

Background

WaterNSW and OEH requested Metropolitan Coal develop a statistical procedure to assess whether remediation of pools along Waratah Rivulet and Eastern Tributary has restored the "surface flow and pool holding capacity". This report is a review of potential statistical methods to assess the success of remediation using the data currently available to carry out such a task.

Approach

The Revised Metropolitan Coal Rehabilitation Management Plan (RMP-R01-F) outlined in the WaterNSW letter of 18 June 2018 to Peabody states "A statistically valid means of defining success … should be urgently developed to support the outcomes of the proposed remediation". I note in Attachment B (Appendix A) that pool impacts and success in rehabilitation are discussed and the document suggests "… an objective statistical comparison of pool recession rates before and after impact and later rehabilitation…" be carried out using a "… Null Hypothesis of no difference in recession rates from before to after mining impact and before and after rehabilitation" (page 3). Furthermore, in the Appendix A it is noted that this can only occur at pools which have adequate baseline data for statistical comparison.

There are at least five potential approaches to assess the pre-impact – post-impact – post-remediation relationships as follows:

1. Paired catchment approach (target compared to control)
   The paired catchment approach allows variations in rainfall and evaporation over time to be taken into account by comparing the impacted site that includes rainfall and evaporation against another site with similar rainfall and evaporation but no impact effect.
   i) Pool water level (target) vs measured discharge (control)
   ii) Pool water level (target) vs estimated discharge by rainfall-runoff model (where the control could be the target pool)
   iii) Pool water level (target) vs pool water level (control).
2. Sequential analyses
   i) Analysis of recession curve directly
   ii) Recession slope analysis.

The approach finally adopted should be based on credible science and its application should be straightforward. It is noted the first three approaches listed above are not strictly recession rate analysis as required above "… an objective statistical comparison of pool recession rates before and after impact and later rehabilitation…" (page 3).

Pool water level (target) vs measured discharge (control)

In this approach the water level in the pool is modelled using a rating curve concept, for example, assuming the impervious rock barrier is represented as a broad-crested weir and/or a vee-notch weir. Thus, the discharge over the barrier is of the form $Q_{pool} = C\left(h_{pool}\right)^{e}$ (**Chadwick and Morfett, 1998)** where Q_{pool} is the discharge past the barrier, h_{pool} is the water level in the pool above an appropriate datum, the exponent (e) probably varies in the range 1 – 3, and C is a weir or reach coefficient which takes into account flow width. In adopting this 'paired catchment' approach we assume that the pool hypothetical discharge is related to the gauging station discharge as a power function (**Searcy, 1960**) and together with the above equation yields a relationship for the pool water level above cease-to-flow as $h_{pool} = \alpha\left(Q_{gs}\right)^{\beta}$ where the unknowns can be found by least squares.

Pool water level (target) vs estimated discharge by rainfall-runoff model (control)

This approach is similar to that above except the discharge is estimated at the pool barrier by a rainfall-runoff model in which the parameters are calibrated (assuming suitable rainfall, evaporation and discharge data are available) or estimated by transposition from a nearby hydrologically similar catchment.

Pool water level (target) vs pool water level (control)

Here it is assumed both pools can be modelled using the rating curve concept as noted above, and can be related through the **Searcy (1960)** power function yielding $h_{target-pool} = \alpha\left(h_{control-pool}\right)^{\beta}$ where the unknowns can be found by least squares. This approach assumes the discharge-height relationship remains stable over the range of water levels for an effective relationship to be established.

Recession curve

This approach assumes a traditional (linear or non-linear storage) master recession curve can be developed using water levels for both the target and control pools. If daily water level data are used, the usual approach allows the effect of rainfall to be minimized but does not account for evapotranspiration effects. If data permits, a master recession at a daily time-step could be developed for the winter period when evapotranspiration is at a minimum. Due to the limited amount of recession data, it is not possible to determine the uncertainty in the model parameters and, consequently, no hypothesis test can be formulated.

Recession slope analysis

The recession slope analysis is based on relating the first derivative of the traditional recession curve as a function of discharge, namely $-\frac{dQ}{dt} = aQ_{ave}^{b}$ (**Brutsaert and Nieber, 1977**) where Q_{ave} is average discharge over which $-\frac{dQ}{dt}$ is estimated, and a and b are unknown constants to be determined. For the pool analysis discharge would be replaced by water level, given the arguments presented earlier. An advantage of the approach is that the method can be applied to night-time hourly data thus minimizing the effect of evapotranspiration. Furthermore, determining a and b in the previous equation allows one to directly estimate the master recession curve at an hourly time-step. Other than some preliminary analysis as part of this review, as this approach has never been applied, it would be inappropriate to adopt it without thorough testing. Nevertheless, it is included here to provide a more complete picture of available techniques that potentially could be adopted.

Specifying 'recession' data

In surface hydrology, recession discharges are those that occur once surface runoff ceases and the recession curve (the falling limb of the hydrograph) decreases in a linear or non-linear manner. This concept is broadly adopted in the recession analysis and recession slope approaches discussed above. However, for the three paired catchment approaches, all water levels are included unless otherwise specified. In one example below, a subjective decision was made to limit the water levels used in the analysis to only those equal to or less that the median water level.

Hypothesis testing

A requirement of the overall approach is that it must include a statistical test of the hypothesis that there is a difference between the curve representing the impacted water levels and the curve representing the water levels prior to impact or after remediation. I have considered three approaches. The first follows **Salt et al. (2014)** in which a dummy variable is included in a regression equation in which the pool water levels prior and post impact or remediation are computed, and the dummy variable is tested for statistical significance. The second approach is a standard t-test of the means of the residuals (the difference between observed water levels and those computed assuming no impact or remediation) comparing a pre- and a post-situation. The third test is the Mann-Whitney non-parametric test (**Mann and Whitney, 1947**) which is used if the residuals are not normally distributed.

The three tests were applied to several sets of water level data for pools along the Waratah Rivulet. These tests are detailed in a separate report to Metropolitan Coal dated 19 November 2018 and the observations and conclusions noted therein are collated here. The report is provided in Appendix 1.

1. It is noted that both the sequential analyses - traditional recession analysis and recession slopes - not only model baseflow but also evapotranspiration during the period of analysis. The effect of direct rainfall is removed by analyzing only data several days after a rainfall event. However, for sequential analyses of daily water levels, it is near impossible to remove the full effect of evapotranspiration without resorting to a complex rainfall runoff model that incorporates a realistic baseflow algorithm. Analysis of hourly water levels, observed during night-time, minimizes the effect of evapotranspiration, but the approach has not been thoroughly tested.
2. Missing data, daily read data (no weekend readings) and occasional observation errors impeded the statistical analysis particularly for one data set.
3. Only the two sequential methods deal specifically with recessions as defined in hydrograph analysis. For the paired catchment approach, we either used all the data (that is both small and large changes in pool water levels) or water levels less than a fixed level (the median level was adopted for one analysis).

4. *Regression with a dummy variable*
   For the statistical analysis to be credible, the residuals need to be independent, normally distributed and homoscedastic that is, the magnitude of the variance is constant across the range of the variable. Independence can be overcome by sampling the data, non-normal data usually can be normalized through a Box-Cox transformation (**Box and Cox, 1964**) and heteroscedasticity can be reduced by an appropriate transformation. However, in the example we studied we were unable to achieve all these objectives and, therefore, we were unable to fully account for the assumptions required to ensure the statistical test was not compromised. Experience with regression analysis suggests this may be a continuing difficulty with this approach.
5. *Standard t-test of mean*
   We applied the t-test to two data sets: first, Pool G (impacted period compared to remediation period) using Pool J as control and, second, Pool J (pre-change in water level datum to post-change in datum) with Pool Q as control. It was found that in both cases that the residuals were not normally distributed, and the Mann-Whitney test was resorted to.
6. *Non-parametric test (Mann-Whitney)*
   We applied the Mann-Whitney (M-W) test to the same data sets as for the t-test. If the shape and spread of the two data sets being compared are similar, then the M-W assesses the difference in medians. Unfortunately, in each case that we investigated the shape and spread were different and, therefore, the Mann-Whitney test can only be used to test whether the two data sets are from the same population.

Conclusion

1. Based on this review it is unlikely that a null hypothesis test dealing specifically with the recession curve could be specified without major caveats. The daily curve is affected by evapotranspiration, the effect of which cannot be removed in any straightforward manner. An hourly recession curve using the recession slope approach was trialed, however, for water level data the approach was unsatisfactory. As a consequence, in the sequential approaches that were trialed to establish a null hypothesis test, except for one case in which water levels equal to or below a median value were adopted, there was no restriction placed on the water level data used in the analysis.
2. There are two general ways to assess whether remediation of impacted pools is effective: a ‘paired catchment’ approach or a sequential analysis. Both approaches were explored, but it was not possible to remove adequately the effect of evapotranspiration from the sequential methods.
3. Three hypothesis tests (two parametric and one non-parametric) were applied: dummy variable hypothesis test, the standard t-test of the mean, and the Mann-Whitney test when the residuals are not normally distributed. In each application of the t-test and the Mann-Whitney test, the assumptions underlying the correct application could not be strictly adhered, thus the results of the null hypothesis were compromised.
4. Given the nature of the data (large variability, missing data and some manually read) and that some assumptions required for credibility of the null hypothesis cannot be fully met, I consider it inappropriate to prescribe a specific null hypothesis that can be

applied universally. However, we have shown that a null hypothesis test is feasible in a limited way and could be incorporated in the general methodology without detailed prescription that Metropolitan Coal are required to adopt to assess the remediation activities.

References

Box GEP, Cox DR, 1964. An analysis of transformations. Jour. Royal Statistics Soc. Series B, 26, 211-243.

Brutsaert W, Nieber JL, 1977. Regionalized drought flow hydrographs from a mature glaciated plateau. Water Resour. Res. 13, 637–643.

Chadwick A, Morfett J, 1999. Hydraulics in Civil and Environmental Engineering. Third Edition, E & FN Spon, London.

Hart A, 2001. Mann-Whitney test is not just a test of medians: differences in spread can be important. BMJ (formerly the British Medical Journal) 323, 391-393.

Mann HB, Whitney DR, 1947. On a Test of Whether one of Two Random Variables is Stochastically Larger than the Other. The Annals of Mathematical Statistics 18(1), 50-60.

Saft M, Western AW, Zhang L, Peel MC, Potter NJ, 2014. The influence of multiyear drought on the annual rainfall-runoff relationship: An Australian perspective. Water Resour. Res. 51, 2444-2463.

Searcy JK, 1960. Graphical correlation of gaging-station records. Manual of Hydrology: Part 1. General Surface-Water Techniques. United States Geological Survey Water -Supply Paper 1541-C.

APPENDIX 1

STATISTICAL ANALYSIS OF WATER LEVEL VARIATIONS IN POOLS ALONG WARATAH RIVULET

STATISTICAL ANALYSIS OF WATER LEVEL VARIATIONS IN POOLS ALONG WARATAH RIVULET

TA MCMAHON

19 NOVEMBER 2018

TABLE OF CONTENTS

1 BACKGROUND

WaterNSW and OEH requested Metropolitan Coal develop a statistical procedure to assess whether remediation of pools along Waratah Rivulet and Eastern Tributary has restored the “surface flow and pool holding capacity”.

This report is a review and application of potential methods to assess the success of remediation using the data currently available to carry out such a task.

2 APPROACH

The Revised Metropolitan Coal Rehabilitation Management Plan (RMP-R01-F) outlined in the WaterNSW letter of 18 June 2018 to Peabody states “A statistically valid means of defining success … should be urgently developed to support the outcomes of the proposed remediation”. I note in Attachment B (Appendix A) that pool impacts and success in rehabilitation are discussed and the document offers guidance to the statistical analysis that is required as follow:

“Since the period prior to pool impacts is ill-defined (not clearly specified for any particular pool) and the water level recession 'rates' prior to pool impacts is ill-defined, the success of the rehabilitation objective itself is also ill-defined. As a result, the 'success' measure itself is neither directly measurable nor quantifiable and the 'Success' of rehabilitation will therefore likely be based on subjective opinion. This can and should be improved upon by an unambiguous statement about the period before and after pool impacts and an objective statistical comparison of pool recession rates before and after impact and later rehabilitation (Null Hypothesis of no difference in recession rates from before to after mining impact and before and after rehabilitation). It is noted, however that this can only really occur at pools which have adequate baseline data for statistical comparison” (page 3).

There are at least five potential approaches to assessing the pre-impact – post-impact – post-remediation relationships as follows:

1. Paired catchment approach (target compared to control)
   The paired catchment approach allows variations in rainfall and evaporation over time to be taken into account by comparing the impacted site that includes rainfall and evaporation against another site with similar rainfall and evaporation but no impact effect.
   i) Pool water level (target) vs measured discharge (control)
   ii) Pool water level (target) vs estimated discharge by rainfall-runoff model (control which could be the target pool)
   iii) Pool water level (target) vs pool water level (control).
2. Sequential analyses
   i) Analysis of recession curve directly
   ii) Recession slope analysis.

The approach finally adopted should be based on credible science and its application should be straightforward. It is noted the first three approaches listed above are not strictly recession rate analysis as required above "… an objective statistical comparison of pool recession rates before and after impact and later rehabilitation…" (page 3).

3 DATA

Table 1 lists the data that have been used in this review. Monitoring of Pool G commenced in September 2005 and is considered to be impacted from LW mining. There are nearly 11 months of pre-impact water level data. Remediation of the pool took place from September 2015 to mid-August 2016, followed by two years of post-remediation data. Data for Pools J and Q cover a common period from 3 April 2007 to 30 December 2017. A datum adjustment 0.075 m was applied to Pool J on 23 March 2012. The unimpacted pools L and M each have 8½ years of water level data. In addition, unimpacted discharge data, measured at the Waratah Rivulet gauging station (Fire Road #95) are available for more than 11 years starting in February 2007. Twelve years of daily rainfall for a local site are available.

Figures 1 and 2 are plots of the water levels in Pools G and J respectively. Pool G exhibits several different patterns of water level variability and Pool J shows the effect of the adjusted datum.

4 POOL WATER LEVEL (TARGET) VS MEASURED DISCHARGE (CONTROL)

In this approach the water level in the pool is modelled using a rating curve concept assuming the impervious rock barrier can be represented as a broad-crested weir and/or a vee notch weir. Thus, the discharge over the barrier can be represented as $Q_{pool} = C\left(h_{pool}\right)^{e}$ (**Chadwick and Morfett, 1998)** where Q_{pool} is the discharge past the barrier, h_{pool} is the water level in the pool above an appropriate datum, the exponent (e) probably varies in the range 1 – 3 and C is a weir or reach coefficient which takes into account flow width. In adopting this 'paired catchment' approach it is assumed that the pool hypothetical discharge (target) is related to the gauging station discharge (control) as a power function (**Searcy, 1960)** and together with the above 'weir' equation yields a relationship for the pool water level above cease-to-flow as $h_{pool} = \alpha\left(Q_{gs}\right)^{\beta}$ where the unknowns can be found by least squares.

5 POOL WATER LEVEL (TARGET) VS ESTIMATED DISCHARGE BY RAINFALL-RUNOFF MODEL (CONTROL)

This approach is similar to that above except the discharge is estimated at the pool barrier by a rainfall-runoff model in which the parameters are calibrated (assuming suitable rainfall, evaporation and discharge data are available) or estimated by transposition from a nearby hydrologically similar catchment. No observed data are available to calibrate a rainfall-runoff model for any of the pools along Waratah Rivulet although information may be available to transpose model parameters. This approach was not considered further in the investigation.

6 POOL WATER LEVEL (TARGET) VS POOL WATER LEVEL (CONTROL)

Here it is assumed that both pools can be modelled using the rating curve concept noted above and can be related through the **Searcy (1960)** power function yielding $h_{\boldsymbol{target-pool}} = \alpha(h_{\boldsymbol{control-pool}})^{\beta}$ where $h_{\boldsymbol{target-pool}}$ and $h_{\boldsymbol{control-pool}}$ are respectively the water levels at a target and control pools, and the unknowns can be found by least squares. This approach assumes the discharge-height relationship remains stable over the range of water levels for an effective relationship to be established.

7 RECESSION CURVE

The recession approach assumes for a given pool a traditional linear-storage master recession curve (two unknown parameters) or a nonlinear master recession curve (three unknown parameters) can be developed using water levels for pre- and post-conditions. If daily water level data are used, the approach would allow the effect of rainfall to be minimized but does not remove evapotranspiration (ET) effects. If data permits, a master recession at a daily time-step could be developed for the winter period when evapotranspiration is at a minimum. An alternative approach is an hourly recession model (see next section) based on night-time recessions when ET is minimal. Due to limited amount of recession data, it is not possible to determine the uncertainty in the model parameters and, consequently, no hypothesis test can be formulated.

8 RECESSION SLOPE ANALYSIS

The recession slope is the first derivative of the recession curve. As far as I am aware, this approach has never been applied to the type of application considered here. The basic relationship is $-\frac{dQ}{dt} = aQ_{ave}^{b}$ (**Brutsaert and Nieber, 1977**) where Q_{ave} is average discharge over which $-\frac{dQ}{dt}$ is estimated and a and b are unknown constants to be determined. In the pool analysis, discharge is replaced by water level, given the arguments presented earlier. A potential advantage is that the method can be applied to night-time hour data thus minimizing the effect of ET. Furthermore, determining a and b in the above equation allows one to directly estimate a linear or non-linear master recession curve at an hourly time step. Again, due to limited amount of recession data, it is not possible to determine the uncertainty in the model parameters and, consequently, no hypothesis test could be formulated.

I applied the recession slope analysis to year 2010 hourly water level data for Pool N. I was not satisfied with the initial plotted relationship between $-\frac{dh_{pool}}{dt}$ and h_{ave} and, although the approach has potential to produce a master recession curve, I decided the procedure was insufficiently developed to warrant further investigation.

9 HYPOTHESIS TESTING

A requirement of the overall approach to be recommended is that it must include a statistical test of the hypothesis that there is a difference between the curve representing the impacted data and the curve representing the water levels after remediation.

I have considered three approaches. The first follows **Saft et al. (2014)** where a dummy variable is included in the regression equation in which the pool water levels prior and post impact or remediation are computed, and the dummy variable is tested for statistical significance. The second approach is a standard t-test of the means of the residuals (the difference between observed water levels and those computed assuming no impact or remediation) (**Haan, 1977**). The third test is the Mann-Whitney test which would be applied if the residuals in the previous approach are not normally distributed (**Mann and Whitney, 1947**).

10 APPLICATIONS OF HYPOTHESIS TESTING

Comments on the application of several of the above procedures, which were applied in full or in part, follow.

10.1 POOL WATER LEVEL (TARGET) VS MEASURED DISCHARGE (CONTROL)

The water levels in Pool G were related to the discharges measured at the Fire Road No 95 gauging station on the Waratah Rivulet. A single equation including a dummy variable, D, was developed based on the combined data for the impact period from February 2007 to March 2013 and the post-remediation period September 2016 to present. The dummy variable was then tested for statistical significance to assess whether the water levels post remediation are different to those that were impacted. Details of this test follows.

10.1.1 Dummy variable hypothesis test

The hypothesis test is applied to the Impact period 1 and the post-remediation data in **Figure 3**. The following equation representing the data was developed:

$$\frac{(h_{pool})^{\lambda}-1}{\lambda} = a + b\ log_{10}(Q_{gs}) + cD \qquad (1)$$

where h_{pool} is the daily water level in Pool G, Q_{gs} is the daily discharge measures at the Fire Road No 95 gauging station, and D = 0 for days during Impact period 1, and D = 1 for days during post-remediation, a, b and c, are constants to be determined. Because parametric statistical tests require the residuals to be approximately normally distributed, a Box-Cox transformation (**Box and Cox, 1964**) ($x_t = \frac{x^{\lambda}-1}{\lambda}$) with λ = 0.61 (adopted when the coefficient of skewness of $\frac{(h_{pool})^{\lambda}-1}{\lambda}$ is computed as zero) was applied to h_{pool}, and a logarithmic transformation was applied to Q_{gs}. For a regression model to be plausible there should be no co-linearity in the dependent variables, no autocorrelation in the residuals, and they should be homoscedastic, that is, the residuals should have finite variance. **O'Brien (2007)** discusses the issue of co-linearity without providing an unambiguous recommendation although it seems for Variance Inflation Factors (VIFs) < 10 co-linearity may not be very important. Because the water level and discharge data have many gaps (e.g. during the impact period 1, there was only 36% of daily water levels available) no attempt was made to remove the effect of autocorrelation**.** Both **Saft el al. (2014**) and **Helsel and Hirsch (1992, page 252**) suggest straightforward methods to remove the autocorrelation effect. Homoscedasticity of the residual should also be checked. For the application discussed below, the variance did not vary monotonically with the fitted value of the dependent variable. If the residuals were not homoscedastic, it would be desirable to adjust the dependent variable by an appropriate transformation.

Adopting the above approach, the least squares analysis of the data yielded the following relationship:

$$\frac{(h_{pool})^{\lambda}-1}{\lambda} = 24.399 + 18.574\, log_{10}(Q_{gs}) - 11.719D \qquad (2)$$

for n (sample size) = 1193, R^2(adj) (adjusted multiple correlation coefficient) = 76.0%, S (standard error of estimate) = 8.02, and VIF = 1.69. In **Equation 2,** the regression coefficient c has a value of -11.719 with a standard error of 0.641 and a p-value of 0.000. However, even with incorporating a Box-Cox transformation (λ = 0.61) of the water levels and a logarithmic transformation of the discharges, the residuals were not normally distributed (Anderson-Darling (A-D) statistic (A2) = 91, p-value < 0.01 and, therefore, the null hypothesis that the data are normally distributed was rejected) (see **Anderson and Darling, 1954**). Thus, we cannot be confident in concluding that c = -11.719 is not due to chance. Hence, we also cannot be confident in rejecting the null hypothesis that the coefficient c = 0 in favour of the alternate hypothesis that $c \neq 0$. If we were confident that the null hypothesis could be rejected, then the two relationships are different, and the water levels post-remediation are different to those that were impacted during period 1.

The success or otherwise of this approach as a satisfactory method to test the statistical significance of difference between two data sets depends on being able to normalize the data and ensure homoscedasticity. Normality was not achieved in this case and, therefore, the procedure should not be applied unless the residuals can be normalized.

10.2 POOL WATER LEVEL (TARGET) VS POOL WATER LEVEL (CONTROL)

Two examples were considered here: Water levels in Pool G were related to water levels in Pool J (replacing the discharge data in the previous example), and water levels in Pool J were related to those in Pool Q.

10.2.1 Water levels Pool G and Pool J

An alternative to the previous approach is to replace the discharge with pool water level; in this example, the water levels in Pool J are the control. For the two periods October 2013 to August 2015 (Pool G impacted) and September 2016 to present (Pool G post remediation) relationships were developed between water levels of Pools G and J as shown in **Figure 4**.

The following equation for the remediation period was then used to estimate the water levels in Pool G assuming no impact.

$$h_{PoolG} = 1.11h_{PoolJ} - 35.7 \quad (3)$$

where h_{PoolG} and h_{PoolJ} are the water levels in Pools G and J respectively, for n = 351, R^2(adj) = 91.4%, and S = 9.63. The residuals are plotted as **Figure 5**.

Two hypothesis tests – a parametric and a non-parametric test – were applied to test the difference in the two groups of residuals in **Figure 5**.

a) Parametric hypothesis test

The parametric hypothesis test adopted is the standard t-test to assess whether the means of the two residual data sets (Pool G impacted and Pool G post-remediation) in **Figure 5** are different. The null hypothesis is that there is no difference between the two means:

Null hypothesis $H_0: \mu_R - \mu_I = 0$

Alternative hypothesis $H_1: \mu_R - \mu_I \neq 0$

where μ_R and μ_I are the means of the Pool G remediated and impacted water levels respectively, and the variables are assumed to be approximately normally distributed.

The statistics for the two residual series are:

Residual series	N*	Mean	Standard error of mean
Pool G impacted	178	-29.7	0.97
Pool G post-remediated	351	-0.01	0.51

*sample size

and the test results are:

t-value	Degrees of freedom	p-value
-27.0	278	0.000

As the p-value is less than 0.05, the null hypothesis is rejected in favour of the alternative hypothesis in which the average Pool G water level post-remediation is different to (and higher than) the average impacted water level. But the individual data sets are not normally distributed (for the A-D normality test, p-value < 0.01 in both cases) although the combined set is normal. Nevertheless, this places some doubt about the adequacy of the t-test in this application.

b) Non-parametric hypothesis test

The Mann-Whitney is the alternative test as it does not require the assumption of normality and can detect differences in distribution shape and spread. Where the shape and spread of the data are approximately the same, the test detects the difference in the medians (**Hart, 2001**).

The statistics for the two residual series are:

Residual series	N	Median
Pool G impacted	178	-27.0
Pool G post-remediated	351	0.199

Null hypothesis $H_0: \eta_R - \eta_I = 0$
Alternative hypothesis $H_1: \eta_R - \eta_I \neq 0$
where η_R and η_I are the median water levels of the Pool G remediated and impacted respectively, and the test result is:

U-value	p-value
16963	0.000

The Mann-Whitney test is used to assess whether residuals for the impacted period and those drawn from the remediation period are from the same population. As the p-value is less than 0.05, the null hypothesis is rejected in favour of the alternative hypothesis in which the average Pool G water level post-remediation is different to (and higher than) the average impacted water level.

To examine statistically the difference in medians the Mann-Whitney test assumes the shape and spread of the data are approximately the same. This was explored in **Figure 6,** where histograms of the residuals of the water levels for impact period and remediation periods are plotted, and the figure suggests the shapes are dissimilar. How much this affects the validity of the statistical test of the median is unknown but the hypothesis that the water levels for the impact period and those post-remediation were from the same population is rejected in favour of the alternative hypothesis.

10.2.2 Water levels Pool J and Pool Q

In this analysis the period from the 3 April 2007 to the 22 March 2012 (1788 days of data, 28 were missing) for Pool J is designated as the pre-datum adjustment or pre-change period and the period from 23 March 2012 to 30 December 2017 (2109 days of data) as the post-adjustment period. Pool J is considered the dependent variable (the target pool) and Pool Q is adopted as the independent variable (the control pool).

Two sets of data were investigated.

1. The first data set consisted of all water level data for Pool J, which incorporated the datum adjustment, and Pool Q.
2. To represent recession water levels, the second data set included only water levels equal to or below the median water levels in both pools. The median water levels are:

	Pool J	Pool Q
Pre-datum adjustment	0.380 m	0.146 m
Post- datum adjustment	0.368 m	0.119

10.2.2.1 Analyses of all water level data

The water levels in the two pools are plotted as an x-y plot in **Figure 7** for the pre-change period. The figure shows a least-squares fit of a second-order polynomial yielding the following equation:

$$WL_J = 0.4656WL_Q^2 + 0.2542WL_Q + 0.3289 \quad (4)$$

where WL_J is water level in Pool J (m), WL_Q is water level in Pool Q (m), and n = 1788, R^2(adj) = 0.97, and se = 0.011. Note that as the residuals are not normally distributed (A2 = 3.2, p-value < 0.01), the true values of R^2 will be lower and the se values will be larger.

This equation is used to test the water levels in Pool J during the post-change period assuming the pre-change relationship is applicable during the post-change period. The difference in water levels between those based on **Equation 4** and the observed water levels in Pool J, adjusted by 0.075 m, are plotted as residuals in **Figures 8a and 8b** (the latter showing a reduced range but more detail). The test considers whether the mean or the median of the residuals of the post-change is different to the mean or median of the residuals of the pre-change period.

As before, two hypothesis tests – parametric and non-parametric – were considered.

a) Parametric test

The standard t-test was used to assess whether the means of the two data sets (pre-change water levels in Pool J to post-change water levels), represented by the residuals (**Figure 8**), are different. The null hypothesis is that there is no difference between the two means:

Null hypothesis $H_0: \mu_A - \mu_B = 0$

Alternative hypothesis $H_1: \mu_A - \mu_B \neq 0$

where μ_A and μ_B are the means of the water levels post-change and water levels pre-change respectively, and the variables are assumed to be approximately normally distributed.

The statistics for the two residual series are:

Residual series	N	Mean	Standard error of mean
Pre-change	1788	0.000	0.00027
Post-change	2103	0.0002	0.00079

and the test results are:

t-value	Degrees of freedom	p-value
-0.20	2577	0.844

As the p-value is not less than 0.05, the null hypothesis cannot be rejected, and thus we are unable to show there is a difference between the means of the water levels between the two periods. The strength of this rejection (p-value is high) is tempered by the fact that the individual data sets are not normally distributed, and this places some doubt about the efficacy of the test.

b) Non-parametric test

The statistics of the Mann-Whitney analysis are as follows:

The statistics of the two residual series are:

Residual series	N	Median
Pre-change	1788	0.00093
Post-change	2109	0.00074

Null hypothesis $H_0: \eta_A - \eta_B = 0$
Alternative hypothesis $H_1: \eta_A - \eta_B \neq 0$
where η_A and η_B are the median water levels of the Pool J post-change and pre-change respectively, yielding the following p-value.

U-value	p-value
3465471	0.581

The Mann-Whitney test is used to assess whether the pre- and post-datum adjustment data sets were drawn for the same population. As the p-value is not less than 0.05, the null hypothesis is not rejected and, therefore, it could not be shown there is a difference between the pre-change group and post-change group of water levels in Pool J.

As noted above, to examine statistically the difference in medians, the Mann-Whitney test assumes the shape and spread of the data are approximately the same. This was examined in **Figure 9,** where histograms for pre-change and post-change water levels are plotted, and the figure suggests the shapes are dissimilar although the Mann-Whitney suggests otherwise. How much this affects the validity of the statistical test of the median is unknown, but the hypothesis that the two pre- and post-data sets as representative in the Mann-Whitney are the same was not rejected.

10.2.2.2 Analyses of low water level data

Figure 10 is a plot of Pools J and Q water levels prior to the datum change but, in this case, all the water levels are less than or equal to medians (representing small water level changes and akin to 'recession' water levels). A least-squares second-order polynomial yields the following equation:

$$WL_J = -5.333WL_Q^2 + 1.6814WL_Q + 0.2443 \quad (5)$$

where n = 834, R^2(adj) = 0.867, and se = 0.0044. Note that as the residuals are not normally distributed (A2 = 3.2, p-value < 0.01), the R^2 and the se values are approximate. Following the same steps as used for all water level data analysis outlined above, the residuals for Pool J including the adjustment of 0.075 m are presented in **Figure 11**. Compared **to Figure 8**, the pre- and post-adjustment residuals presented in **Figure 11** appear to be different.

Again, two hypothesis tests – parametric and non-parametric – were considered.

a) Parametric test

The standard t-test was again applied to assess whether the means of the two data sets (pre-change water levels in Pool J to post-change water levels) represented by the residuals (**Figure 11**) are different.

The statistics for the two residual series are:

Residual series	N	Mean	Standard error of mean
Pre-change	887	-0.00057	0.00016
Post-change	1055	0.00040	0.00025

and the test results are:

t-value	Degrees of freedom	p-value
-3.26	1720	0.001

As the p-value is less than 0.05, the null hypothesis is rejected, and thus there is a difference between the means of the water levels between the two periods. But the individual low water level data sets are not normally distributed (although they are considerably more normal than for all the data), so one cannot be too sure about the conclusions (although they are similar to our visual observations).

b) Non-parametric test

The statistics for the Mann-Whitney test are:

Residual series	N	Median
Pre-change	887	-0.00044
Post-change	1055	0.00037

and the test result is:

U-value	p-value
839076	0.066

As the p-value is not less than 0.05 (although very close), the null hypothesis is not rejected and, therefore, it could not be shown there is a difference between the two groups of water levels (pre-change and post-change) in Pool J. The shape and spread of the two sets of water levels are presented in **Figure 12** which appear again to suggest that care needs to be taken in not rejecting the null hypothesis that there is no difference in the medians.

11 CONCLUSION

1. There are two general ways to assess whether remediation of impacted pools is effective: 'paired catchment' approach and sequential analysis. Both approaches were explored, and it was not possible to remove adequately the effect of evapotranspiration from the sequential methods. The potential method is a 'paired catchment' procedure in which a target pool is related to a control pool.
2. Based on this review it is unlikely that a null hypothesis test dealing specifically with the master recession curve could be developed. The daily curve is affected by evapotranspiration and its effect cannot be eliminated in any straightforward manner. An hourly recession curve using the recession slope approach was trialed, however, for water level data the approach was unsatisfactory. As a consequence, in my review of the paired catchment approaches to establish a null hypothesis test, except for one data set, there was no restriction placed on the water level data used in the analyses.
3. Three hypothesis tests were applied: dummy variable hypothesis test, the standard t-test of the mean, and the Mann-Whitney test for the median when the residuals are not normally distributed. In each application of the t-test (with respect to the mean) and the Mann-Whitney test (with respect to the median), the assumptions underlying the correct application of each test could not be strictly adhered to such that the results of the null hypothesis was compromised. However, the broader interpretation of the Mann-Whitney test permitted the difference between two groups of residuals to be statistically assessed.
4. Given the nature of the data (large variability, missing data and some manually read) I consider it inappropriate to prescribe a specific null hypothesis that can be applied universally. However, we have shown that a null hypothesis test is sometimes feasible and could be incorporated in the general methodology without detailed prescription that Metropolitan Coal are required to adopt to assess the remediation activities.

12 REFERENCES

Anderson TW, Darling DA, 1954. A test of goodness of fit. Jour. Amer. Statistical Assoc. 49(268), 7650769.

Box GEP, Cox DR, 1964. An analysis of transformations. Jour. Royal Statistics Soc. Series B, 26, 211-243.

Brutsaert W, Nieber JL, 1977. Regionalized drought flow hydrographs from a mature glaciated plateau. Water Resour. Res. 13, 637–643.

Chadwick A, Morfett J, 1999. Hydraulics in Civil and Environmental Engineering. Third Edition, E & FN Spon, London.

Haan CT, 1977. Statistical Methods in Hydrology. The Iowa State University Press, Ames.

Hart A, 2001. Mann-Whitney test is not just a test of medians: differences in spread can be important. BMJ (formerly the British Medical Journal) 323, 391-393.

Helsel DR Hirsch RM, 1992. Statistical methods in water resources. Studies in Environmental Science 49, Elsevier, Amsterdam.

Mann NB, Whitney DR, 1947. On a test of whether one or two random variables is stochastically larger than the other. The Annals of Mathematical Statistics. 18 (1), 50-60.

O'Brien RM, 2007. A caution regarding rules of thumb for Variance Inflation Factors, Quality & Quantity 41, 673-690.

Saft M, Western AW, Zhang L, Peel MC, Potter NJ, 2014. The influence of multiyear drought on the annual rainfall-runoff relationship: An Australian perspective. Water Resour. Res. 51, 2444-2463.

Searcy JK, 1960. Graphical correlation of gaging-station records. Manual of Hydrology: Part 1. General Surface-Water Techniques. United States Geological Survey Water -Supply Paper 1541-C.

13 TABLE 1 DATA USED IN THIS REVIEW

Variable	Period	Units (daily time-step)	Monitoring	Comment
Pool water level data				
Pool G	20 Sep 2005 – 31 Aug 2018	mm depth below local datum	Manual read except at weekends and when area in inaccessible due to wet conditions	Pre-impact period 20 Sep 2005 – 14 Aug 2006 Impaction period 15 Aug 2006 – 14 Sep 2015 Remediation period 15 Sep 2015 – 14 Aug 2016 Post-remediation period 15 Aug 2016 – 31 Aug 2018
Pool J	3 Apr2007 – 30 Dec 2017	mm depth above local datum	Recording sensor	Datum adjusted upwards by 0.075 m on23 Mar 2012.
Pool L	1 Jan 2010 – 3 Jul 2018	mAHD	Recording sensor	No impact
Pool M	1 Jan 2010 – 3 Jul 2018	mAHD	Recording sensor	No impact
Pool N	2010	mAHD	Recording sensor	No impact during 2010
Pool Q	20 Feb 2007 – 30 Jan 2018	mm depth above local datum	Recording sensor	No impact
Discharge data				
Waratah R @ Fire Rd # 95	21 Feb 2007 – 30 Jun 2018	ML/day	Rated gauging station	No impact
Rainfall data				
PV1	11 Jul 2006 – 3 Aug 2018	mm/day		

14 FIGURES

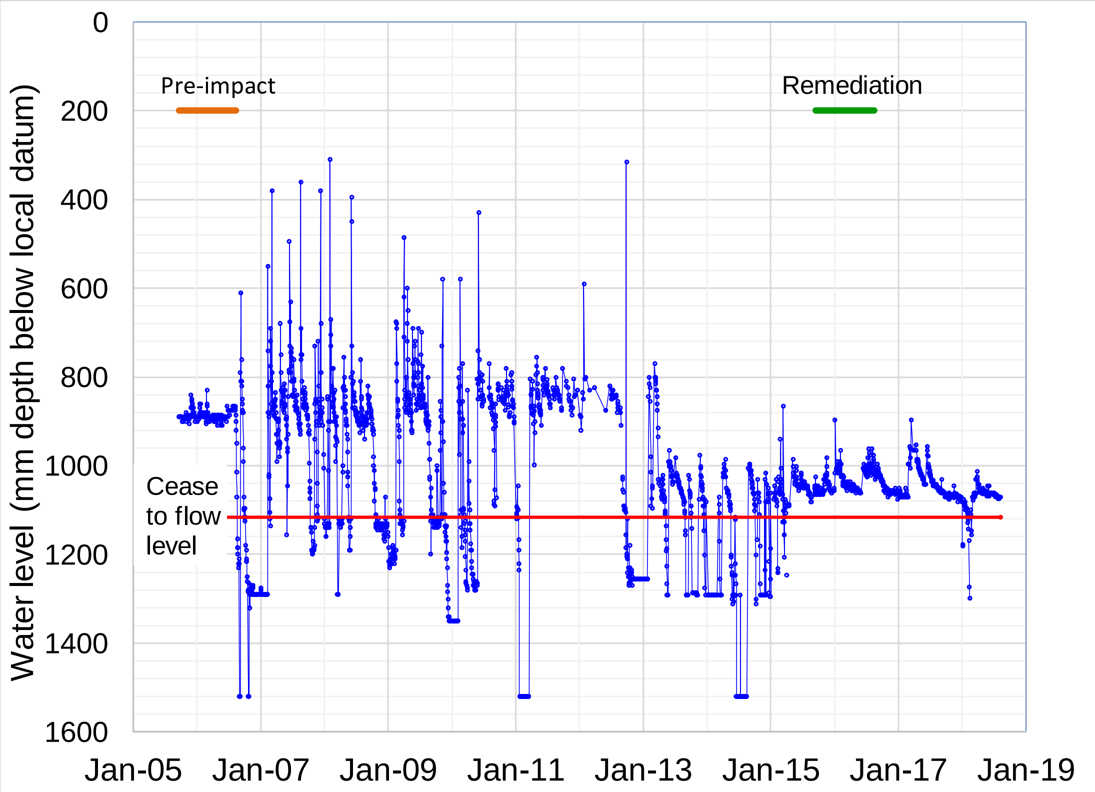


Figure 1 Water level variation in Pool G.

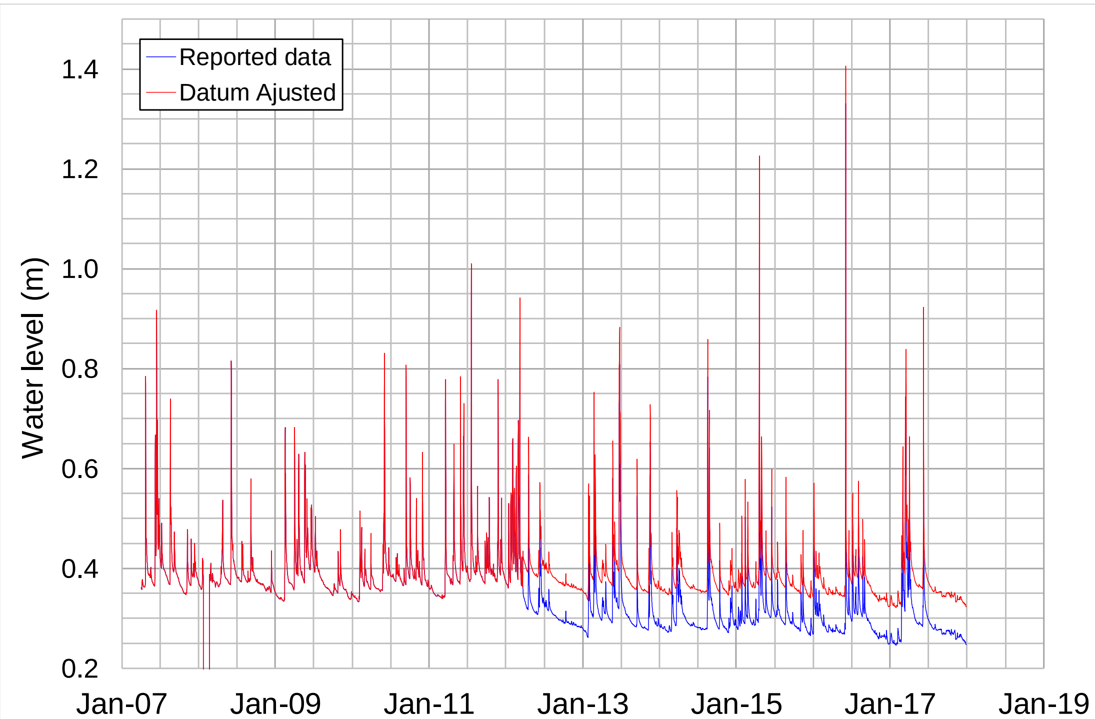


Figure 2 Water level in Pool J over time showing datum adjustment from 23 March 2012.

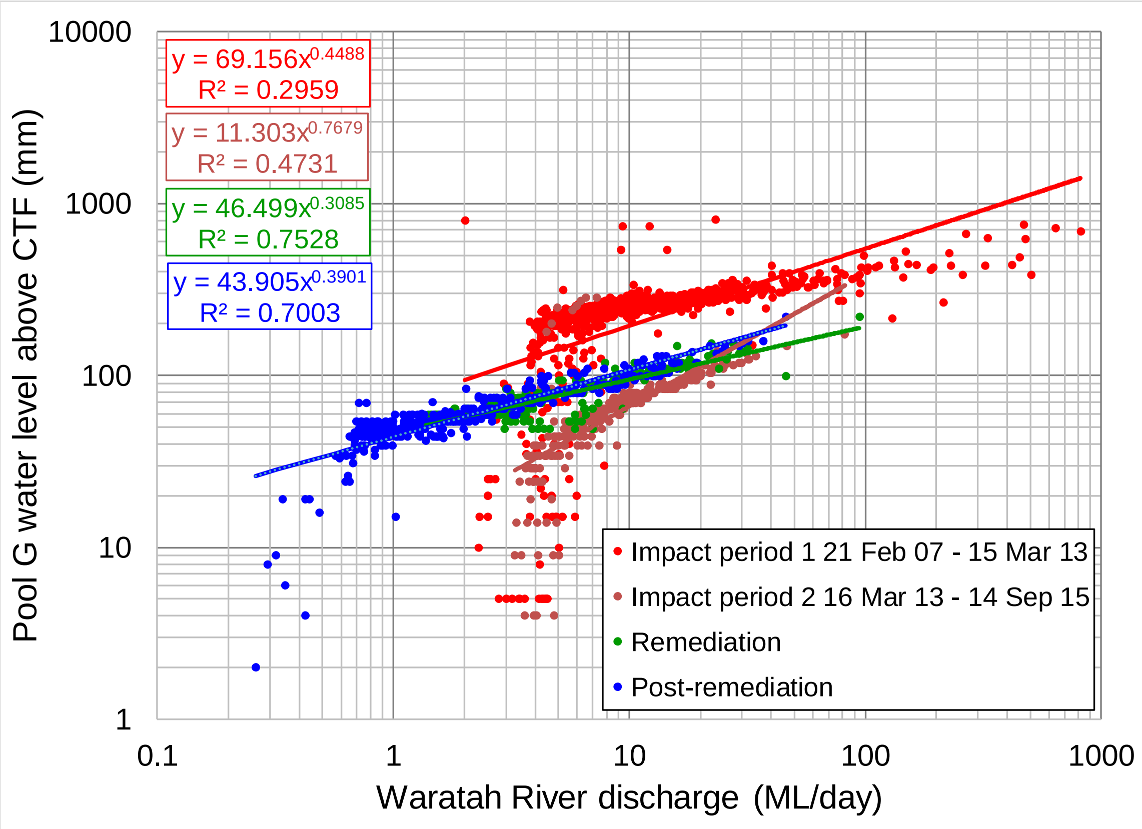


Figure 3 Relationships between pool water levels in Pool G and discharges at Waratah Rivulet gauging station.

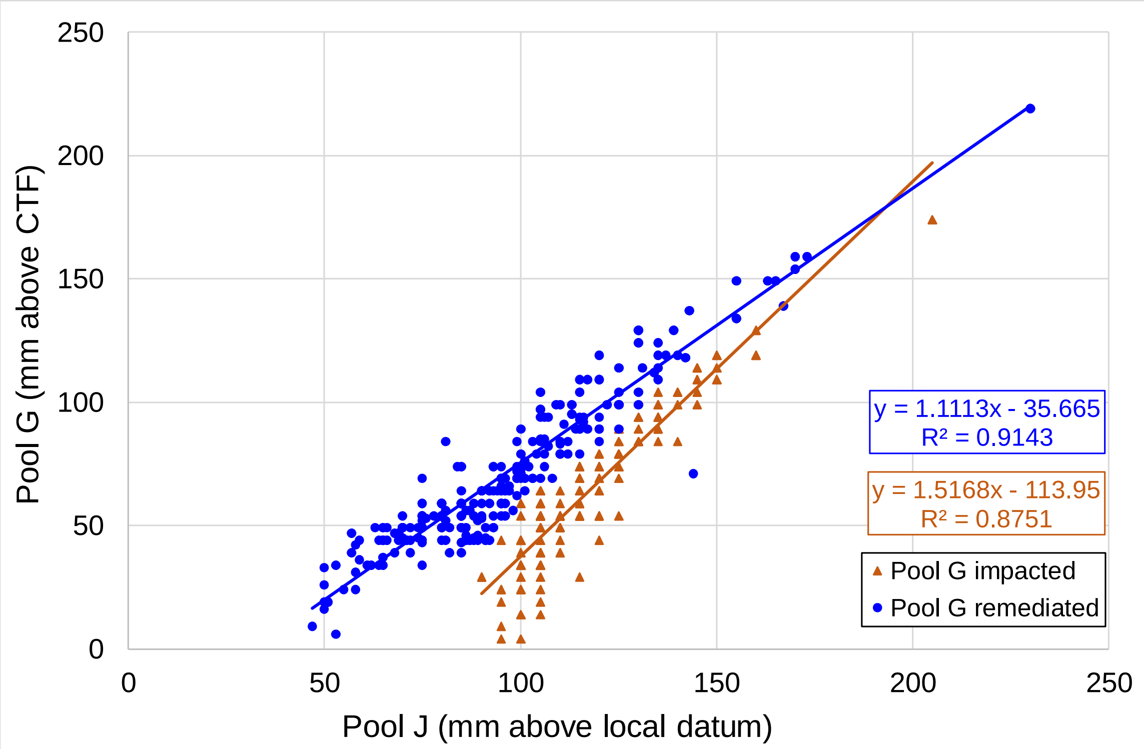


Figure 4 Relationships between Pool G and Pool J for impacted and remediated periods.

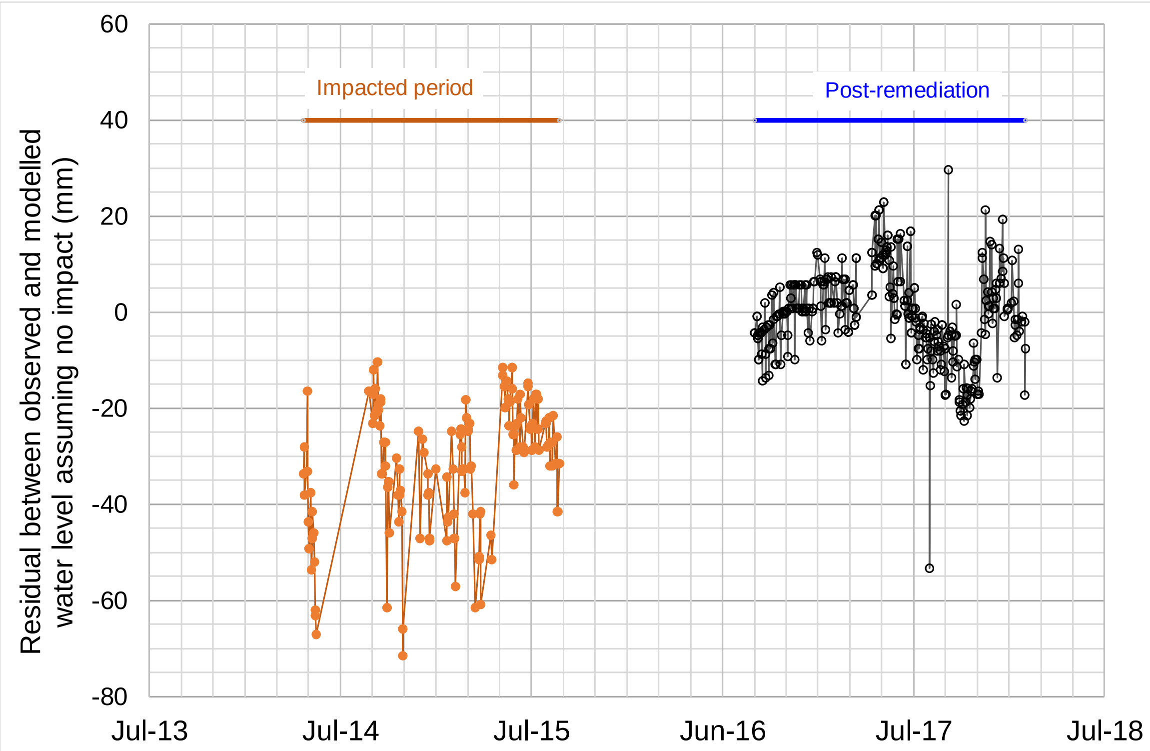
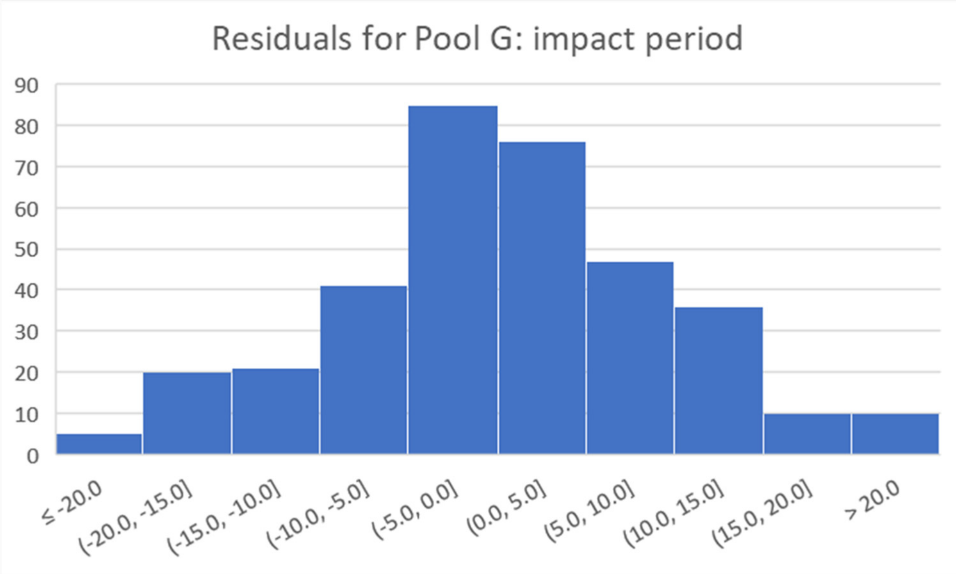


Figure 5 Residuals between observed water and modelled (removing the effect of impact) water levels in Pool G.



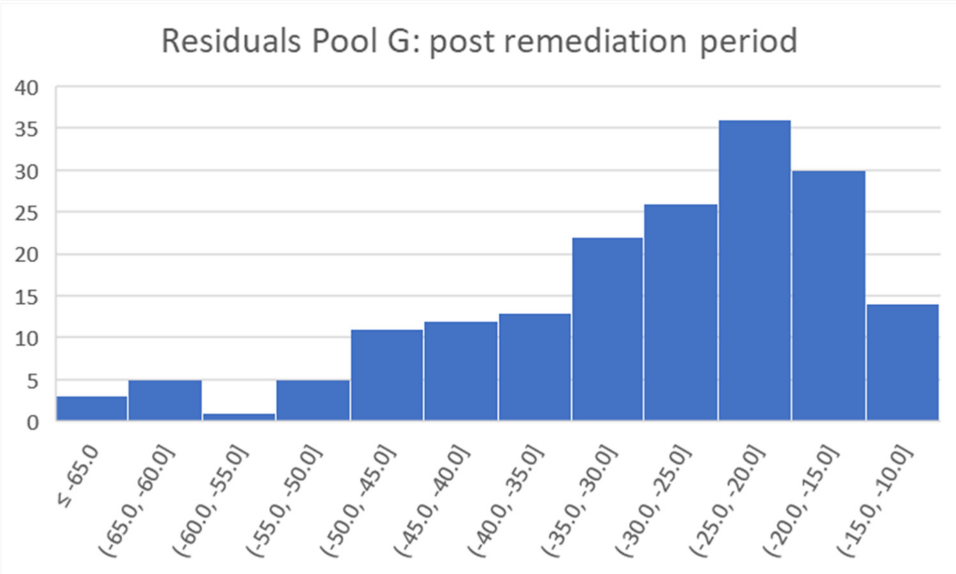


Figure 6 Comparison between the histograms of residuals for the impact and post-remediation periods for Pool G.

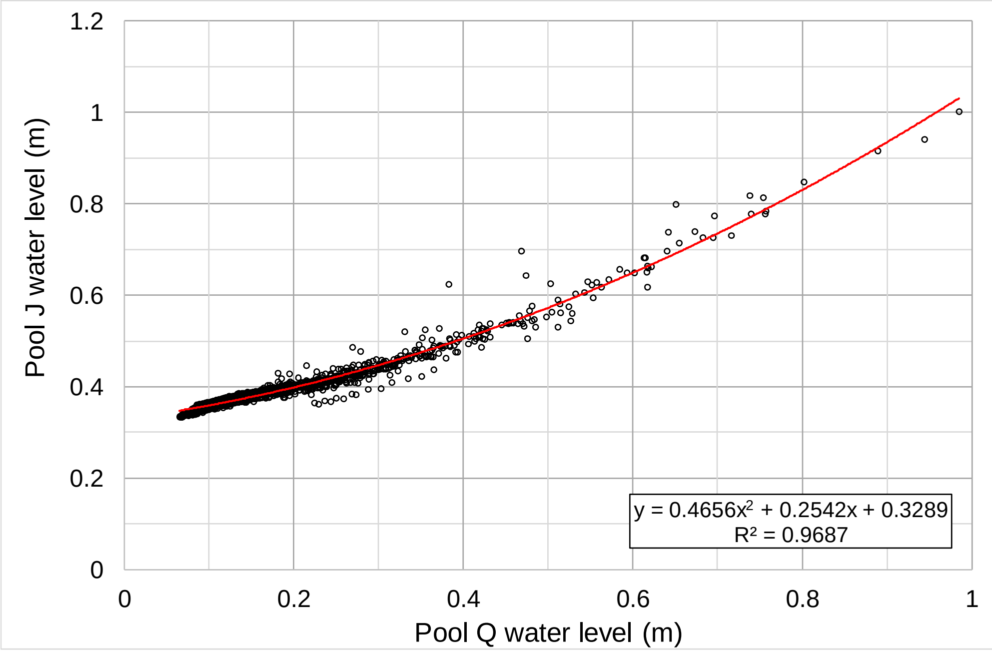


Figure 7 Water levels for all the data in Pool J plotted against those in Pool Q for the pre-adjustment period (3 April 2007 to 22 March 2012) showing a line of best fit.

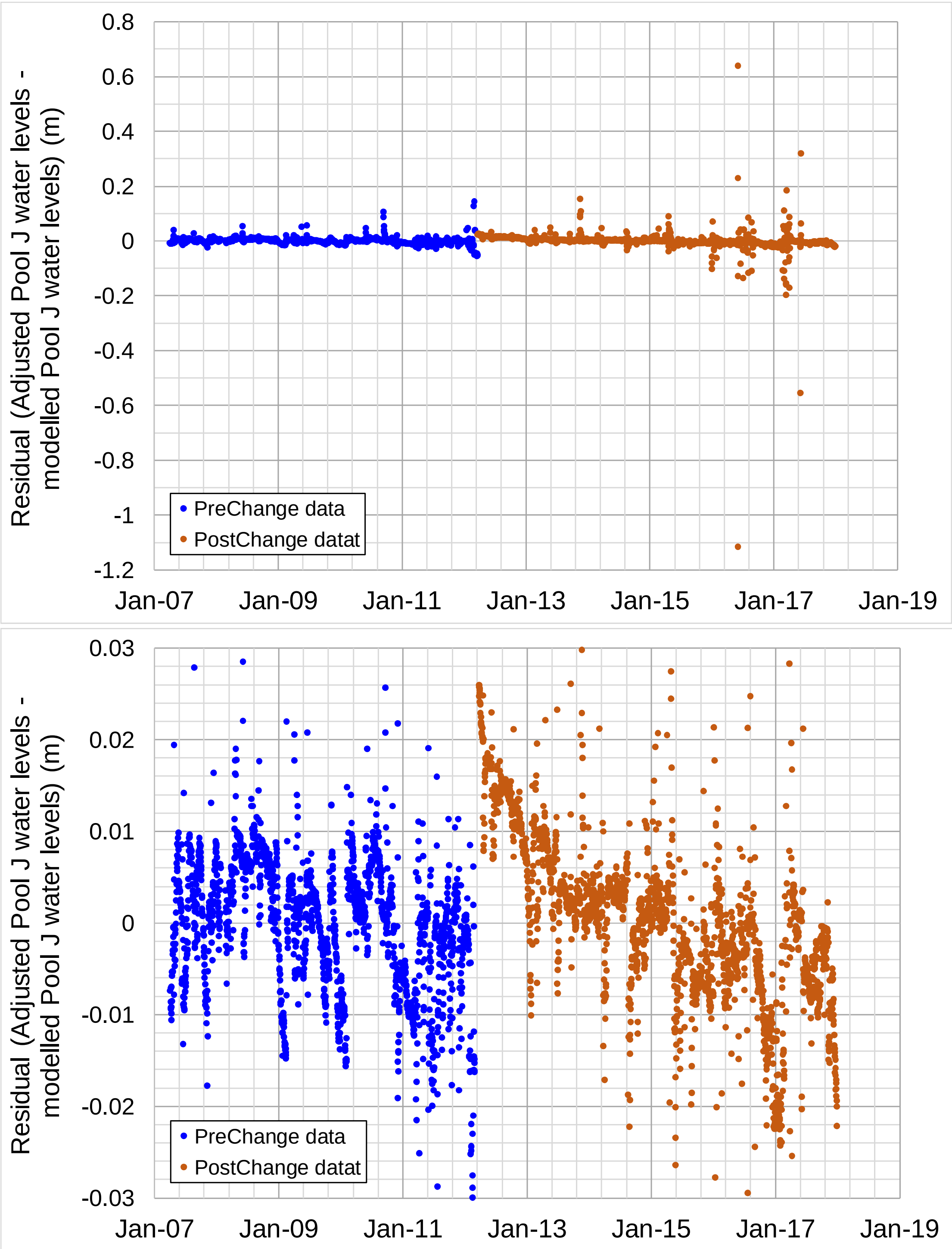


Figure 8 (a) (top panel) Residual values for Pool J plotted against date. An adjustment of 0.075 m was imposed on 23 March 2012. **(b) Reduced range of residual values.** The residual is defined as the water level in Pool J adjusted post March 2012 minus the modelled Pool water levels.

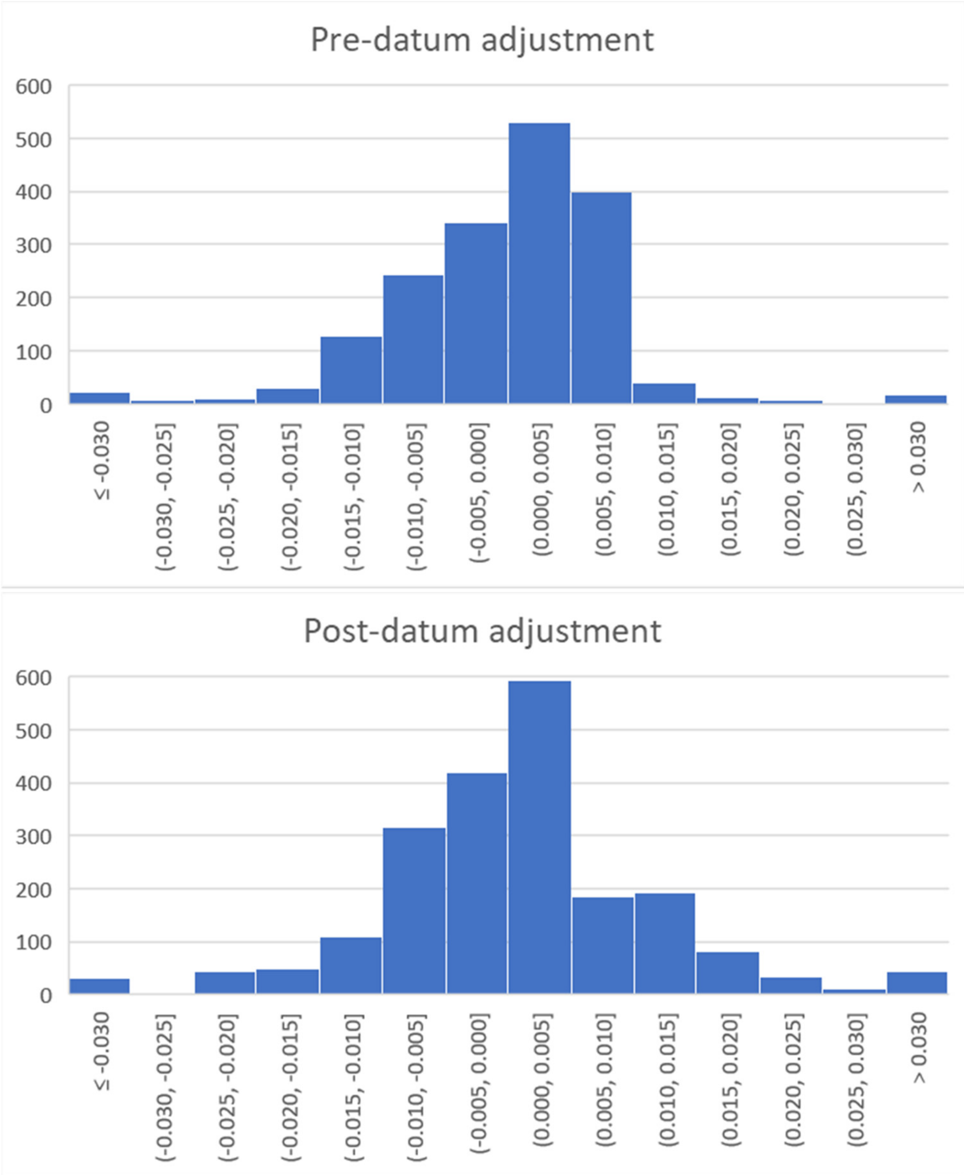


Figure 9 Comparison between the histograms of residuals for the pre- and post-adjustment periods for Pool J.

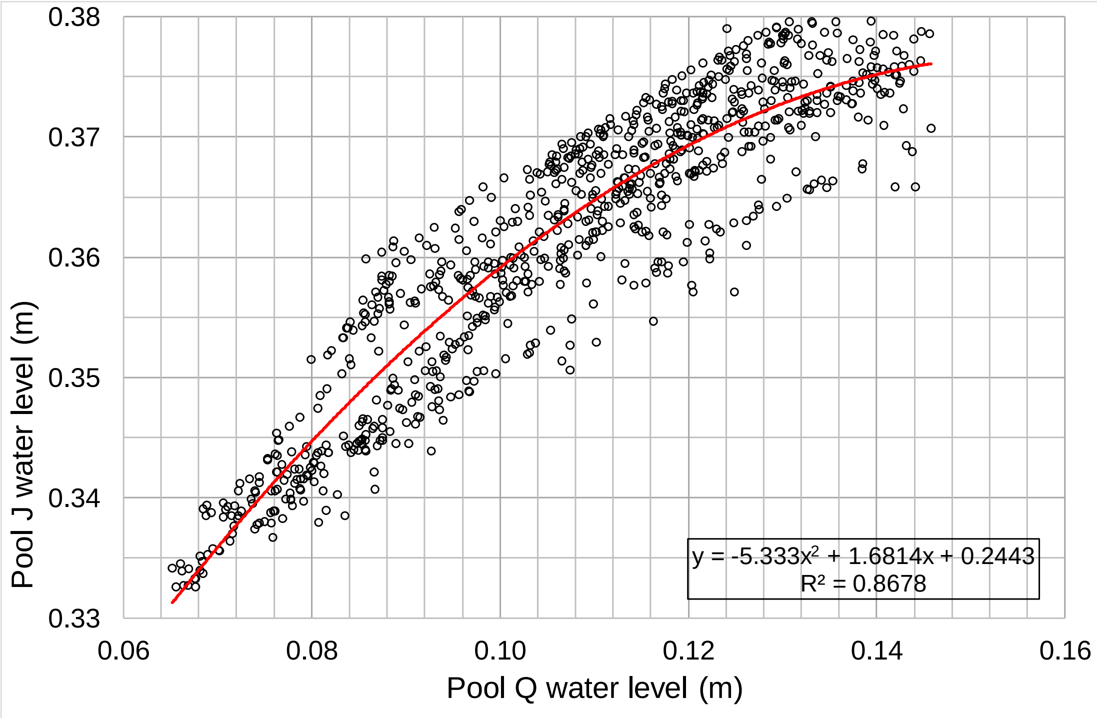


Figure 10 Comparison of low water levels (those less than or equal to the medians) in Pool J with those in Pool Q for the pre-adjustment period (3 April 2007 to 22 March 2012) showing a line of best fit.

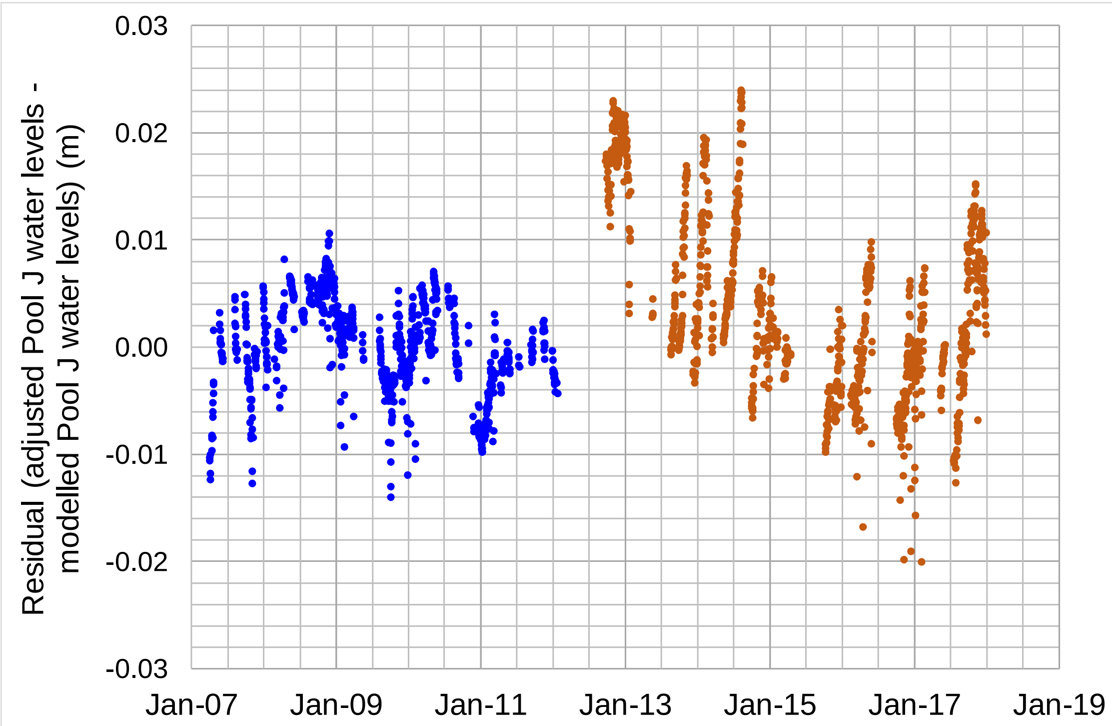
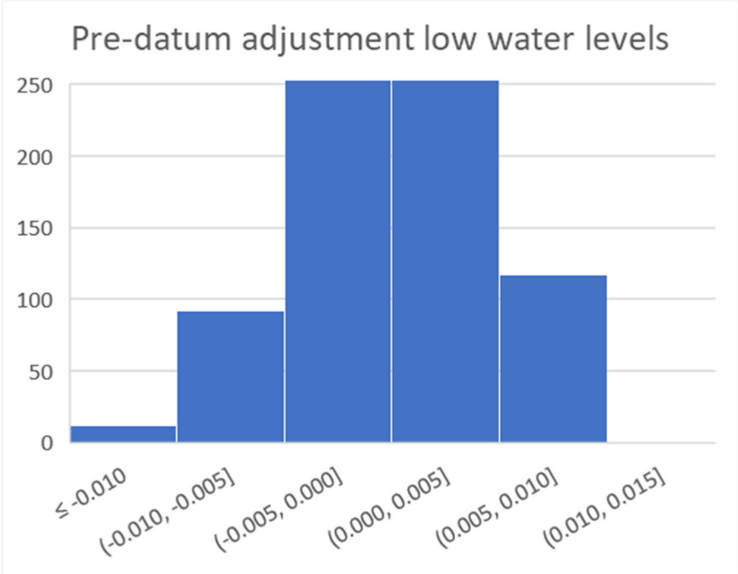


Figure 11 Residual values of low water levels in Pool J plotted against date. An adjustment of 0.075 m was imposed on 23 March 2012.



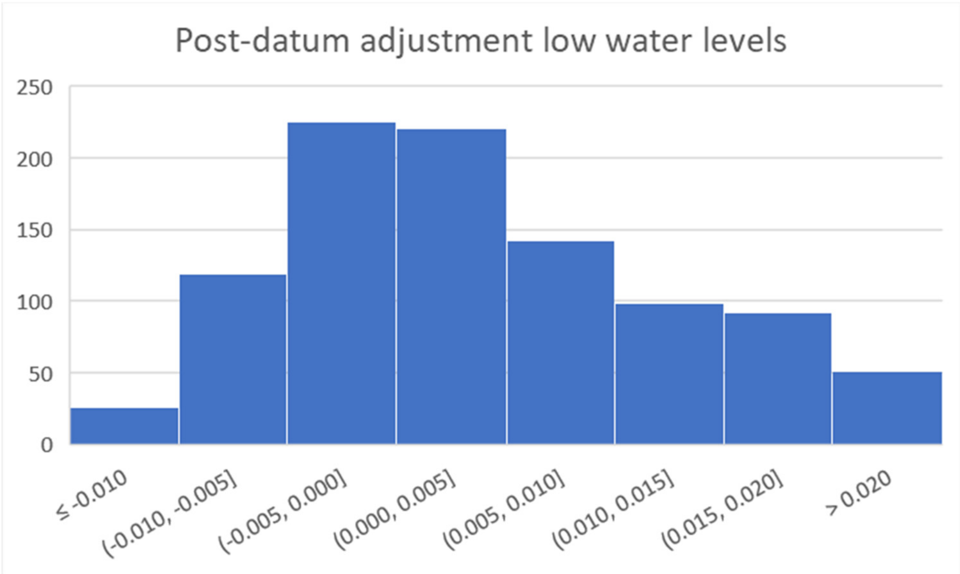


Figure 12 Comparison between the histograms of residuals for the pre- and post-change periods using low water levels (median or less) for Pool J.

ATTACHMENT 9

EXAMPLE OF STREAM REMEDIATION ASSESSMENT METHOD 1

(HYDRO ENGINEERING & CONSULTING, 2018b)

STREAM REMEDIATION ASSESSMENT METHOD 1

Comparison of pre-impact and post-remediation pool water level recession in rock-bar controlled pools.

Applicable to pools with competent rock-bar controls where there is adequate, pre-impact and post-remediation pool water level data.

The method involves comparison of dry weather pool water level recession data for both the pre-impact and post-remediation periods.

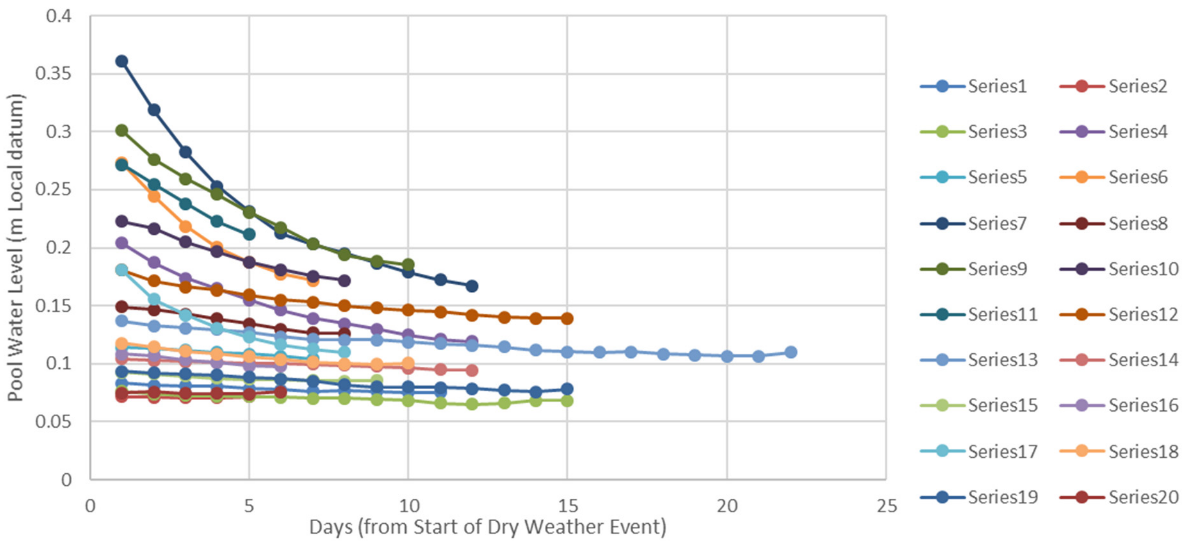
Example of Application to Pool Q on the Waratah Rivulet

Pool Q has not been impacted by mine subsidence, however can be used to demonstrate how the assessment method would be applied by using dry weather events recorded in 2009 (for the purpose of the exercise, nominated as 'pre-impact' pool water level recessions) and dry weather events recorded in 2017 (for the purpose of the exercise, nominated as 'post-remediation' pool water level recessions).

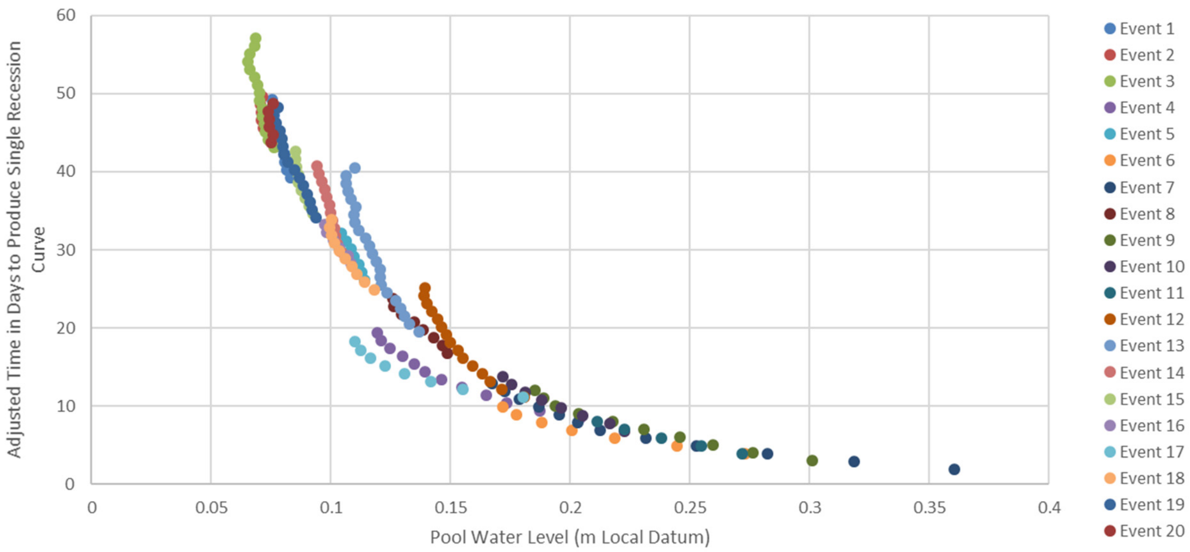
Dry weather has been defined as periods of a minimum of five days when the maximum rainfall recorded in any day was 0.5 mm. There were twenty dry weather events recorded in 2009 at pluviometer site PV1. These were taken to be representative of pre-impact dry weather pool water level recessions. There were fifteen dry weather events in 2017 which were taken to represent post-remediation recessions.

Application of the method to Pool Q involved the following steps:

1. Identify dry weather recessionary events from the available record for the pre-impact period and post-remediation period.
2. Convert recorded (hourly) dry weather pool water level data into daily averaged water level data. The dry weather pool water level recessions are shown below:

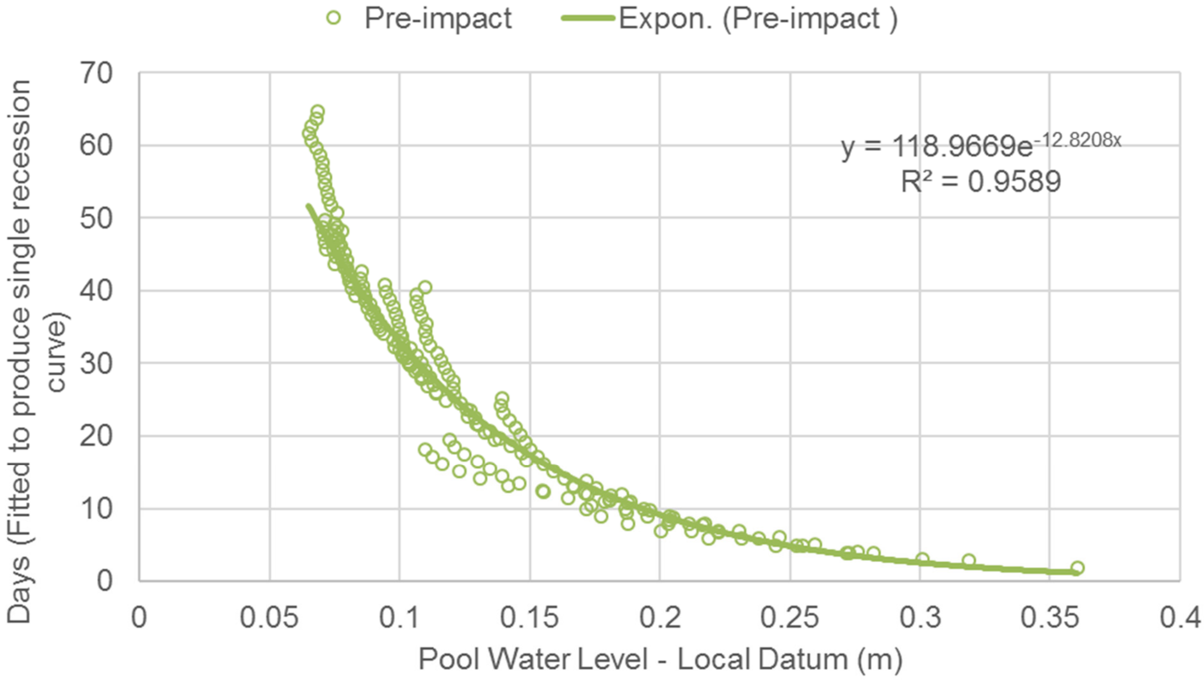


3. The starting time of each event of the pre-impact period (i.e. 2009) was then adjusted manually to produce a single time scale data set based on adjusting the start time (in days) for each recessionary event so that starting water levels formed a good match with other recessionary events. The results of this process are shown below:

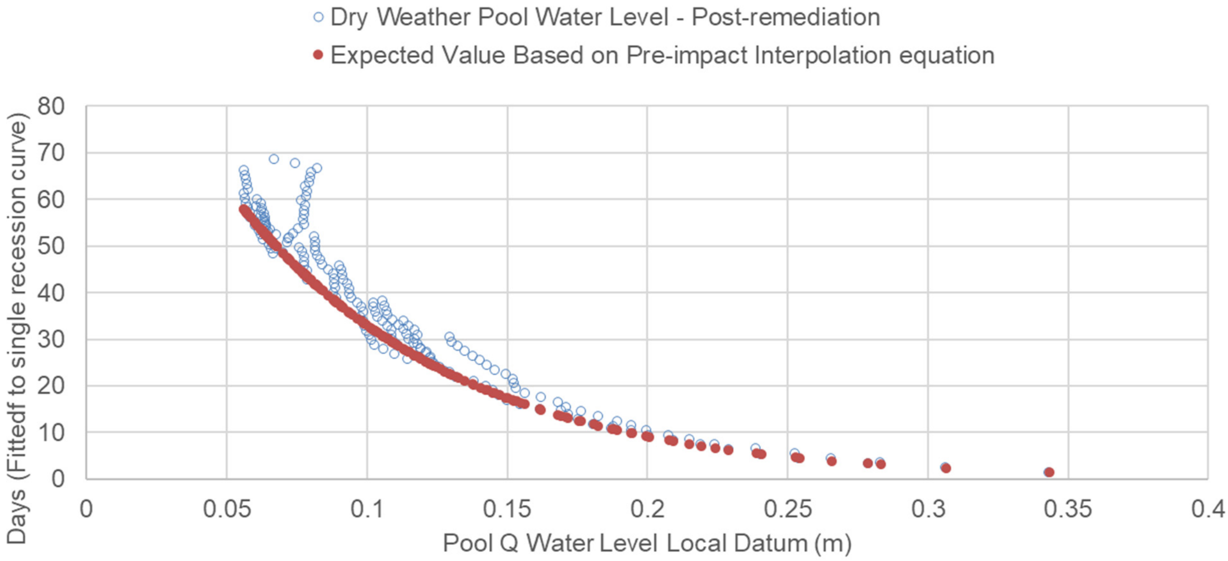


4. An interpolating exponential equation was fitted to the combined time adjusted, pool recessionary data set for the pre-impact data set.

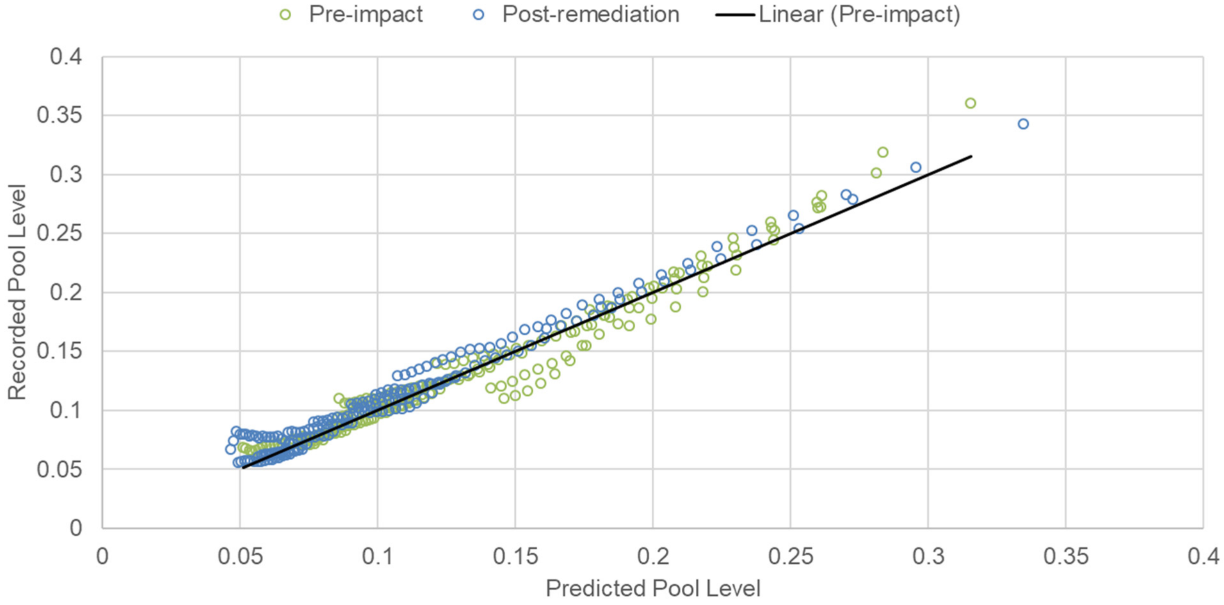
5. The start time for each recession event was readjusted using the interpolating equation to produce a mathematically refined recession curve and a second interpolating exponential curve was fitted to this refined recession curve. This curve was judged to be representative of the dry weather water level recessionary behaviour of the pre-impact Pool Q data – results of these steps are illustrated below:



6. The start time of the 2017 dry weather events (i.e. post-remediation) were adjusted using the adopted interpolating equation fitted to the 2009 dry weather events to produce an overall recession curve for the post-remediation period. The resultant post-remediation recession data is shown below together with the “expected” values based on the interpolating equation derived from the pre-impact dry weather events.



7. The pre-impact and post-remediation data sets were then compared. Results of this comparison are illustrated below:



There is slightly more scatter evident in the pre-impact data. Comparison of the post-remediation data with the pre-impact curve illustrates that the recession rates are effectively the same as they were pre-impact. In this case the remediation would be judged to have been successful.

ATTACHMENT 10

EXAMPLE OF STREAM REMEDIATION ASSESSMENT METHOD 2

(HYDRO ENGINEERING & CONSULTING, 2018c)

STREAM REMEDIATION ASSESSMENT METHOD 2

Comparison of pre-impact and post-remediation pool water level recession in pools with boulder-field controls.

Applicable to pools with boulder-field controls where there is adequate, pre-impact and post-remediation pool water level data. This method has been developed separately to Method 1 to allow for the peculiarities of boulder-field controls which can change over time as a result of movement of rocks/boulders within the boulder-field during high energy flows and clogging of voids between rock elements during lower flows.

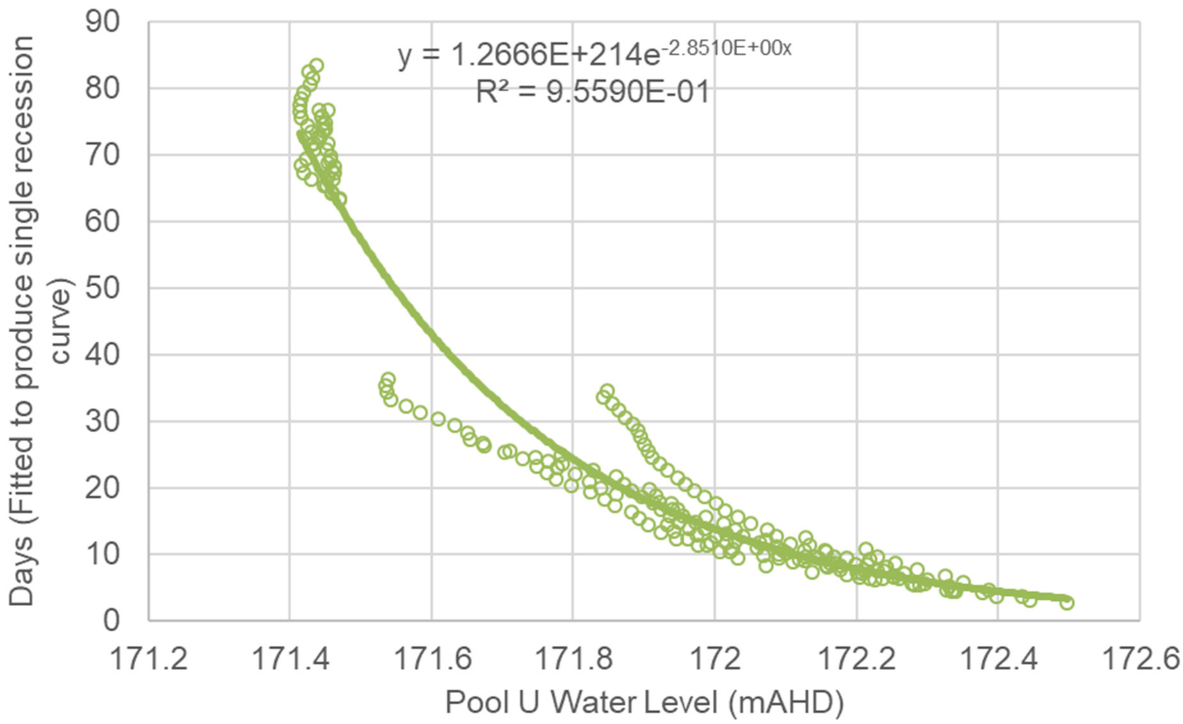
The method involves comparison of dry weather pool water level recession data for both the pre-impact and post-remediation periods.

Example of Application to Pool U on the Waratah Rivulet

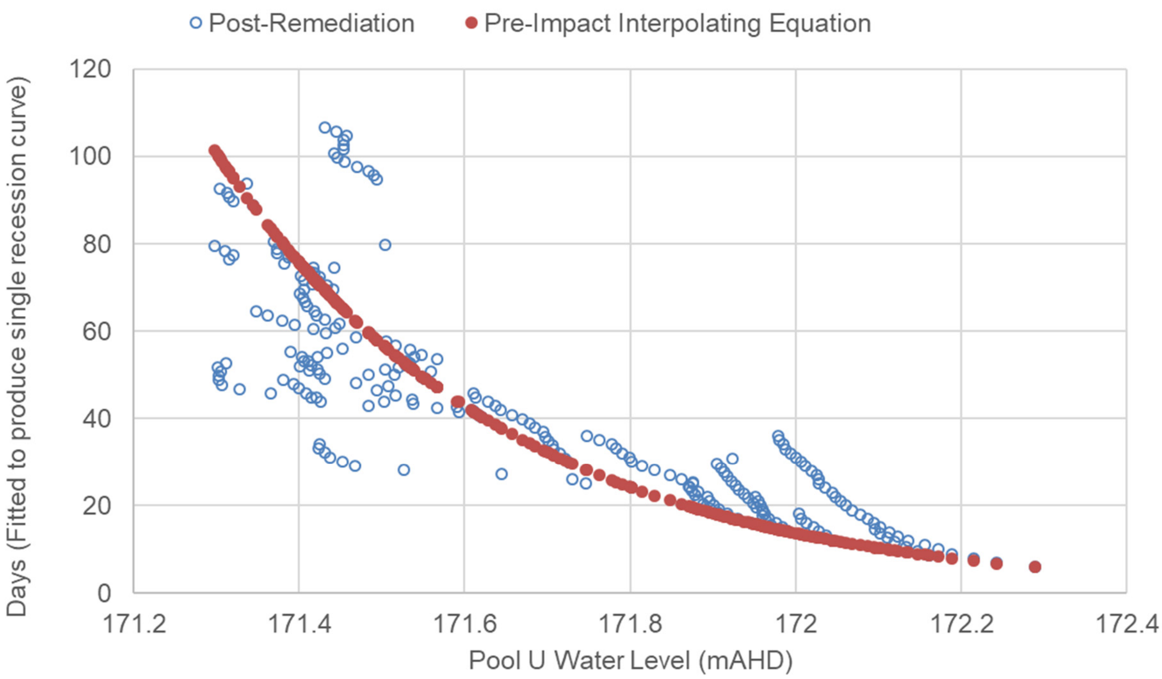
Pool U has not been impacted by mine subsidence, however can be used to demonstrate how the assessment method would be applied by using dry weather events.

Dry weather has been defined as periods of a minimum of five days when the maximum rainfall recorded in any day was 0.5mm. Eighty-five dry weather events were identified in the rainfall record for pluviometer site PV1 over the period where there are water level records available for Pool U. The first twenty dry weather periods in the record were taken to be representative of a hypothetical pre-impact data set. These dry weather events covered the period 23/2/2012 to 9/7/2013. The last twenty dry weather events which spanned the period 16/11/2016 to 28/1/2018, were selected as being representative of a hypothetical post-remediation period. Application of the method to Pool U involved the following steps:

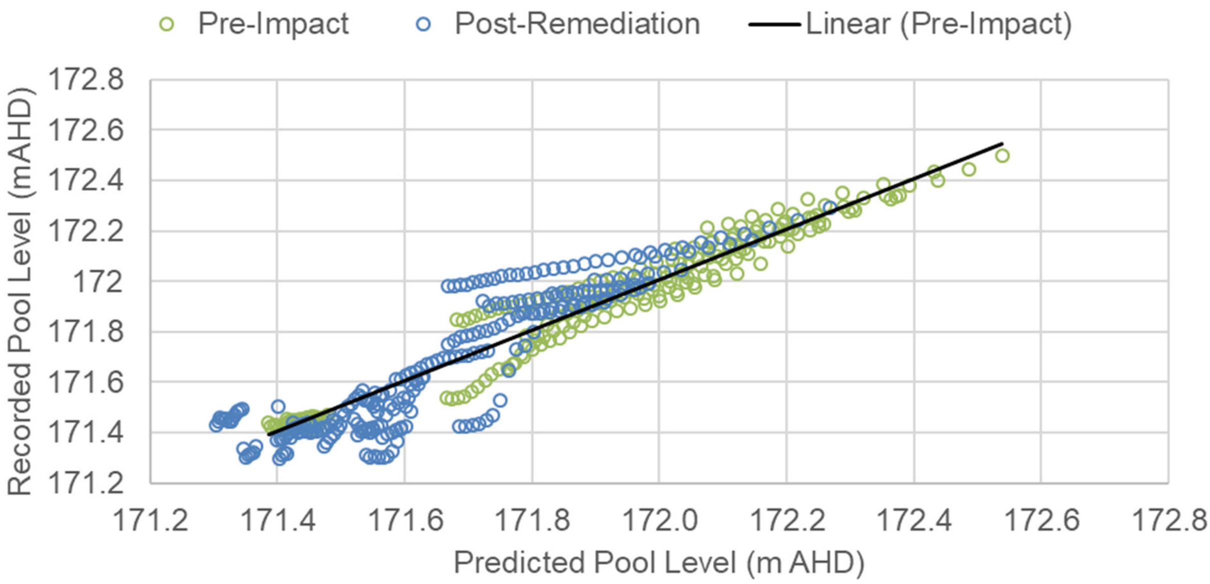
1. Identify dry weather recessionary events from the available record for the pre-impact period and post-remediation period.
2. Convert recorded (hourly) dry weather pool water level data into daily averaged water level data.
3. The starting time of each event of the first twenty dry weather events (i.e. pre-impact) was then adjusted manually to produce a single time scale data set based on adjusting the start time (in days) for each recessionary event so that starting water levels formed a good match with other recessionary events.
4. An interpolating exponential equation was fitted to the combined time adjusted, pool recessionary data set for the pre-impact data set.
5. The start time for each recession event was readjusted using the interpolating equation to produce a mathematically refined recession curve and a second interpolating exponential curve was fitted to this refined recession curve. This curve was judged to be representative of the dry weather water level recessionary behaviour of the pre-impact Pool U data – results of these steps are illustrated below:



6. The start time for each of the last twenty events (i.e. post-remediation) were adjusted using the adopted interpolating equation fitted to the pre-impact dry weather events to produce an overall recession curve for the post-remediation period – refer plot below.



7. The pre-impact and post-remediation data sets were then compared. Results of this comparison are illustrated below:



Whilst there is more scatter evident in the post-remediation data, the data fits the recession curve and is similar to the pre-impact data. The similarity of the post-remediation data fit to the pre-impact recession curve indicates recession rates are similar and if anything, slightly slower than they were pre-impact.

A number of intense rainfall events were recorded between the adopted pre-impact and post-remediation periods – notably 289.5 mm was recorded at pluviometer site PV1 during the period 21 and 23 April 2015 and 295 mm was recorded during the period 5 – 6 June 2016. It is possible that the flow characteristics of the boulder-field have been affected by these events however it does not seem to have significantly affected the dry weather recession rates. In this example, the recession behaviour in the 'post-remediation' period would be considered consistent with the 'pre-impact' period. and the stream remediation would be judged to have been successful.

If, however the post-remediation dry weather water level recession curve was found to be significantly steeper (i.e. greater than could be attributed to data scatter), than the pre-impact water level recession curve, then evidence for changes to the boulder-field control would be investigated. The investigation would include consideration of flow events (in particular high energy flow events) over time.

In the event the investigation indicates there may have been changes in the boulder-field over time, an assessment would be made of the pre-impact and post-remediation recession rates of other boulder-field pools unaffected by subsidence. The assessment would be conducted for the same time periods and methodology described above.

In the event the pool with a boulder-field control unaffected by mine subsidence demonstrates a similar trend (i.e. a significantly steeper recession curve) in the designated 'post-remediation' period, it may be able to be used to compare the post-remediation data sets.

ATTACHMENT 11

EXAMPLE OF STREAM REMEDIATION ASSESSMENT METHOD 3

(HYDRO ENGINEERING & CONSULTING, 2018d)

STREAM REMEDIATION ASSESSMENT METHOD 3

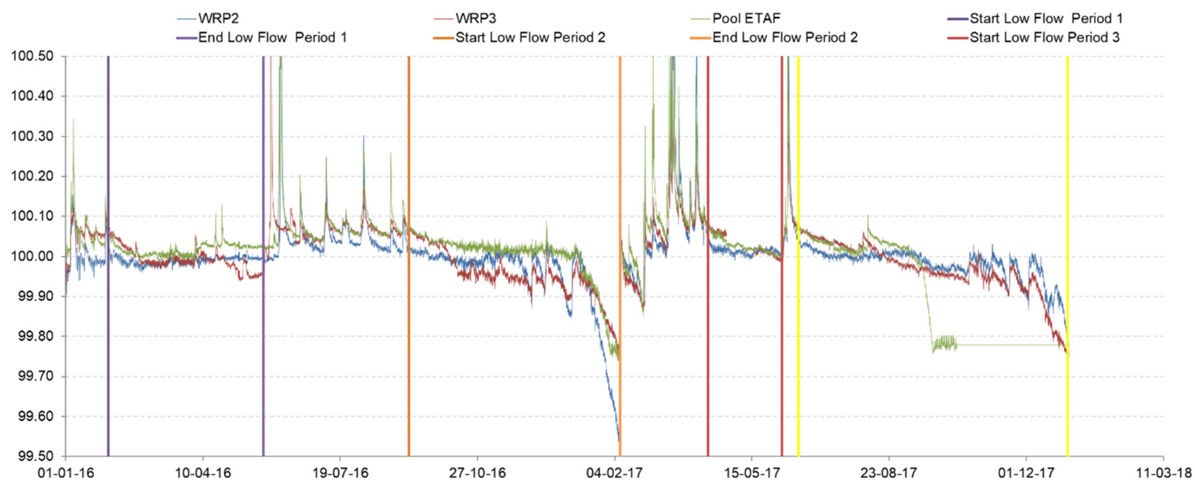
Comparison of pool water levels post-remediation with similar, but unimpacted pools. Unimpacted pools include pools upstream and/or downstream on the same stream, non-impacted pools on other streams and/or control pools on the Woronora River.

Applicable to remediated pools where there is no/or inadequate pre-impact water level data. The method involves comparison of post-remediation pool water level fluctuations with data from at least two similar, but un-impacted pools with the same downstream control type.

The assessment would be based on a subjective assessment of whether the recessionary behaviour of the remediated pool during prolonged periods of low flow is equivalent to the corresponding recessionary behaviour of un-impacted pools particularly during the same periods.

Example of Application to Pool ETAF on the Eastern Tributary Compared to Control Pools WRP2 and WRP3

Pool ETAF on the Eastern Tributary has been impacted by mine subsidence and has not been subject to stream remediation, however can be used to demonstrate how the assessment method would be applied.



In this example the water levels of the pools have been adjusted to a common datum to assist in comparison of recessionary behaviour.

The success of remediation of Pool ETAF would be judged to be unsuccessful given the relatively very rapid water level recession and disparate behaviour from September 2017 onward. If on the other hand Pool WRP2 was being compared with Pool WRP3 their behaviour would be judged to be similar.

To apply these comparisons it would be necessary to include sufficient, representative dry periods in the data sets. Assessments against the performance indicators documented in the Water Management Plan can be undertaken following dry periods in the post-remediation period to assess stream remediation progress. The assessments may indicate further monitoring or remediation effort is required. However, as a guide it is anticipated that a minimum of fifteen dry spells in the post-remediation data set (i.e. periods with a minimum of five days when the maximum recorded daily rainfall is 0.5 mm) will be required to assess the success of the stream remediation against the rehabilitation objective. This may require monitoring over one or more years post-remediation.