METROPOLITAN COAL LONGWALL 304

WATER MANAGEMENT PLAN






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LONGWALL 304

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Revision Status Register

Section/Page/ Annexure	Revision Number	Amendment/Addition	Distribution	DP&E Approval Date
All	WMP-R01-A	Original (Longwall 304)	DP&E, DI-Water, OEH, WaterNSW and DSC	-

April 2019

TABLE OF CONTENTS

Section			Page
1	INTRODUCTION		1
	1.1	PURPOSE AND SCOPE	1
	1.2	STRUCTURE OF THE WATER MANAGEMENT PLAN	1
2	WATER MANAGEMENT PLAN REVIEW AND UPDATE		5
	2.1	DISTRIBUTION REGISTER	5
3	STATUTORY REQUIREMENTS		6
	3.1	ENVIRONMENTAL PLANNING & ASSESSMENT ACT APPROVAL	6
	3.2	LICENCES, PERMITS AND LEASES	8
	3.3	OTHER LEGISLATION	8
4	RELEVANT WATER MANAGEMENT INFORMATION OBTAINED SINCE PROJECT APPROVAL		9
	4.1	SURFACE WATER	9
	4.2	GROUNDWATER	20
	4.3	WORONORA RESERVOIR IMPACT STRATEGY	33
		4.3.1 Groundwater Monitoring Results	34
		4.3.2 Inclinometers	34
		4.3.3 Permeability Measurements	35
5	REVISED ASSESSMENT OF POTENTIAL ENVIRONMENTAL CONSEQUENCES		35
	5.1	LONGWALL 304 EXTRACTION LAYOUT	35
	5.2	ENVIRONMENTAL RISK ASSESSMENT	36
	5.3	RISK ASSESSMENT FOR GEOLOGICAL FEATURES AND WATER QUANTITY TO THE WORONORA RESERVOIR	38
	5.4	REVISED SUBSIDENCE PREDICTIONS	39
	5.5	REVISED ASSESSMENT OF POTENTIAL SUBSIDENCE IMPACTS AND ENVIRONMENTAL CONSEQUENCES	42
		5.5.1 Surface Water	42
		5.5.2 Groundwater	45
6	PERFORMANCE MEASURES AND INDICATORS		51
7	BASELINE DATA		54
	7.1	METEOROLOGY	54
	7.2	SURFACE WATER	56
		7.2.1 Stream Features	56
		7.2.2 Surface Water Flow	57
		7.2.3 Pool Water Levels	58
		7.2.4 Surface Water Quality	59
		7.2.5 Woronora, Nepean and Cataract Reservoir Water Quality	61
	7.3	GROUNDWATER	61
		7.3.1 Swamp Groundwater Levels	61
		7.3.2 Shallow Groundwater Levels Near Streams	63
		7.3.3 Groundwater Levels/Pressures	65
		7.3.4 Mine Water Make	87
		7.3.5 Groundwater Quality	87

TABLE OF CONTENTS (Continued)

8 MONITORING PROGRAM 91
8.1 METEOROLOGY 91
8.2 STREAM FEATURES 91
8.3 SURFACE WATER QUANTITY 92
8.3.1 Surface Water Flow 92
8.3.2 Eastern Tributary Gauging Station 93
8.3.3 Pool Water Levels and Drainage Behaviour 94
8.4 SURFACE WATER QUALITY 95
8.5 WORONORA RESERVOIR WATER QUALITY 96
8.6 GROUNDWATER LEVELS 96
8.6.1 Swamp Groundwater Levels 96
8.6.2 Shallow Groundwater Levels Near Streams 96
8.6.3 Groundwater Levels/Pressures 97
8.6.4 Woronora Reservoir Leakage 98
8.7 MINE WATER MAKE 98
8.8 GROUNDWATER QUALITY 99
8.9 TRIGGER ACTION RESPONSE PLANS AND ASSESSMENT OF PERFORMANCE INDICATORS AND MEASURES 100
8.10 EASTERN TRIBUTARY MONITORING AND ADAPTIVE MANAGEMENT 114
9 MANAGEMENT MEASURES 117
9.1 SUBSIDENCE MANAGEMENT APPROACH 117
9.2 MINE PLANNING AND DESIGN 117
9.3 ADDITIONAL MONITORING 118
9.4 MANAGEMENT MEASURES AND REMEDIATION 118
9.4.1 Stream Remediation 118
9.4.1.1 Waratah Rivulet Stream Remediation 119
9.4.1.2 Eastern Tributary Stream Remediation 120
9.4.1.3 Stream Remediation Activities 121
9.4.2 Other Subsidence Impact Management Measures 122
9.4.2.1 Aesthetic Values 122
9.4.2.2 Stream Bank Erosion 122
9.4.2.3 Cliff Falls 122
9.4.2.4 Swamp Remediation Measures 123
9.4.3 Surface Disturbance 123
9.5 ADAPTIVE MANAGEMENT 123
10 CONTINGENCY PLAN 124
10.1 POTENTIAL CONTINGENCY MEASURES 125
11 FUTURE EXTRACTION PLANS 125
11.1 SURFACE WATER 125
11.2 GROUNDWATER 126

TABLE OF CONTENTS (Continued)

12	ANNUAL REVIEW AND IMPROVEMENT OF ENVIRONMENTAL PERFORMANCE	127
13	INCIDENTS	127
14	COMPLAINTS	128
15	NON-COMPLIANCES WITH STATUTORY REQUIREMENTS	128
16	REFERENCES	129

LIST OF TABLES

Table 1	Management Plan Requirements
Table 2	Stream Water Quality Monitoring Results
Table 3	Groundwater Model Tabulation
Table 4	Maximum Predicted Subsidence, Tilt, Curvature, Upsidence and Closure for the Eastern Tributary Resulting from Longwall 304 Extraction
Table 5	Comparison of Maximum Predicted Conventional Subsidence Parameters for the Eastern Tributary based on the Preferred Project Layout and the Extraction Plan Layout
Table 6	Maximum Predicted Subsidence, Tilt, Curvature, Upsidence and Closure for the Woronora Reservoir Resulting from Longwall 304 Extraction
Table 7	Comparison of Maximum Predicted Conventional Subsidence Parameters for the Woronora Reservoir based on the Preferred Project Layout and the Extraction Plan Layout
Table 8	Summary of Water Resource and Watercourse Performance Indicators and Measures
Table 9	Meteorological Monitoring Station Locations and Recording Periods
Table 10	Gauging Station Locations and Recording Periods
Table 11	Pool Water Level Sites (Manual and/or Continuous Water Level Data)
Table 12	Stream Water Quality Sites
Table 13	Swamp Substrate and Shallow Groundwater Level Sites
Table 14	Shallow Groundwater Level Sites Near Streams
Table 15	Groundwater Transect
Table 16	Groundwater Level and Groundwater Level/Pressure Sites
Table 17	Shallow Groundwater Quality Sites
Table 18	Deep Groundwater Chemistry Sites
Table 19	Trigger Action Response Plan – Negligible Reduction to the Quantity of Water Resources Reaching the Woronora Reservoir
Table 20A	Trigger Action Response Plan – Negligible Reduction to the Quality of Water Resources Reaching the Woronora Reservoir
Table 20B	Adjusted Baseline Mean plus Standard Deviations for Sites WRWQ9, ETWQ AU and WOWQ2

TABLE OF CONTENTS (Continued)

LIST OF TABLES (Continued)

Table 21 Trigger Action Response Plan – No Connective Cracking Between the Surface and the Mine and Negligible Leakage from Woronora Reservoir

Table 22 Trigger Action Response Plan – Negligible Reduction to the Quality of Water Resources in the Woronora Reservoir

Table 23 Trigger Action Response Plan – Negligible Environmental Consequences on Waratah Rivulet

Table 24 Trigger Action Response Plan – Negligible Environmental Consequences on Eastern Tributary

Table 25 Longwall 304 Eastern Tributary Valley Closure Trigger Action Response Plan

LIST OF FIGURES

Figure 1 Longwall 304 and Project Underground Mining Area

Figure 2 Longwall 304 Layout

Figure 3 Environmental Management Structure

Figure 4 Streams within the Project Underground Mining Area and Surrounds

Figure 5 Waratah Rivulet and Eastern Tributary Pools

Figure 6 Surface Water Quantity Sites

Figure 7 Surface Water Quality Sites

Figure 8 Schematic - Longwall Mining and Subsidence Profile

Figure 9 Upland Swamp Groundwater Piezometer Locations

Figure 10 Groundwater Level and/or Pressure Bore Locations

Figure 11 Groundwater Quality Sites

Figure 12 Predicted Profiles of Subsidence, Upsidence and Closure along the Eastern Tributary and Woronora Reservoir due to Longwall 304

Figure 13 Streams over Longwall 304 and Surrounds

Figure 14 Meteorological Sites

LIST OF APPENDICES

Appendix 1 Waratah Rivulet Stream Mapping and Photographic Record

Appendix 2 Eastern Tributary Stream Mapping and Photographic Record

Appendix 3 Tributary A Stream Mapping and Photographic Record

Appendix 4 Tributary B Stream Mapping and Photographic Record

Appendix 5 Visual Inspection and Photographic Survey of Streams in the Vicinity of Longwalls 304-310

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 (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 (Figure 1). Longwall 304 is situated to the west of Longwalls 301-303, and defines the next mining sub-domain within the Project underground mining area (Figures 1 and 2). Longwalls 305 on will be subject to future Extraction Plans.

1.1 PURPOSE AND SCOPE

In accordance with Condition 6(f), Schedule 3 of the Project Approval, this Water Management Plan (WMP) has been prepared as a component of the Metropolitan Coal Longwall 304 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 Longwall 304 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 and 301-303, subject to the previously approved Metropolitan Coal Longwalls 301-303 WMP. Consistent with the recommended approach in the NSW Department of Planning and Environment (DP&E) and NSW Division of Resources and Energy (DRE) (2015) *Guidelines for the Preparation of Extraction Plans*, the Longwalls 301-303 WMP will be superseded by this document following the completion of Longwall 303.

In accordance with Condition 6, Schedule 3 of the Project Approval, this WMP has been prepared by Metropolitan Coal, with assistance from HydroSimulations, Hydro Engineering & Consulting, Associate Professor Barry Noller and Mine Subsidence Engineering Consultants (MSEC).

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.

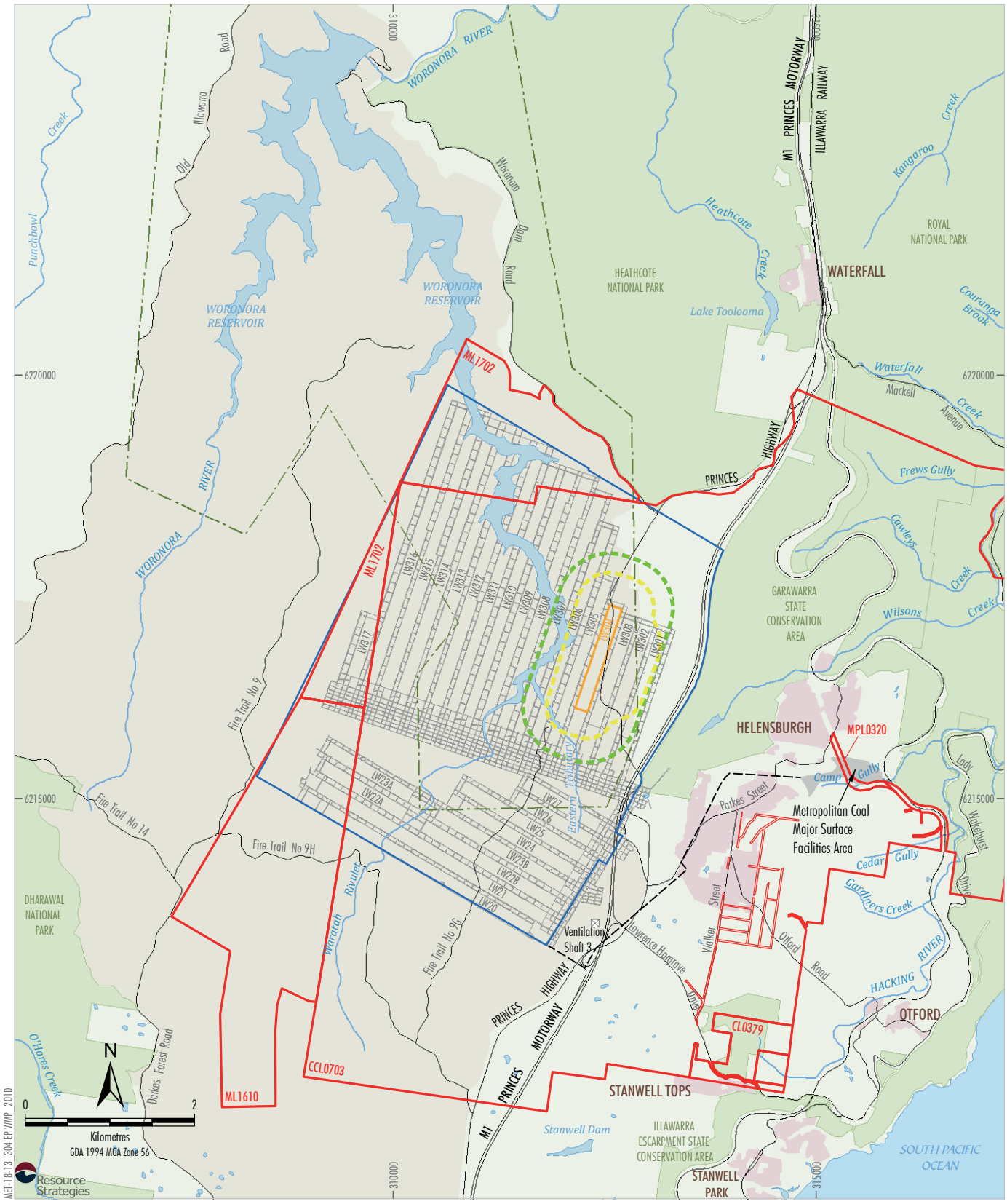
Section 4: Provides a summary of the water management information obtained since Project Approval.

Section 5: Provides a revised assessment of the potential subsidence impacts and environmental consequences for Longwall 304.

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).



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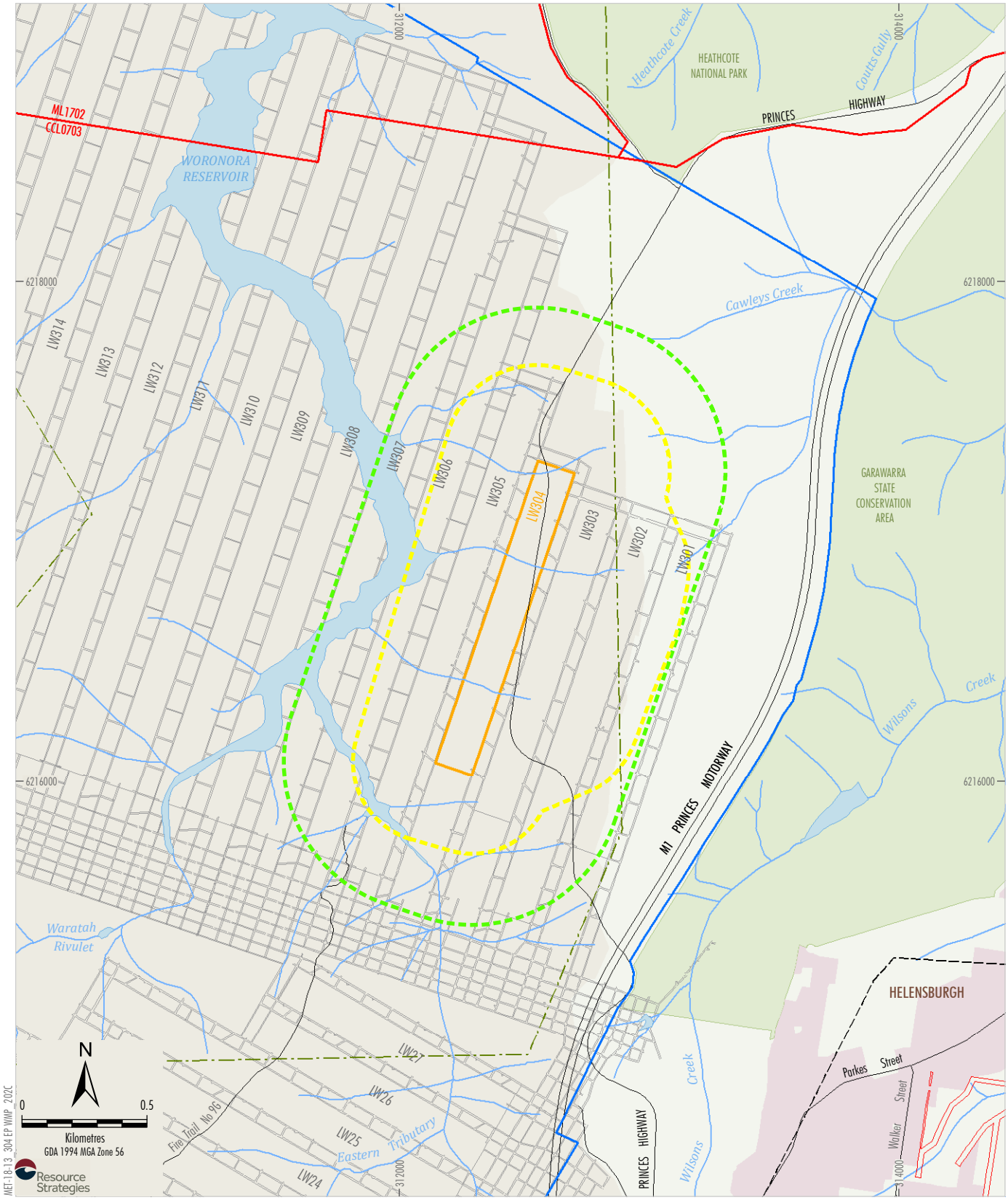
- Mining Lease Boundary
- Woronora Special Area
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwall 304 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwall 304
- Woronora Notification Area
- Existing Underground Access Drive (Main Drift)

Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2019); MSEC (2019)

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Longwall 304 and Project Underground Mining Area

Figure 1



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwall 304 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwall 304
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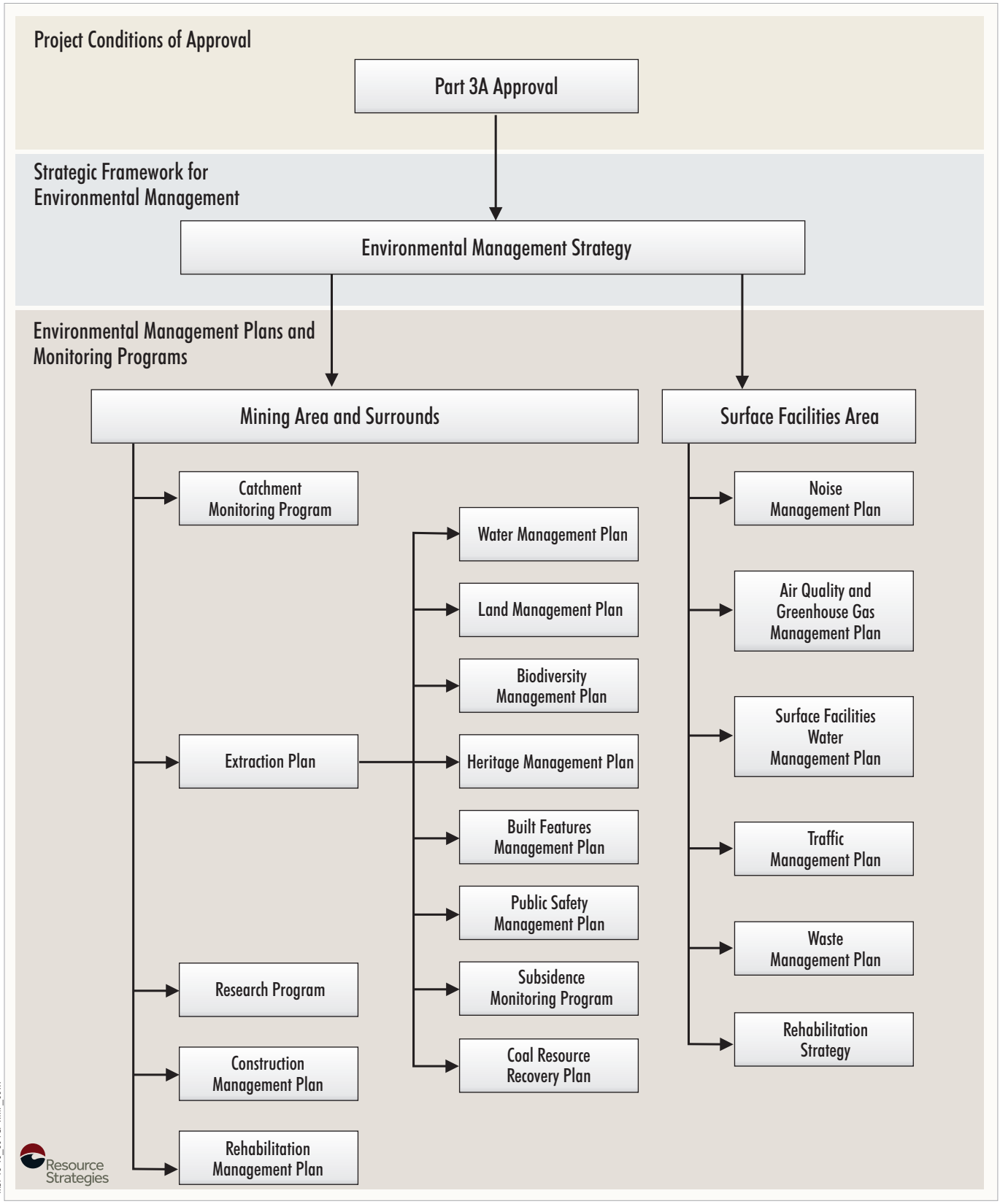
Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2019); MSEC (2019)

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Longwall 304 Layout

Figure 2



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Environmental Management Structure

Figure 3

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 DP&E, 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 DP&E.

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. A hard copy of the WMP will also be maintained at the Metropolitan Coal site.

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, SCA[1] and NOW[2], 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.

1 The Sydney Catchment Authority (SCA) is now WaterNSW.

2 The NSW Office of Water (NOW) is now the Department of Industry – Water (DI – 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 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), under the NSW *Mining Act, 1992* (e.g. Consolidated Coal Lease [CCL] 703, Mining Lease [ML] 1610, ML 1702, Coal Lease [CL] 379 and Mining Purpose Lease [MPL] 320).
- The *Metropolitan Coal Mining Operations Plan 1 October 2012 to 30 September 2019* approved by the DRG.
- 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 Primary Industries – Water (now the Department of Industry – Water [DI - Water]) under the NSW *Water Management Act, 2000*, including WAL 36475 under the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011* and WAL 25410 under the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011.*
- Mining and workplace health and safety related approvals granted by the NSW 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)[3]:

- *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;*

[3] 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;*
- *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

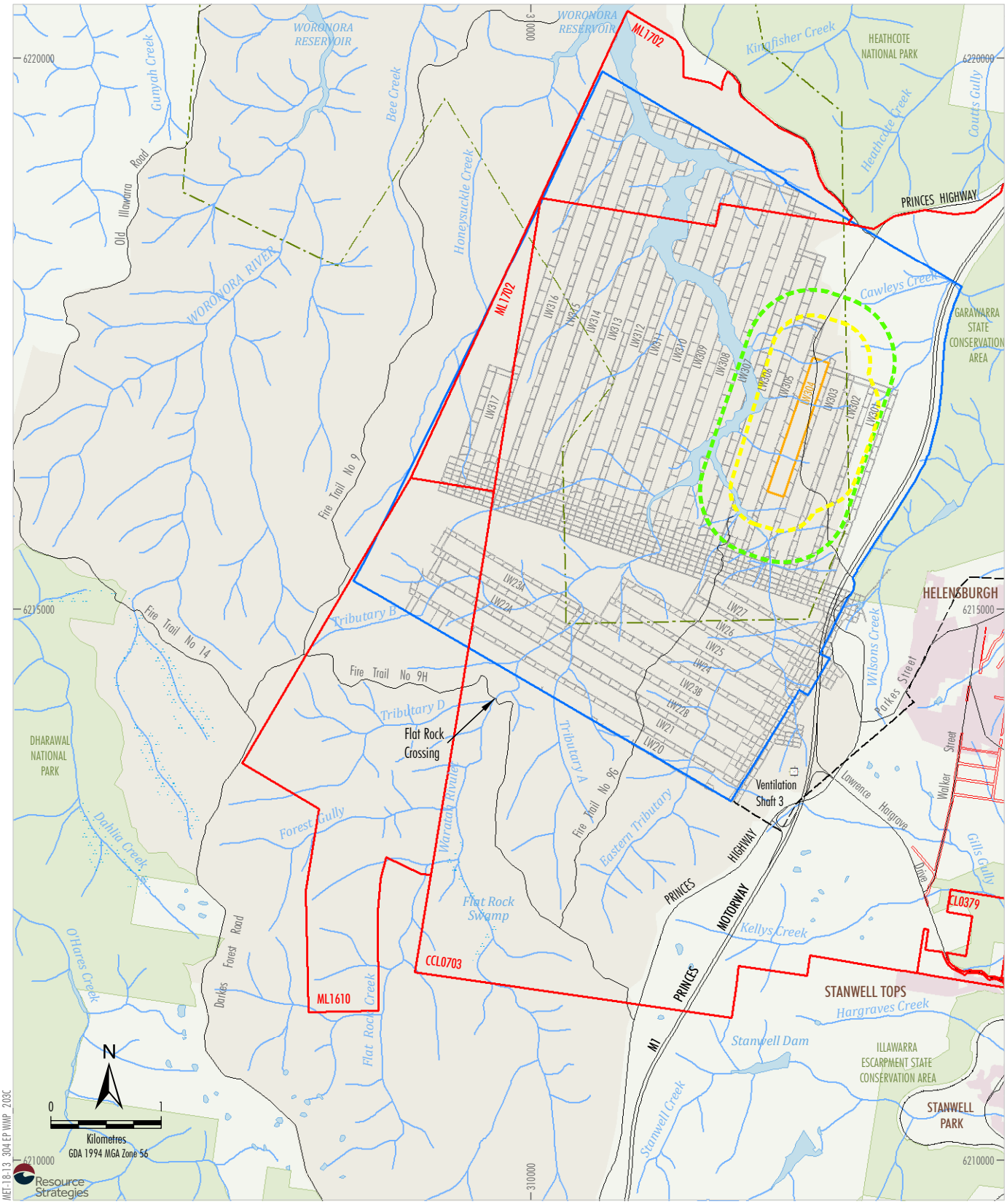
4.1 SURFACE WATER

Streams occurring within 600 m of Longwalls 20-22, Longwalls 23-27 and/or Longwalls 301-303 secondary extraction include the Waratah Rivulet and its tributaries (such as Tributary A and B) and the Eastern Tributary and its tributaries (Figure 4). 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 less than 200 mm.

The Independent Expert Panel for Mining in the Catchment (IEPMC)[4] 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 agrees that the 200 mm valley closure concept requires 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.

[4] The IEPMC was established in November 2017 by the NSW Government to provide expert advice to the DP&E 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
- Longwall 304 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwall 304
- Existing Underground Access Drive (Main Drift)
- Woronora Notification Area

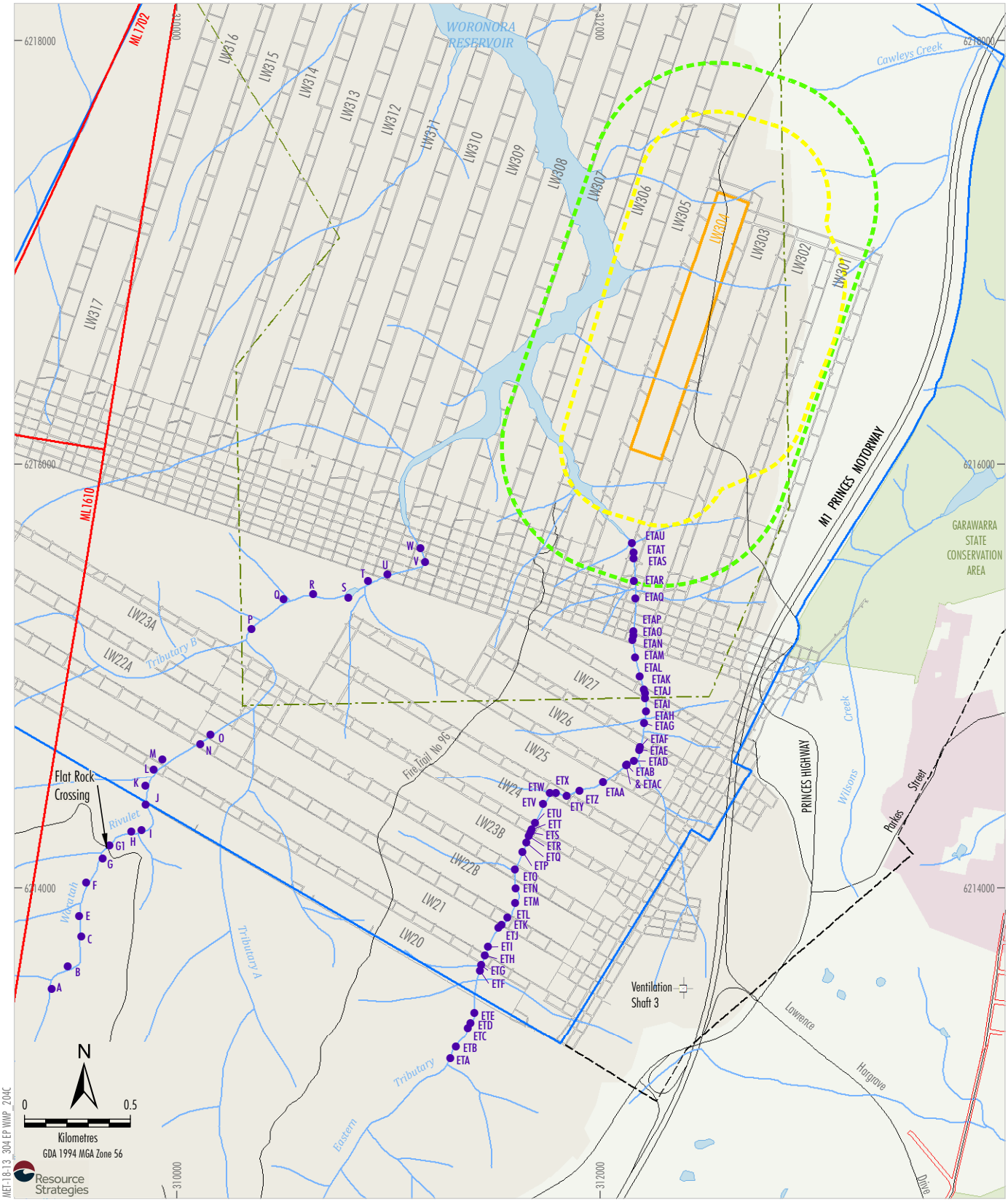
Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2019); MSEC (2019)

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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
- Longwall 304 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwall 304
- Woronora Notification Area
- 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 WMP Appendices 1 to 4.

Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2019); MSEC (2019)

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Waratah Rivulet and Eastern Tributary Pools

Figure 5

Metropolitan Coal has developed a monitoring and adaptive management approach to the mining of Longwall 303 towards the Eastern Tributary. As Longwall 303 mines towards the Eastern Tributary, Metropolitan Coal will use a Trigger Action Response Plan (TARP) designed to detect the development of subsidence effects on the Eastern Tributary. The monitoring and adaptive management approach will also be implemented for subsequent longwalls, including Longwall 304 as they mine closer to the Eastern Tributary. The Eastern Tributary TARP for Longwall 304 is provided in Section 8.10. Similar monitoring of subsidence movements has been successfully implemented to avoid impacts on the Sandy Creek Waterfall at the Dendrobium Coal Mine by South32.

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), a number of pools on the Eastern Tributary (Pools ETG, ETJ, ETM, ETU, ETW, ETAF, ETAG, ETAH, ETAI/ETAJ/ETAK[5], ETAL, ETAM, ETAN, ETAO, ETAP, ETAQ ETAR, ETAS/ETAT[6] and ETAU) and Tributary B (Pools RTP1 and RTP2) have also either been manually monitored on a daily basis or monitored using a continuous water level sensor and logger (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.

[5] 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.

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

- 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 (i.e. the pool water level had fallen below the cease to flow level). 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, namely, Pool G1 in 2011 and Pool N in September 2012) (Figure 5). Stream remediation activities on the Waratah Rivulet have been conducted at Pools A, F and G. To date, 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).

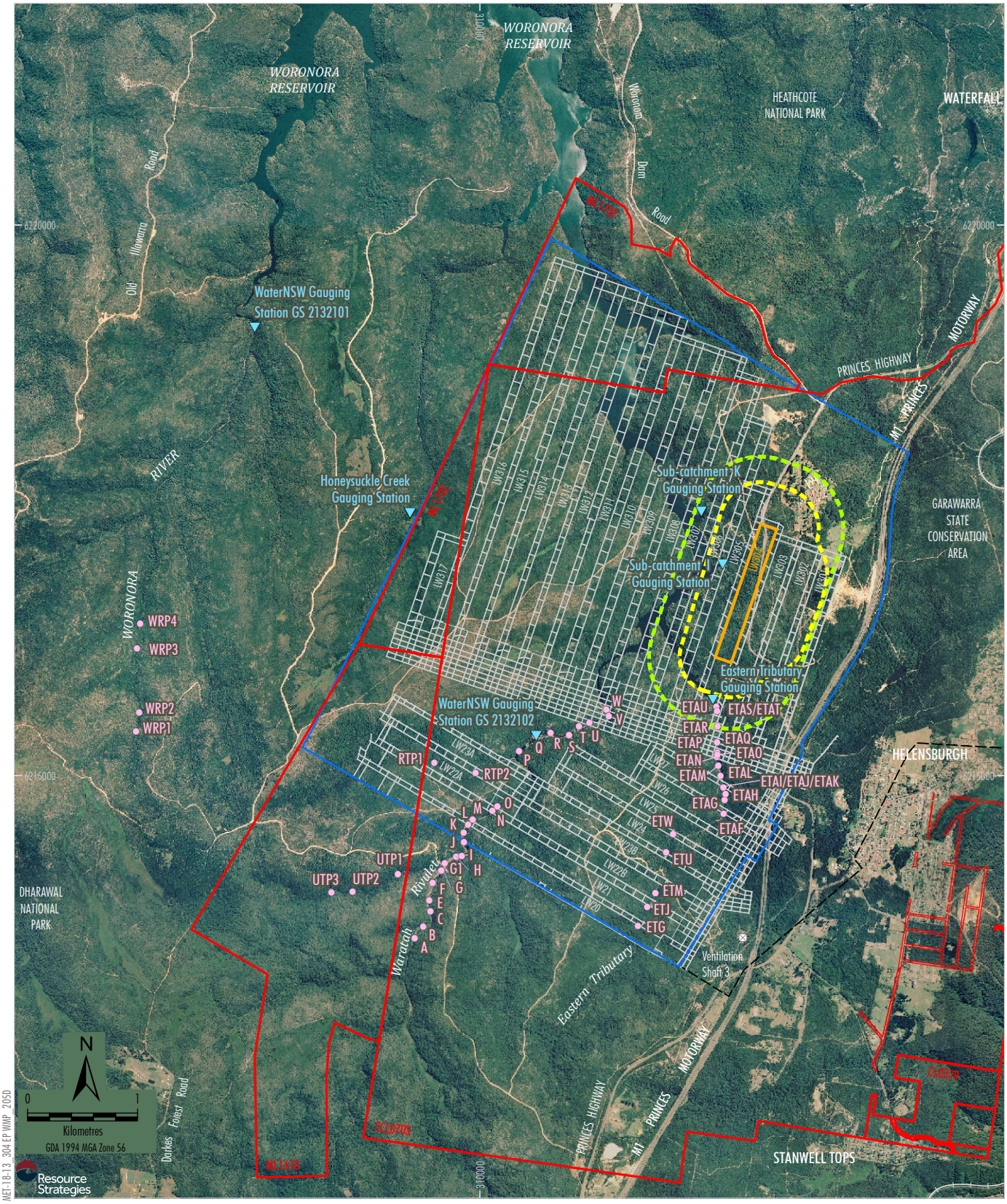
Since 2012 sections of Tributary B have been mostly dry (in the vicinity of site RTP1, Figure 6) with no surface flow. Pool RTP2 on Tributary B regularly falls below its cease to flow level, however generally overflows during and following rainfall events.

Up until December 2016, the monitoring of water levels/drainage behaviour of pools on the Eastern Tributary between the full supply level of the Woronora Reservoir and the Longwall 26 maingate was 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 less than 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%) 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 less than 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 less than 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). To date, mining has not resulted in the diversion of flows or change to the natural drainage behaviour of Pools ETAS, ETAT and ETAU (Figure 5).

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.



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwall 304 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwall 304
- 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); MSEC (2019)

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Surface Water Quantity Sites

Figure 6

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 Environmental Assessment, the Waratah Rivulet catchment model is capable of reliably identifying a loss of 1 ML/day. One (1) ML/day meets the definition of 'negligible' (being small and unimportant, such as not to be worth considering) on the basis that it is a small component of overall inflows – it represents about 1.4% of annual average inflow to the reservoir; and is small compared to changes in inflows caused by changes in climate and catchment conditions. 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 consistent with model predictions.

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.

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 [DoP], 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 DP&E 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, 2018). 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 (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, 2018a). The iron oxyhydroxide gradually converts to goethite (Yee et al., 2006) which has a darker colour and is commonly found in the creek sediment. Goethite is much darker in colour (a dark reddish-brown) and 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 to be conducted on the Eastern Tributary 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, 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).

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, Honeysuckle Creek, Bee Creek and Woronora River. Trends in the monitoring data to date 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 (2018). The water quality sites are shown on Figure 7.

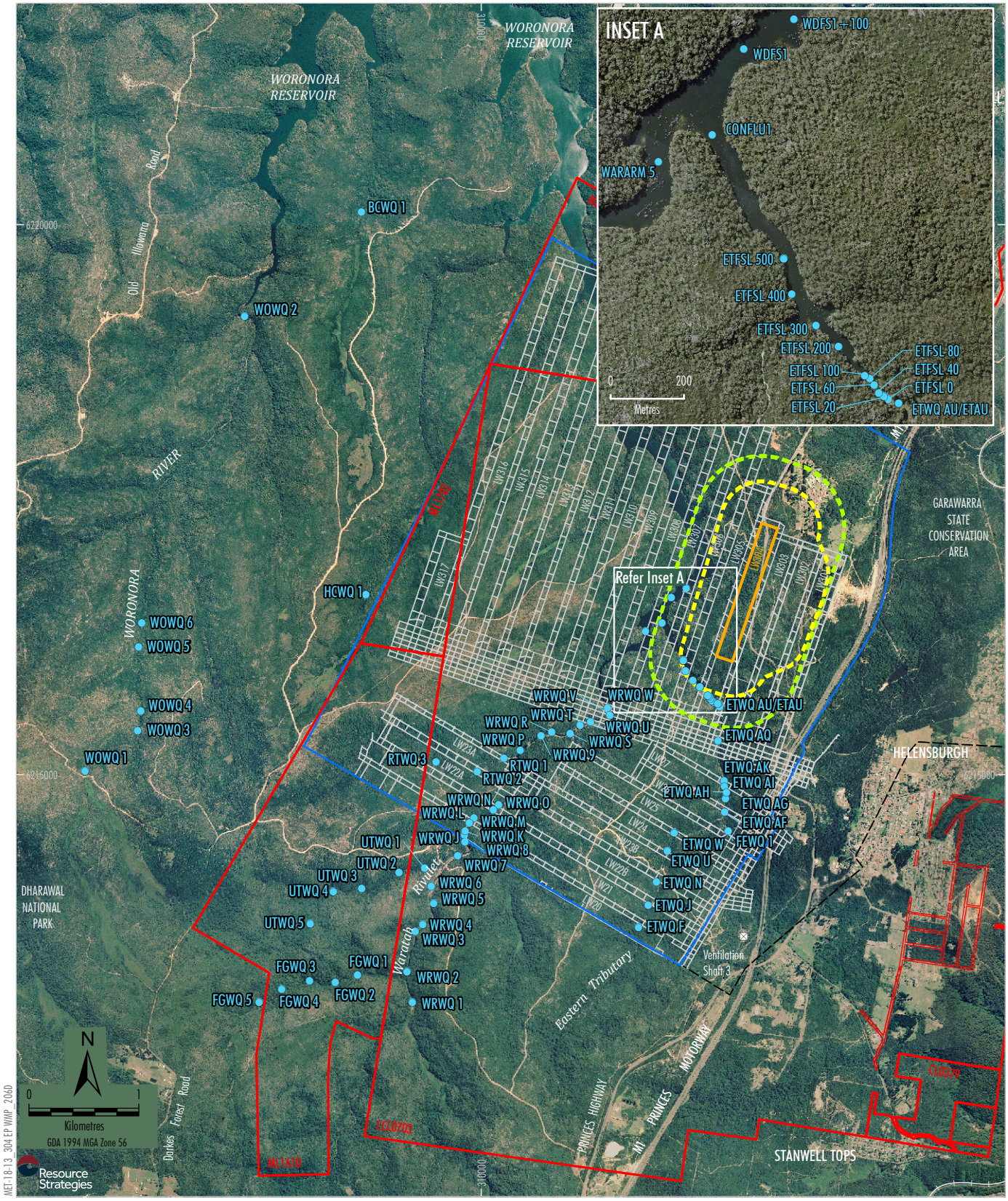
The cracking and dilation of bedrock and associated diversion of surface flow and leakage of water through rock bars at pools which has occurred on the Eastern Tributary (including the reach associated with the exceedance of the Eastern Tributary watercourse performance measure) has resulted in impacts on water quality, in particular increases in dissolved manganese and 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 micrometres [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 mg/L exist in the natural creek water. Dissolved manganese is however easily 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 – 2018j) 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.

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 patterns have generally been consistent with earlier data. • Upstream sites on Waratah Rivulet show slightly acidic to near neutral pH values with higher (slightly alkaline) values being recorded at downstream sites. • Electrical conductivity has been consistently low. Higher than previously recorded values were recorded at some upper to middle reach sites from January to June 2018. • Dissolved iron and manganese concentrations have typically been higher at the upper to middle reach sites. • Dissolved aluminium has been consistent from upstream to downstream and low.
Woronora River (control sites WOWQ 1 and WOWQ 2)	• Sites on Woronora River typically show slight acidity and high variability in pH. • Electrical conductivity values have been consistently low and similar to values recorded on Waratah Rivulet. • Dissolved iron has been generally low and similar to values recorded in Waratah Rivulet. • Dissolved aluminium concentrations have been typically low and typically higher upstream. • Dissolved manganese has been typically low with evidence of more elevated concentrations occurring in the summer months.
Eastern Tributary (sites ETWQ F, ETWQ J, ETWQ N, ETWQ U, ETWQ W, ETWQ AF, ETWQ AH, ETWQ AQ and ETWQ AU)	• Sampling sites on Eastern Tributary show variable but typically near neutral pH values. • Electrical conductivity values have historically been low, however have been more variable since mid 2016, with higher than historical values recorded. • Dissolved aluminium concentrations are typically low, with some spikes occasionally recorded. • Higher dissolved manganese and dissolved iron concentrations have been recorded since mid 2016, corresponding with an extended period of low flow/rainfall and mine subsidence impacts to a number of pools. • Recent variable results are considered to be associated with low water levels and sampling of non-flowing or stagnant pools.
Bee Creek, Honeysuckle Creek, Far Eastern Tributary, Tributary B and Tributary D (sites BCWQ 1, HCWQ 1, FEWQ 1, RTWQ 1, and UTWQ 1)	• Sampling sites in Bee Creek and Honeysuckle Creek have recorded variable to slightly acidic pH levels, while pH levels in Far Eastern Tributary, Tributary B and Tributary D have been near neutral. Since mid-2015, the pH at all sites has generally been less variable. • Electrical conductivity values have been generally low at most of these sites, however, recorded values on Tributary B have been variable and periodically elevated since late 2013. • Dissolved iron concentrations have been generally low at these sites with periodic small spikes in dissolved iron recorded mostly during summer months. • Dissolved manganese concentrations have been generally low and consistent with historical values. • Dissolved aluminium concentrations at Far Eastern Tributary, Tributary B and Tributary D have been low. Dissolved aluminium concentrations at Bee Creek and Honeysuckle Creek have been higher (in relation to other tributary sites over the period of record).

Source: after Hydro Engineering & Consulting (2018)



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwall 304 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwall 304
- Existing Underground Access Drive (Main Drift)
- Surface Water Quality Site

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2019); MSEC (2019)

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Surface Water Quality Sites

Figure 7

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 Trigger Action Response Plan in Section 8.9. 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 Woronora Reservoir.

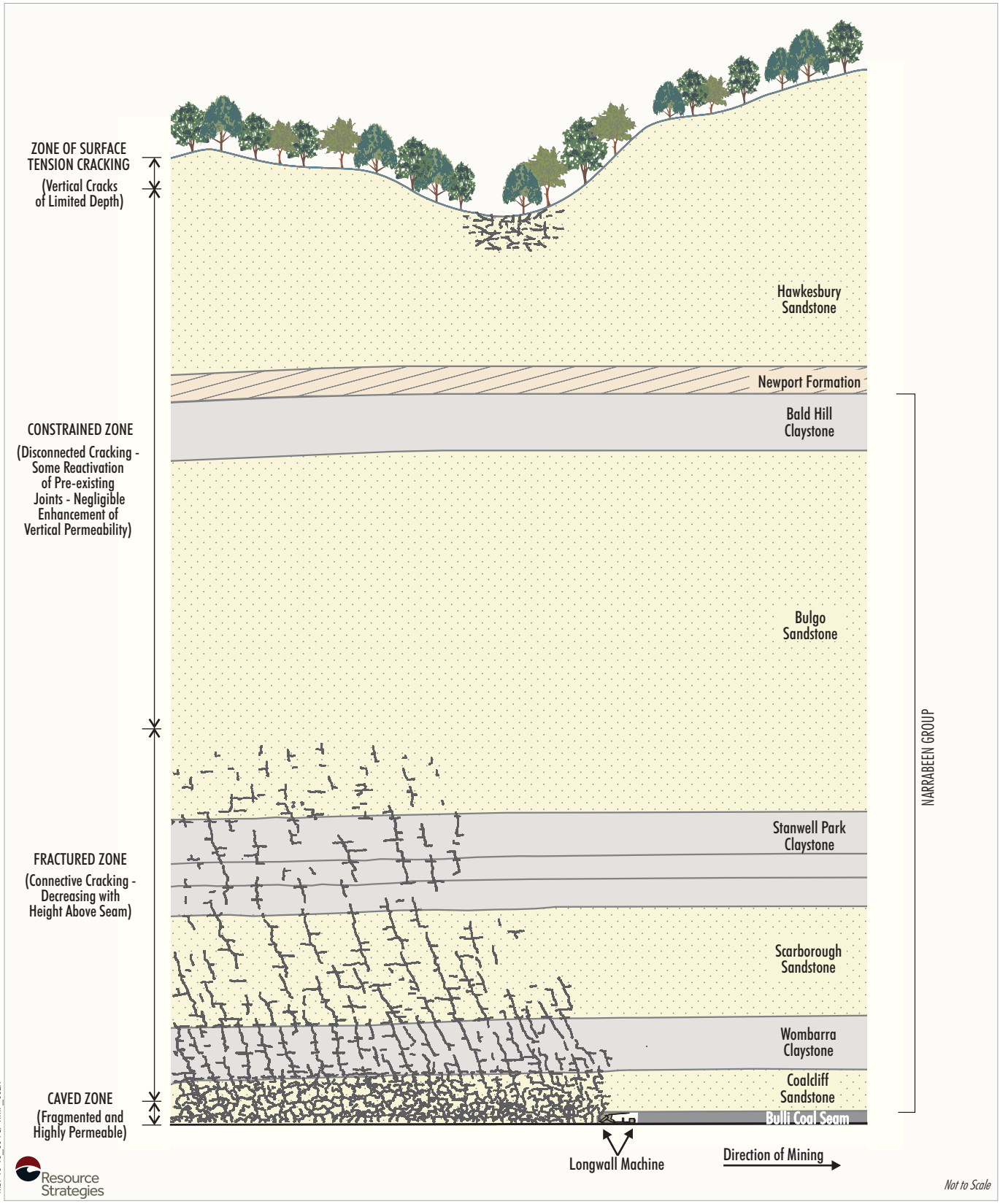
4.2 GROUNDWATER

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

- Perched groundwater system – generally above and independent of the regional groundwater table (typically less than 50 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 less than 100 m below the ground surface) is separate from the perched groundwater system and defines a regional water table.
- 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 more than 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 the sandstone hills with ultimate discharge to incised 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 (February 2019) indicates no privately owned registered bores, other than those registered by Metropolitan Coal, are located in the vicinity of the 300 series longwalls.



Source: After Geosensing Solutions (2008); Heritage Consulting (2008)

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Schematic - Longwall Mining and Subsidence Profile

Figure 8

Groundwater Model

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

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.

A three-dimensional 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 to incorporate Metropolitan Coal updates to the geological model. The revised model 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. A report for the updated model has been prepared (HydroSimulations, 2018a) and this model has been used for the assessment of Longwall 304.

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 immeasurable 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:

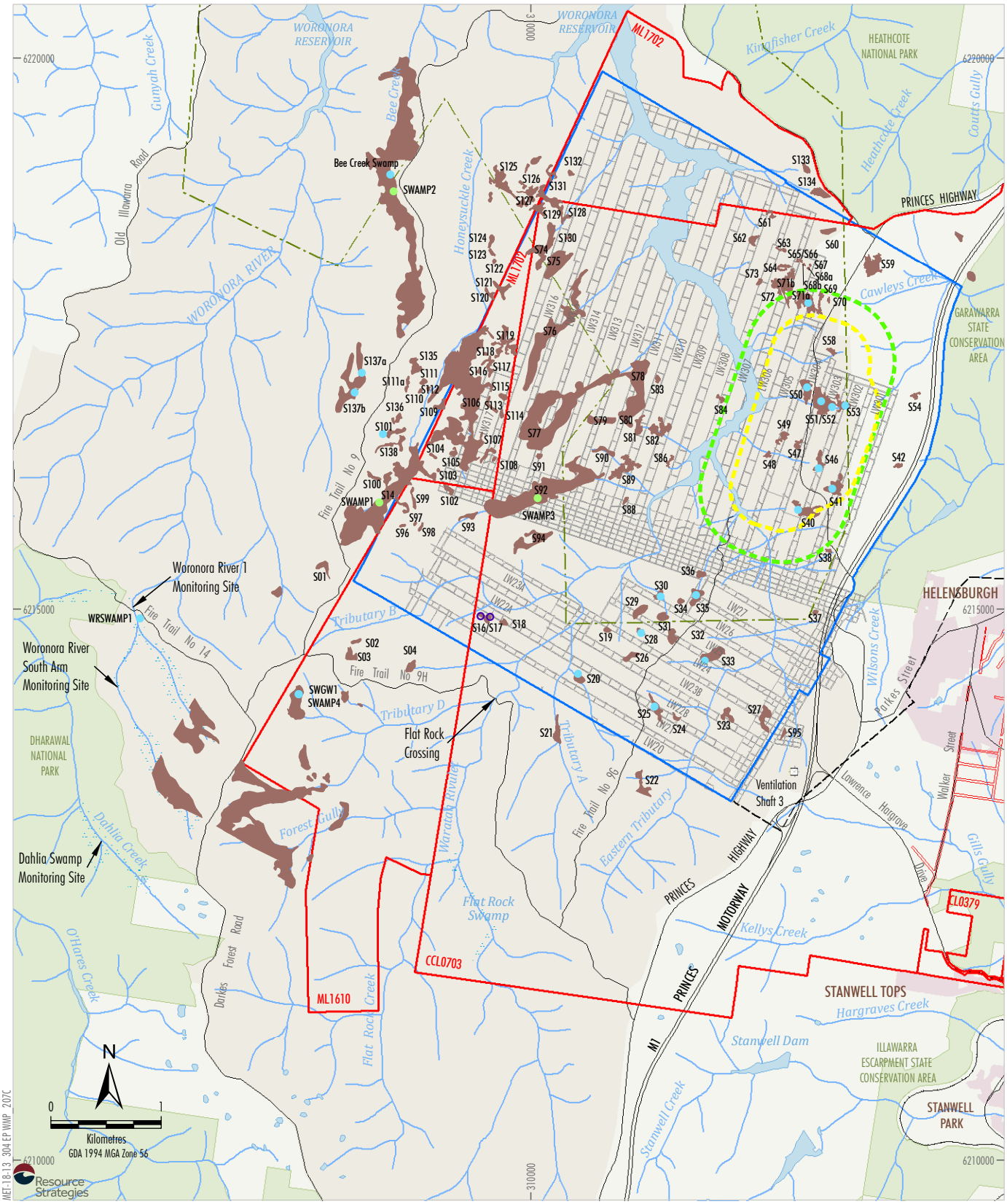
- for most swamps in the Project Area, there was a low risk of negative environmental consequences; and
- that there was a very low risk that a significant number of swamps would suffer such consequences.

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 Swamp 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 and in control Swamps 101, 137a and 137b (Figure 9). At Swamp 20 and at 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) (HydroSimulations, 2018b). 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 (HydroSimulations, 2018b).

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) (HydroSimulations, 2018b). 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 (HydroSimulations, 2018b).



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwall 304
- Existing Underground Access Drive (Main Drift)
- Woronora Notification Area
- Upland Swamp
- Swamp Substrate and Shallow Groundwater Piezometer
- Swamp Substrate Groundwater Piezometer
- Swamp Shallow Groundwater Piezometer

Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2019); MSEC (2019); after NPWS (2003), Bangalay Botanical Surveys (2008) and Eco Logical Australia (2015; 2016; 2018)

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Upland Swamp Groundwater Piezometer Locations

Figure 9

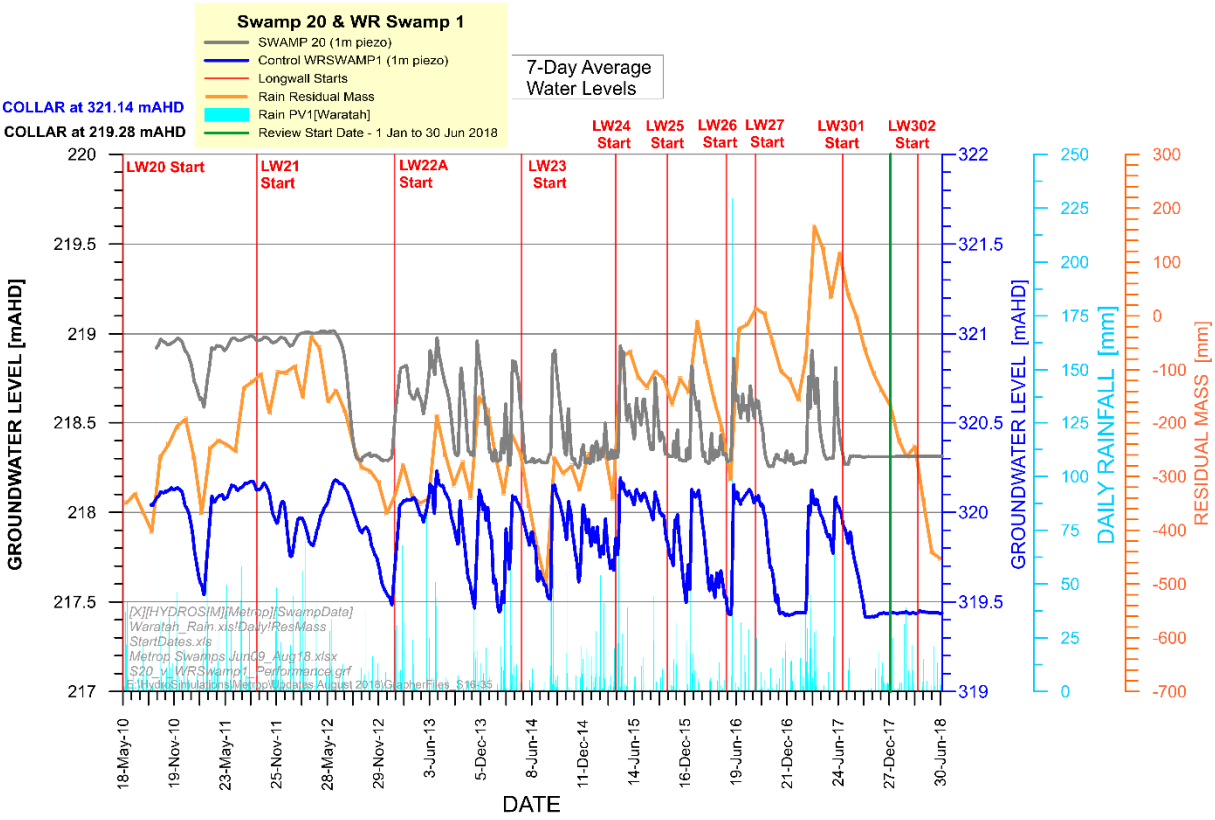


Chart 1 Comparison of Piezometer Responses at Swamp 20 and Woronora River 1 Control Swamp

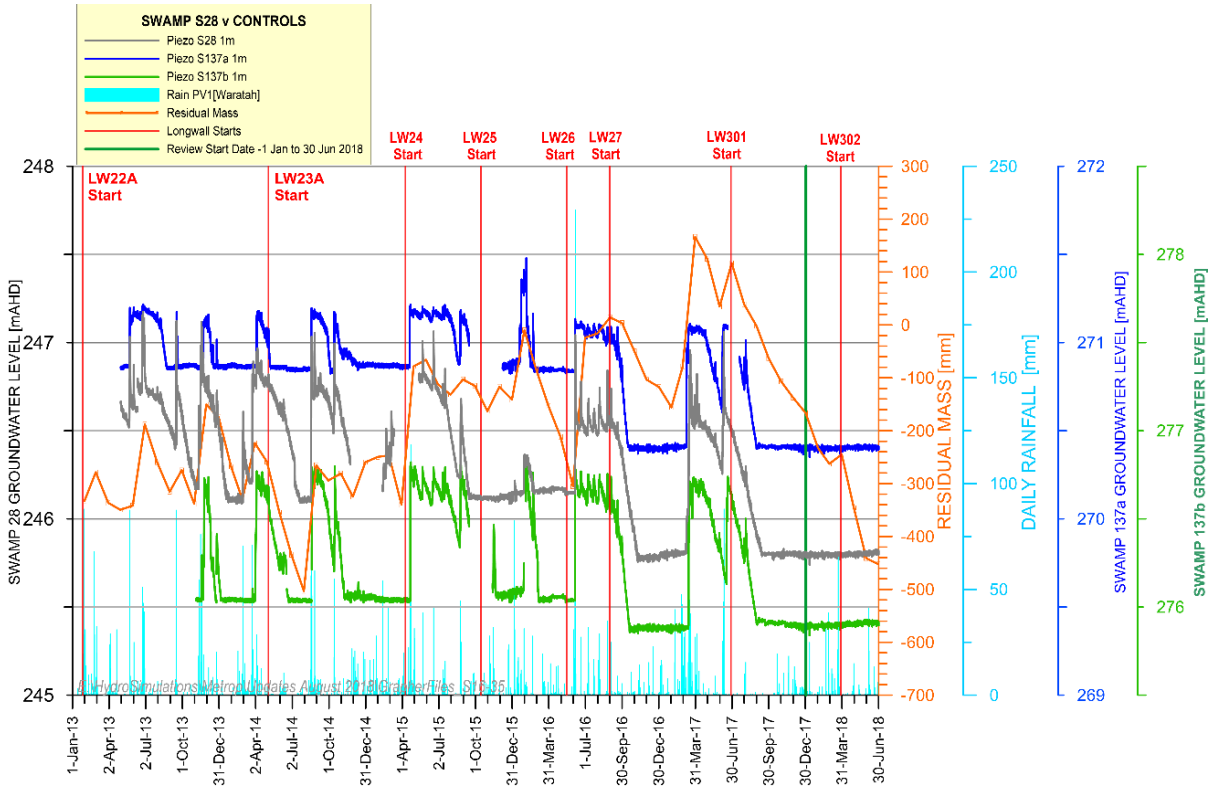


Chart 2 Groundwater Hydrographs at Swamp 28 and Two Control Swamps (137a and 137b)

Semi-quantitative comparisons of the swamp substrate water levels of Swamps 25, 30, 33, 35, 40, 41, 46, 51, 52 and 53 with control swamps and rainfall records have not shown a definitive mining effect and the dry conditions recorded in the swamps to date are regarded as a natural response to reduced rainfall (HydroSimulations, 2018b).

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 autumn and spring 2017 vegetation monitoring results suggest the changes in vegetation occurring in Swamp 28 are significantly different to changes in the control swamps.

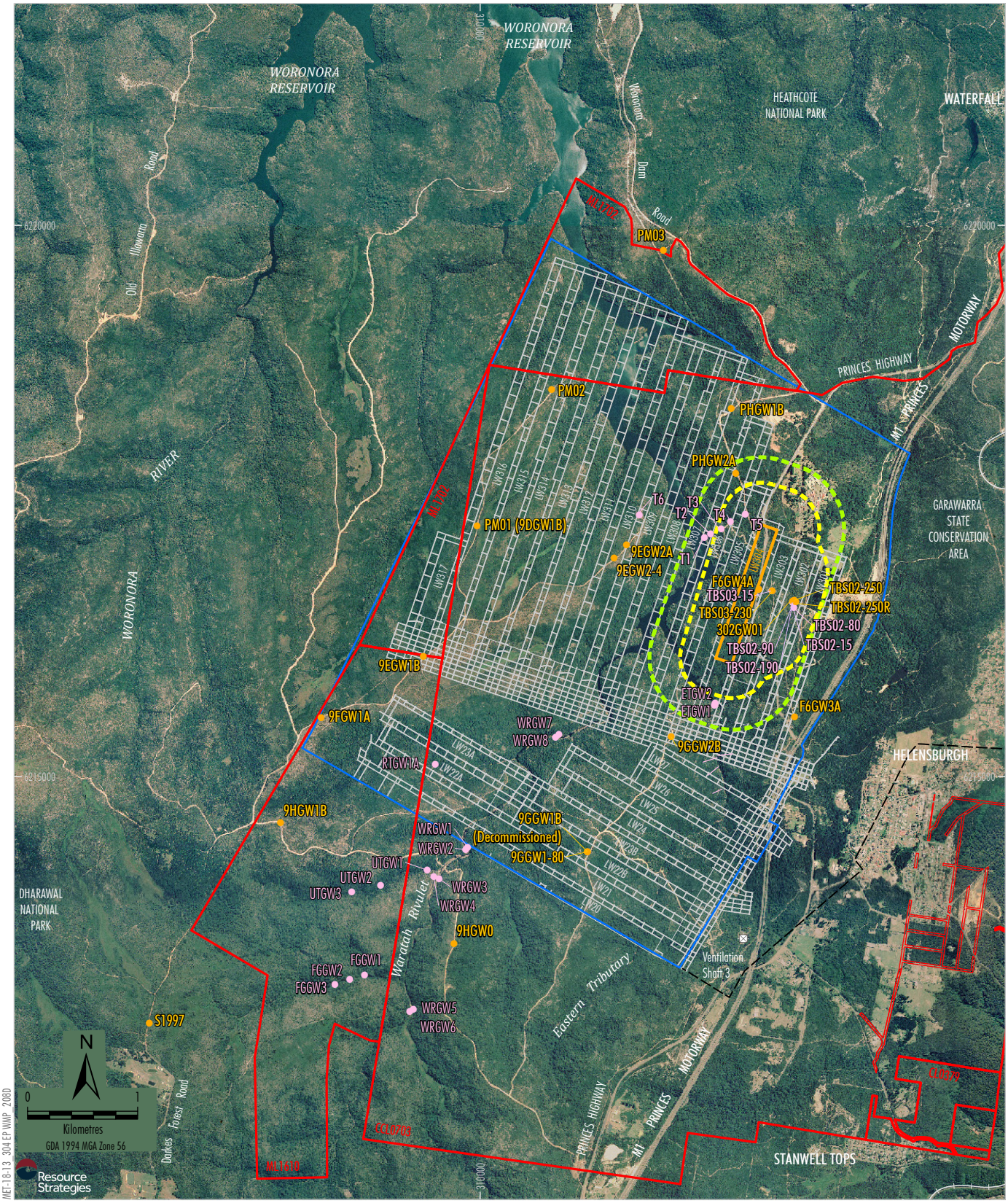
Shallow Groundwater Systems and Inflows to the Woronora Reservoir

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.
- Based on the analysis of the conceptual groundwater system, there would be negligible loss of groundwater yield to the Woronora Reservoir. This was reinforced by the groundwater modelling which 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 provides 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
- Longwall 304 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwall 304
- Existing Underground Access Drive (Main Drift)
- Groundwater Level/Pressure Bore
- Groundwater Level Bore

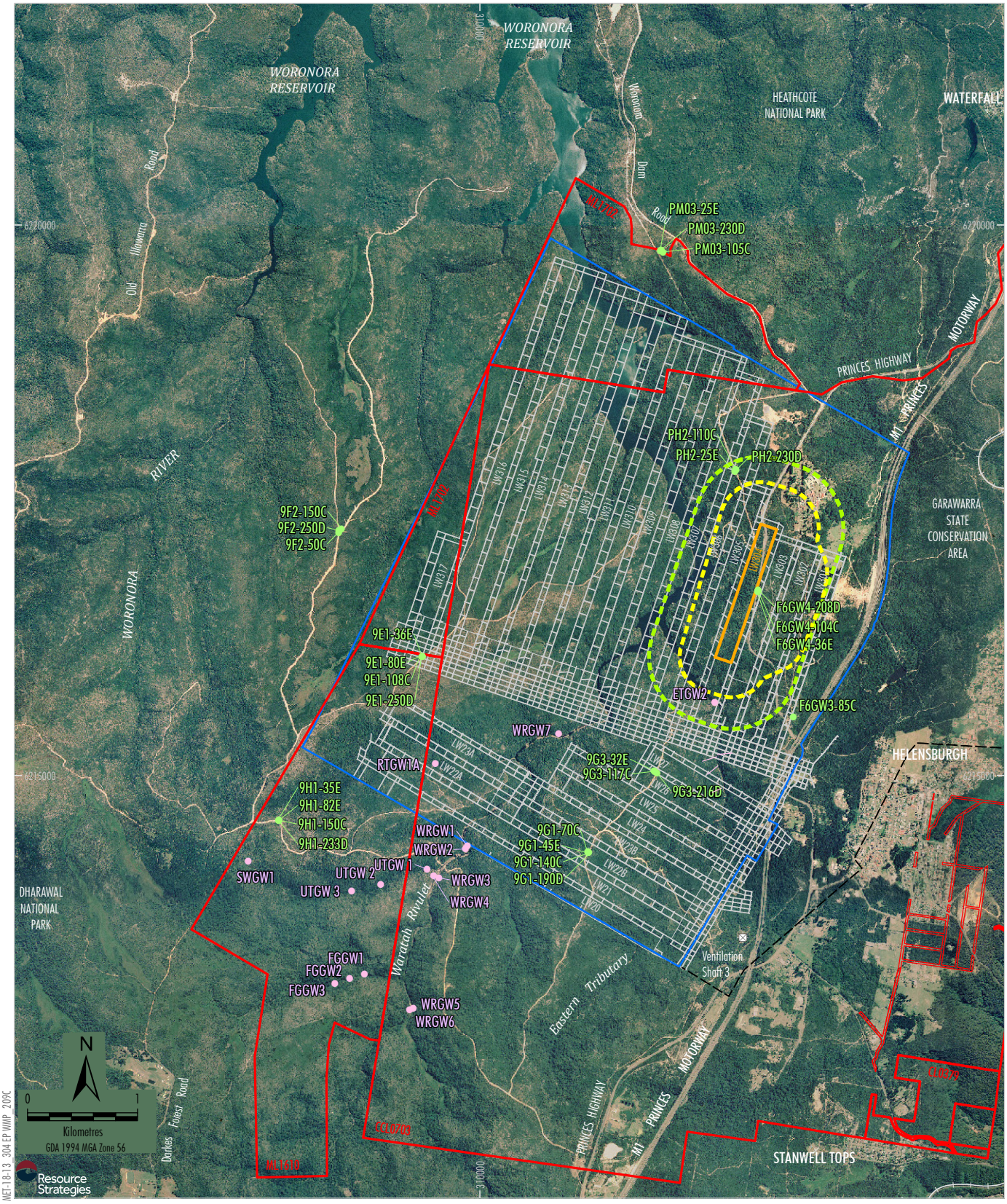
Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2019); MSEC (2019)

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
- Longwall 304 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwall 304
- 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 (2019); MSEC (2019)

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 expected to be in the order of 0.1 megalitres per day (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[7]. The revised groundwater model (that has been used for Longwall 304 [Section 5]) predicts that inflow for Longwalls 301-303 would be in the order of 0.003 to 0.10 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, that, 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.

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. 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.

[7] 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.

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.

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). The 20 day average daily mine water make has consistently been less than 0.5 ML/day since 2009 (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). Since 2009, the mine water make has averaged 0.09 ML/day, which is less than that predicted by groundwater modelling for the Project. The monitoring results are consistent with the predictions for mine water make.

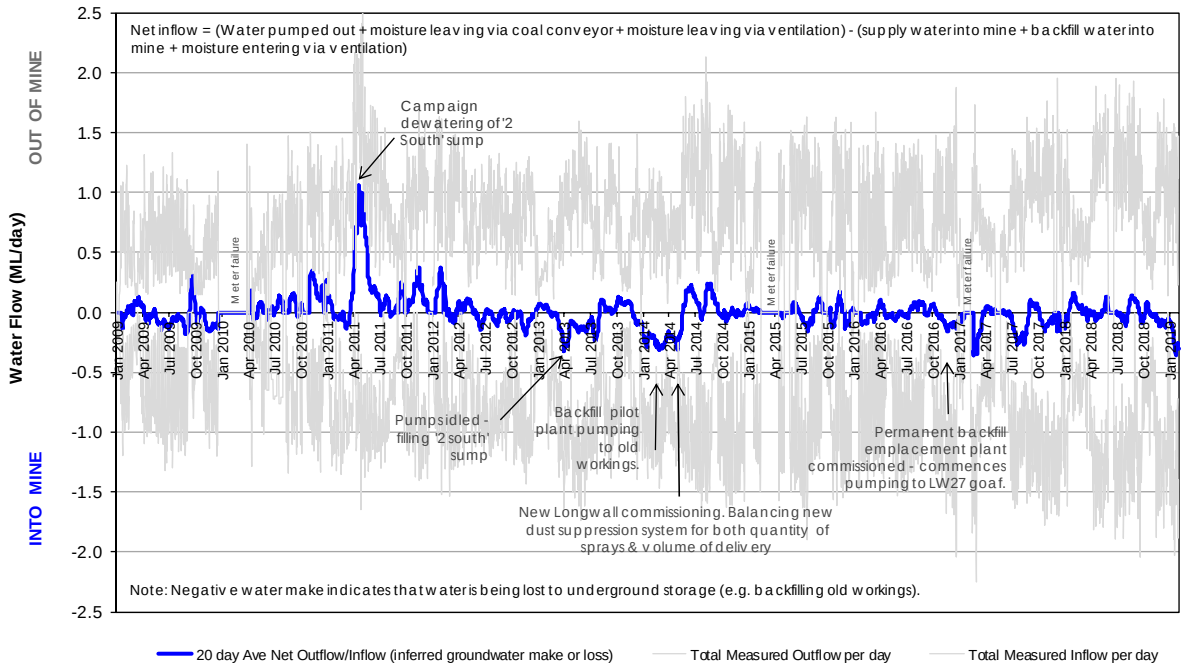


Chart 3a Estimated Daily Mine Water Make, 2009 to January 2019

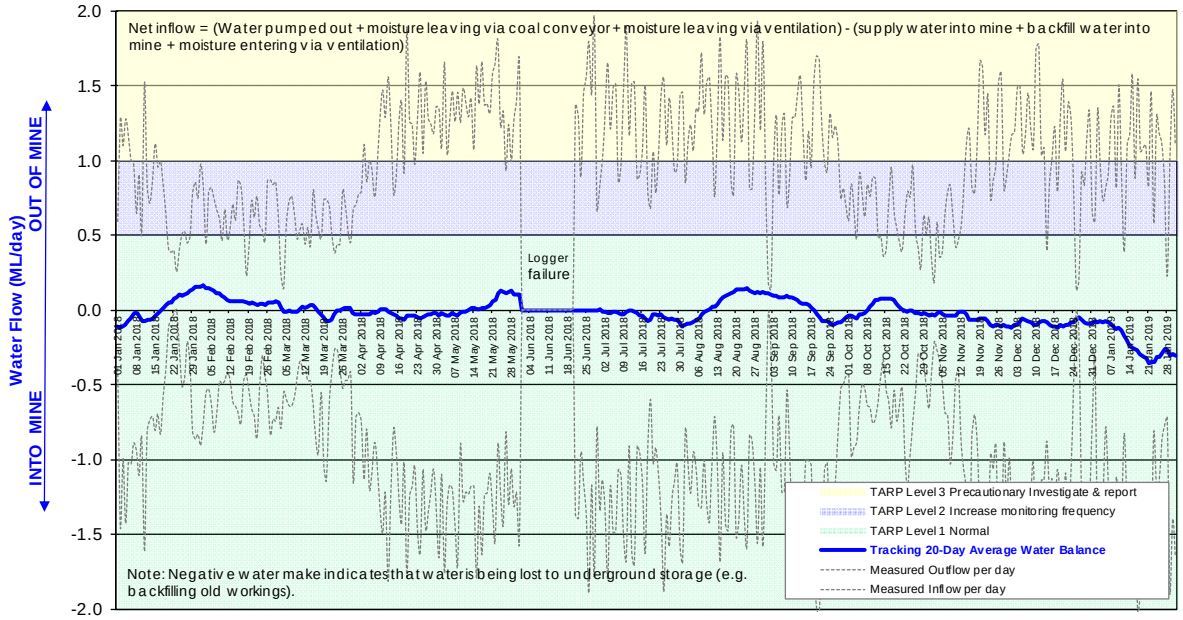


Chart 3b Estimated Daily Mine Water Make, January 2018 to January 2019

Further to a request from the Dams Safety Committee, a water balance for the 300 area (i.e. a localised water balance underground in and about the 300 series longwalls) was established using a series of water meters installed underground. The results of the localised water balance are shown in Chart 3c. Metropolitan Coal provide the results of the localised water balance, with the results of the overall mine water balance (Charts 3a and 3c) to the Dams Safety Committee monthly.

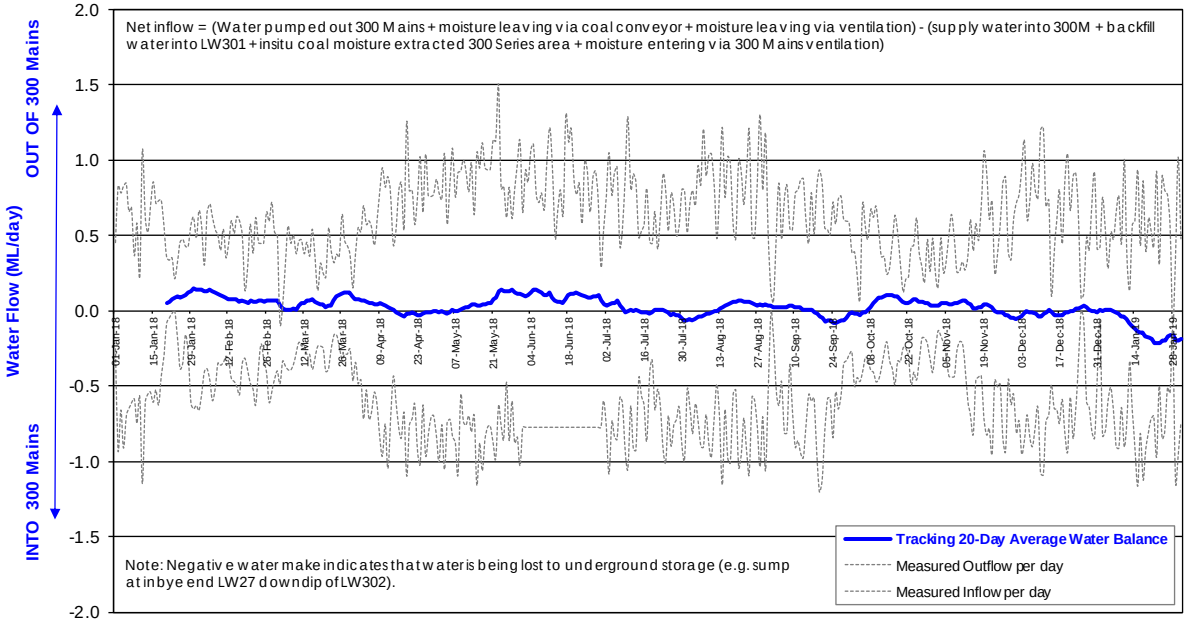


Chart 3c 300 Mains Water Balance, January 2018 to January 2019

Continuous groundwater level/pressure monitoring has been conducted at bores 9HGW0 (Longwall 10 Goaf Hole), 9EGW1B, 9FGW1A, 9GGW1-80, 9GGW2B, 9HGW1B, PM02, PM01 (9DGW1B), 9EGW2A[8], 9EGW2-4, PM03, PHGW1B, PHGW2A, F6GW3A 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.

In accordance with the Dams Safety Committee Approval (26 April 2012), for mining within the Woronora Reservoir Notification Area, 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 was analysed through statistics, trend diagrams (Stiff, Schoeller and Piper), time-series plots, spatial maps, and ratio plots for the Longwalls 301-303 WMP. The analysis indicated that although a few sampling sites were grout-impacted, there was 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 was 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.

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. 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 less than 10 percent.

[8] 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 RL's as the failed piezometers in December 2017.

The cross-sectional model was not sensitive to the fracture zone shape. Changing the fracture zone from a rectangular to a parabola 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. A draft report has been prepared and is currently under review (HydroSimulations, 2019).

4.3 WORONORA RESERVOIR IMPACT STRATEGY

Condition 2 of the Longwalls 301 and 302 approval requires 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 DP&E for the Woronora Reservoir Impact Strategy in May 2017.

The *Woronora Reservoir Strategy Report - Stage 1* 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 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.

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 and continued through to 6 October 2018. Secondary extraction of Longwall 303 commenced on 13 November 2018 and was ongoing at the end of the assessed flow record (16 January 2019). An assessment of the dry weather recessions recorded at the flumes on sub-catchments I and K show consistent behaviour. In comparing the recorded recessionary behaviour of sub-catchment I with the control on sub-catchment K it is evident that mining activity over the period has not resulted in any noticeable change in recessionary behaviour in sub-catchment I that is also not evident in sub-catchment K. That is, 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.

A preliminary water balance of Woronora Reservoir has been developed as a component of the Woronora Reservoir Impact Strategy. The outcomes of the preliminary water balance will be reported in the Woronora Reservoir Strategy Report - Stage 2 report.

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.

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 have continued to record meaningful data. The 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 have recovered by about 20 m and 10 m respectively (at September 2018), so that the pressure heads (the height of water above the sensor) at that time were about 50 m and 25 m 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.

Further west, over the pillar between Longwalls 303 and 304, bore F6GW4 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). The heads at TBS03 are consistent with those measured at F6GW4, and the responses at F6GW4 are consistent with those at 302GW01.

The two shallow 15 m standpipes have recorded stable depths to water of about 7 m at TBS02-15 and about 9 m at TBS03-15 since measurements commenced. 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 has become obstructed.

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 monitor horizontal shearing locations, measure the magnitude and direction of shearing in the Hawkesbury Sandstone and record any basal shearing on the sandstone contact with the Bald Hill Claystone formation. 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.

4.3.3 Permeability Measurements

In September 2017, pre-mining packer testing was conducted in bore 302GW01 for 15 12-metre sections from 238 m to 490 m depth, finishing in the Scarborough Sandstone. The interpreted hydraulic conductivities ranged from $8x10^{-7}$ 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 bore 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). Standpipes were installed at the same time to depths of 90 m (TBS02-90) and 190 m (TBS02-190). 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.

5 REVISED ASSESSMENT OF POTENTIAL ENVIRONMENTAL CONSEQUENCES

5.1 LONGWALL 304 EXTRACTION LAYOUT

Longwall 304 and the area of land within 600 metres (m) of Longwall 304 secondary extraction are shown on Figures 1 and 2. Longwall extraction will occur from north to south. The longwall 304 layout includes a 163 m panel width (void) and a 45 m pillar width (solid).

Longwall 304 is scheduled to commence in July 2019 and be completed in December 2019.

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 Longwall 304 Extraction Plan[9] *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 DP&E and DRE (2015) *Guidelines for the Preparation of Extraction Plans*.

The suitably qualified and experienced experts endorsed by the Secretary of the DP&E for the preparation of the Metropolitan Coal Longwall 304 Extraction Plan participated in the ERA[10]. The ERA process involved the key steps described below.

Review of Relevant Documentation

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 *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 (PAC) 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 301-303 Environmental Risk Assessment Report (Metropolitan Coal, 2016)[11].
- Subsidence predictions and assessments included in Metropolitan Coal's Longwalls 304-306 First Workings Application (correspondence to the DP&E dated 9 October 2018).
- Information regarding the Longwalls 301-303 layout and requirement to have no further exceedance of the relevant performance measure applicable to the Eastern Tributary.
- Subsidence predictions for the proposed Longwall 304 Extraction Plan layout (including subsidence contours, Eastern Tributary, cliff sites, upland swamps and Aboriginal heritage sites).

Risk Identification

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.

[9] Individual risk assessments have been undertaken separately for the Metropolitan Coal Longwall 304 Built Features Management Plan and the Metropolitan Coal Longwall 304 Public Safety Management Plan, and are reported in their respective documents.

[10] Participants included Mr Peter DeBono (Mine Subsidence Engineering Consultants, Subsidence and Land), Dr Noel Merrick (HydroSimulations, Groundwater), Mr Lindsay Gilbert and Mr Tony Marszalek (Hydro Engineering & Consulting, Surface Water), Associate Professor Barry Noller (The University of Queensland, Surface Water Quality), Dr David Goldney (Cenwest Environmental Services, Fauna), Ms Elizabeth Norris (Ecoplanning, Flora), Mr Jamie Reeves (Niche Environment and Heritage, Heritage), Ms Stacey Gromadzki (Resource Strategies), Mr Jon Degotardi (Metropolitan Coal) and Mr Stephen Love (Metropolitan Coal).

[11] This report includes a description of the approved changes made to the first workings layout for Longwalls 301-303 in 2015 and 2016.

ERA Workshop

The ERA workshop for Longwall 304 was conducted on 23 November 2018, with some participants attending via video conferencing and others attending in person at the Metropolitan Coal Mine. The ERA workshop was facilitated by an independent specialist, Operational Risk Mentoring 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 Longwall 304 were broadly assessed and ranked as part of the 2008 Environmental Risk Analysis and Longwalls 301-303 ERA. It was considered that the five "loss scenarios" identified for the Longwalls 301-303 ERA (within two key topics of discussion viz. Upland Swamps and the Eastern Tributary) were appropriate for the assessment of Longwall 304.

The assessed level of risk for each of the five loss scenarios identified for Longwalls 301-303 were reviewed for Longwall 304, considering the experience to date and using the same probability, consequence and risk rankings tables. A key assumption that was applied to the Longwall 304 ERA was that the Longwall 304 Extraction Plan layout would not result in any further exceedance of the performance measure relevant to the Eastern Tributary.

The assessed levels of risk for Longwalls 301-303 were considered by the participants to remain valid for Longwall 304. The re-assessed risk rankings for Longwall 304 were within the "low" range and consequently the potential outcomes can still be integrated into the existing management systems for effective review and monitoring (Operational Risk Mentoring, 2019).

Review of Issues/Risks and Assessed Levels of Risk for Revised Longwall 304 Extraction Plan Layout

Subsequent to the Longwall 304 ERA workshop, Metropolitan Coal proposed a change to the layout of Longwalls 303 and 304 for the Longwall 304 Extraction Plan. The participants were asked to review a number of additional documents relevant to the risk assessment and revised layouts and Longwall 304 risk assessment. This included:

- Metropolitan Coal's Longwall 303 Extension Application (February 2019), which seeks further approval from the Secretary to undertake secondary extraction beyond 1,143 m in Longwall 303 for the first 1,325 m of Longwall 303. This application includes details of Metropolitan Coal's proposed monitoring and adaptive management approach for the Eastern Tributary. The application states that the same monitoring and adaptive management approach for the Eastern Tributary will be applied to Longwall 304.
- Confirmation that the Longwall 304 Extraction Plan will be based on a Longwall 303 extraction length of 1,325 m and a Longwall 304 extraction length of 1,286 m, noting that this layout differs from that assessed in the ERA Workshop (November 2018), with Longwall 303 being extended by 128 m and Longwall 304 being shortened by 42 m.
- A figure showing the revised Longwall 303 and Longwall 304 layouts to be used for the Longwall 304 Extraction Plan compared to the longwall lengths assessed by the ERA workshop.
- The MSEC (2019) *Metropolitan Mine – Longwall 304 Subsidence Predictions and impact Assessments for the Natural and Built Features in Support of the Extraction Plan* report (Report MSEC1009), detailing the subsidence predictions and impact assessments for the revised longwall layout for the Longwall 304 Extraction Plan.

The ERA participants were asked to identify any additional (specific) issues/risks and/or changes to previously assessed levels of risk associated with the revised Longwall 304 Extraction Plan Layout. The assessed levels of risk were considered to remain valid for the revised Longwall 304 Extraction Plan layout.

ERA Report Review

All ERA participants were asked to review the draft report that was prepared to summarise the outcomes of the risk assessment workshop and risk review as a result of the change in longwall layout. Participants' comments were incorporated into the final Operational Risk Mentoring (2019) 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

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 20 February 2019 to assess the potential for mining effects on geological features to impact on the quantity of water available to the Woronora Reservoir. The workshop participants[12] 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.

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 Longwall 304 Coal Resource Recovery Plan.

[12] Participants included Professor Bruce Hebblewhite (B. K. Hebblewhite Consulting), Dr Noel Merrick (HydroSimulations, Groundwater), Mr Peter DeBono (Mine Subsidence Engineering Consultants, Subsidence), Mr Shane Kornek (Metropolitan Coal, Geotechnical Engineer), Mr Jon Degotardi (Metropolitan Coal, Technical Services Manager), Mr Tim Kendrick (Peabody, Water Specialist) and Ms Stacey Gromadzki (Resource Strategies). The risk assessment was facilitated by Mr Mick Allen (Peabody, Safety Superintendent).

5.4 REVISED SUBSIDENCE PREDICTIONS

The subsidence predictions for Longwall 304 in relation to streams have been prepared by MSEC (2019)[13].

Waratah Rivulet

The Waratah Rivulet is located over 1.1 km south-west of Longwall 304, at its closest point to Longwall 304 secondary extraction (Figure 1). At this distance, the Waratah Rivulet is not predicted to experience any measurable subsidence or valley related movements resulting from the extraction of Longwall 304 (MSEC, 2019).

Eastern Tributary

The Eastern Tributary flows in a northerly direction into the full supply level of the Woronora Reservoir to the south of the 35° angle of draw and/or predicted 20 mm subsidence contour for Longwall 304.

The maximum predicted values of total conventional subsidence, tilt, curvature, upsidence and closure for the Eastern Tributary, resulting from the extraction of Longwall 304, is provided in Table 4 (MSEC, 2019).

Table 4
Maximum Predicted Subsidence, Tilt, Curvature, Upsidence and Closure for the Eastern Tributary Resulting from Longwall 304 Extraction

Longwall	Maximum Predicted					
	Subsidence[1] (mm)	Tilt[2] (mm/m)	Hogging Curvature[3] (km^{-1})	Sagging Curvature[3] (km^{-1})	Upsidence[4] (mm)	Closure[5] (mm/m)
LW304	40	<0.5	<0.01	<0.01	50	70

Source: after MSEC (2019).

mm = millimetres; mm/m= millimetres per metre; km^{-1} =1/kilometres

1 Subsidence refers to vertical displacements of the ground.

2 Tilt is the change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the distance between those points.

3 Curvature is the second derivative of subsidence, the rate of change of tilt and is calculated as the change in tilt between two adjacent sections of the tilt profile divided by average length of those sections.

4 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.

5 Closure is the reduction in the horizontal distance between the valley sides.

The maximum predicted valley closure for Pools ETAS/ETAT and ETAU on the Eastern Tributary resulting from the extraction of Longwall 304 is 70 mm total closure (MSEC, 2019).

A comparison of the maximum predicted subsidence, upsidence and closure for the Eastern Tributary resulting from the Extraction Plan Layout of Longwall 304, with those based on the Preferred Project Layout for Longwall 304, is provided in Table 5. The revised maximum predicted subsidence, upsidence and closure for the Eastern Tributary, are less than the maxima for the Preferred Project Layout (MSEC, 2019). The maximum predicted total closure on the Eastern Tributary resulting from the extraction of Longwall 304 is 70 mm (Table 5).

13 The revised subsidence effects, subsidence impacts and potential environmental consequences to upland swamps are addressed in the Metropolitan Coal Longwall 304 Biodiversity Management Plan (Figure 3).

Table 5
Comparison of Maximum Predicted Conventional Subsidence Parameters for the Eastern Tributary 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 (LW304)	325	300	200
Extraction Plan Layout	40	50	70

Source: after MSEC (2019)
mm = millimetres

The predicted profiles of subsidence, upsidence and closure along the Eastern Tributary, resulting from the extraction of Longwall 304, are shown on Figure 12 (MSEC, 2019). The maximum predicted closure for Pools ETAS/ETAT and ETAU resulting from the extraction of Longwall 304 is 70 mm, compared with 200 mm for the Preferred Project Layout after Longwall 304.

Woronora Reservoir

A portion of the Woronora Reservoir full supply level is located inside the Longwall 304 35° angle of draw and/or predicted 20 mm subsidence contour, to the south-west of Longwall 304 (Figure 2). The area of the Woronora Reservoir full supply level immediately downstream of the 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. Longwall 304 does not extend beneath the Woronora Reservoir full supply level.

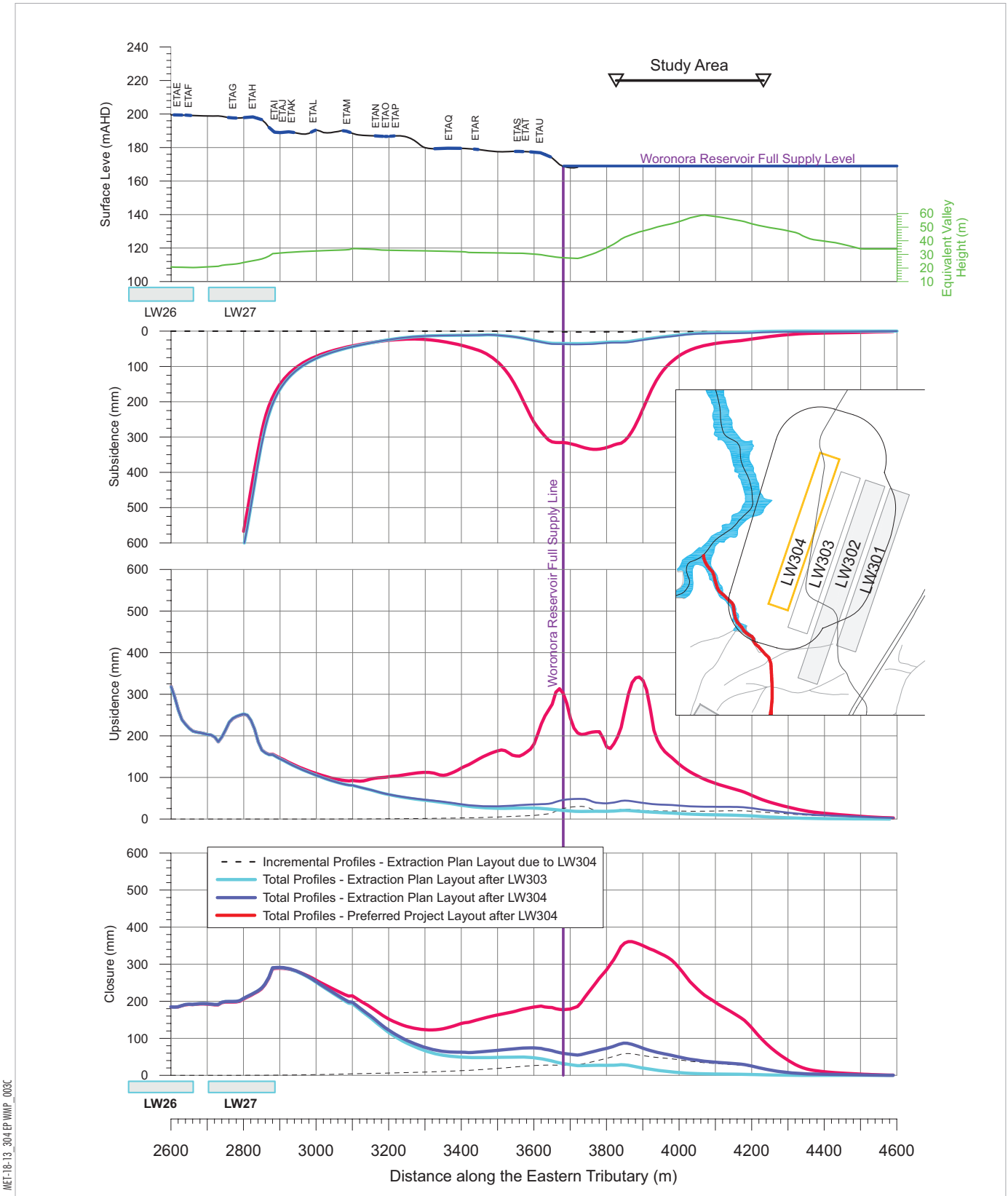
A summary of the maximum predicted values of total conventional subsidence, tilt, curvature, upsidence and closure for the Woronora Reservoir full supply level, resulting from the extraction of Longwall 304 is provided in Table 6.

Table 6
Maximum Predicted Subsidence, Tilt, Curvature, Upsidence and Closure for the Woronora Reservoir Resulting from Longwall 304 Extraction

Longwall	Maximum Predicted					
	Subsidence (mm)	Tilt (mm/m)	Hogging Curvature (km^{-1})	Sagging Curvature (km^{-1})	Upsidence (mm)	Closure (mm/m)
LW304	40	<0.5	<0.01	<0.01	50	90

Source: after MSEC (2019).
mm = millimetres; mm/m= millimetres per metre; km^{-1} =1/kilometres

The predicted profiles of subsidence, upsidence and closure for the Woronora Reservoir full supply level, resulting from the extraction of Longwall 304, are shown on Figure 12 (MSEC, 2019).



MET-18-13_304 EP WMP_003C

Source: MSEC (2019)

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Predicted Profiles of Subsidence, Upsidence and Closure along the Eastern Tributary and Woronora Reservoir due to Longwall 304

Figure 12

A comparison of the maximum predicted subsidence, upsidence and closure for the Woronora Reservoir full supply level resulting from the Extraction Plan Layout of Longwall 304, with those based on the Preferred Project Layout for Longwall 304, is provided in Table 7. The revised maximum predicted subsidence, upsidence and closure for the Woronora Reservoir full supply level, are less than the maxima for the Preferred Project Layout (MSEC, 2019). The maximum predicted total closure on the Woronora Reservoir full supply level resulting from the extraction of Longwall 304 is 90 mm (Table 7).

Table 7
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 (LW304)	475	800	825
Extraction Plan Layout	40	50	90

Source: after MSEC (2019)
mm = millimetres

Other Drainage Lines/Streams

Small first and second order streams are located within the Longwall 304 35° angle of draw and/or predicted 20 mm subsidence contour (Figure 2). These streams consist of shallow drainage lines from the topographical high point above Longwalls 301-303, forming streams where valley heights increase and drain into the Woronora Reservoir to the west of the longwalls. Three streams are located above Longwall 304, and could experience the full range of predicted subsidence movements (MSEC, 2019). The shallow drainage lines above the northern and southern ends of Longwall 304 have small valley heights of generally less than 10 m and are predicted to experience small magnitudes of predicted upsidence and closure. The valley heights increase at the lower reaches. The drainage line with the largest valley height is located above the middle of Longwall 304, and is predicted to experience maximum total closure due to Longwall 304 of 350 mm near the Longwall 304 maingate.

5.5 REVISED ASSESSMENT OF POTENTIAL SUBSIDENCE IMPACTS AND ENVIRONMENTAL CONSEQUENCES

5.5.1 Surface Water

The maximum predicted subsidence parameters for the Eastern Tributary, 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, 2019). Impacts to some pools along the Eastern Tributary resulting from the extraction of Longwalls 23-27, 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 and 304 have been set back to minimise predicted valley closure at the Eastern Tributary.

Metropolitan Coal has established a comprehensive monitoring and adaptive management program to identify subsidence related movements at the Eastern Tributary during the extraction of Longwall 303 so that additional mining of Longwall 303 would have no further exceedance of the Eastern Tributary performance measure. The same monitoring and adaptive management program will be used for the extraction of Longwall 304. Similar monitoring of subsidence movements using high resolution survey methods has been successfully implemented for the Sandy Creek Waterfall at the Dendrobium Coal Mine by South32. The Longwall 304 Eastern Tributary TARP is provided in Section 8.10.

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[14]. Further to advice from the IEPMC, the DP&E requested that specific regard be given in the Longwall 304 Extraction Plan to the potential impacts of mining near and under lineaments on surface water features, including waterfalls[15].

Lineaments mapped by Metropolitan Coal proximal to streams within 600 m of Longwall 304 are shown on Figure 13. The lineament that runs north-south across Longwalls 20-27 extends over Longwall 304. Over Longwalls 20-27, this lineament is associated with an underground fault (F-008) and it is possible that this fault extends over Longwall 304. Longwalls 20-27 mined through this fault structure and did not intercept water (i.e. the fault did not act as a conduit at depth).

A lineament that aligns with the Eastern Tributary at the waterfall at downstream end of rock bar ETAU (Figure 13) 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 Longwall 303 maingate. WaterNSW representatives were shown this particular strike-slip fault, along with F0008 during an underground inspection on 19 March 2019[16]. WaterNSW representatives concurred that the faults are not readily apparent without the assistance of Metropolitan Coal's geologist.

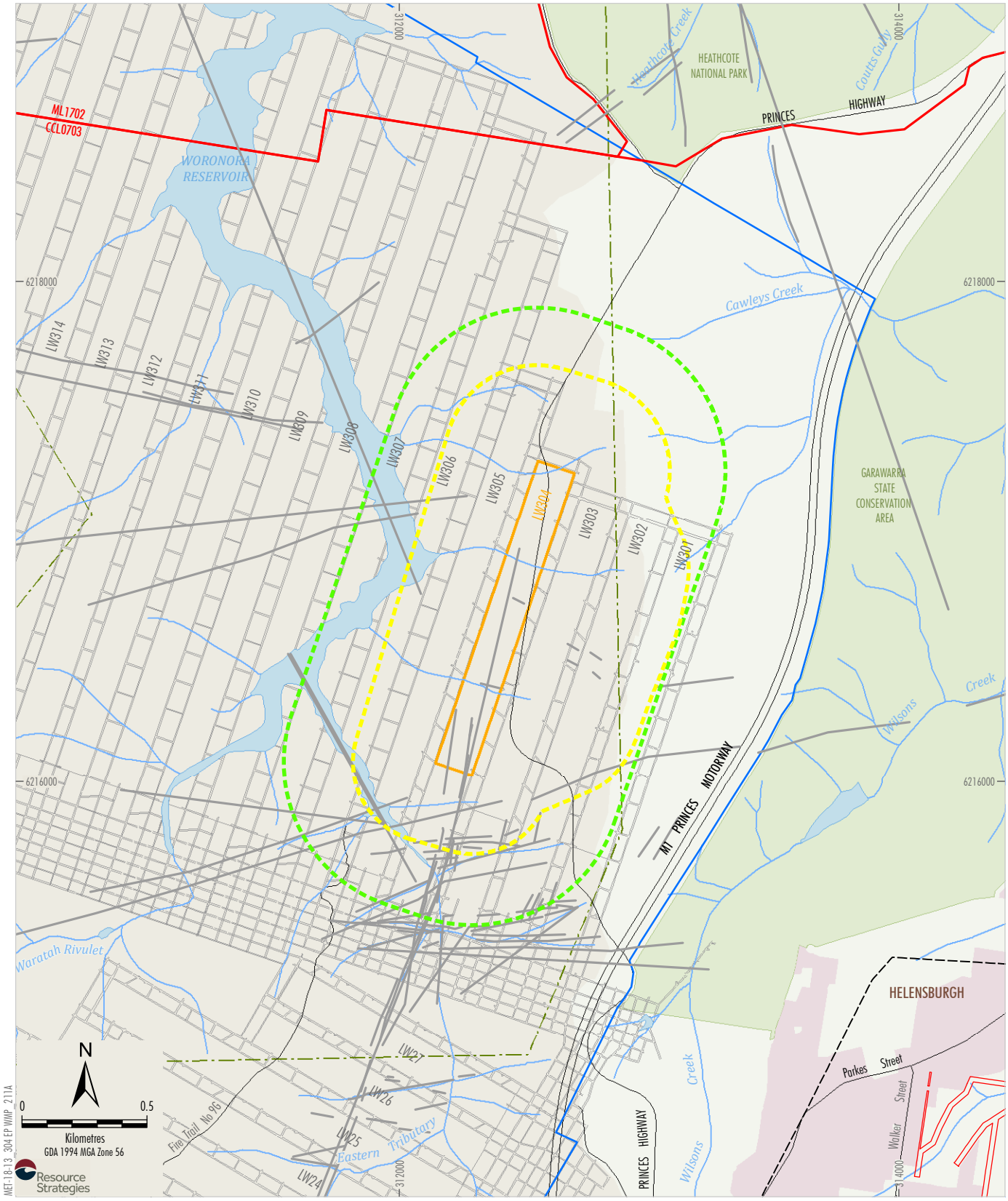
It is considered likely that Fault F008 (were it to continue across Longwall 304) and Fault F0021, would have similar characteristics and behave in a similar manner to that experienced by mine extraction and development to date. Hydraulic connectivity via lineaments to the waterfall at rock bar ETAU on the Eastern Tributary is considered to be highly unlikely.

The maximum predicted subsidence parameters for the Woronora Reservoir full supply level, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout. The Preferred Project Layout of Longwall 304 extended beneath the Woronora Reservoir full supply level, while the Extraction Plan Layout does not. This has resulted in a significant reduction in the predicted subsidence parameters for the Woronora Reservoir full supply level. As a result, there is a lower likelihood of impacts (fracturing/dilation of bedrock and localised diversion of surface flow when the reservoir level is lower than the full supply level) due to the Extraction Plan Layout compared to impacts assessed for the Preferred Project Layout.

[14] 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.

[15] 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.

[16] 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
- Longwall 304 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwall 304
- Woronora Notification Area
- Existing Underground Access Drive (Main Drift)
- Lineament

Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2019); MSEC (2019)

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Streams over Longwall 304 and Surrounds

Figure 13

The small first and second order streams located within the Longwall 304 35° angle of draw and/or predicted 20 mm subsidence contour (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[17]

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 Longwall 304 extraction on aquifers and baseflow to watercourses have been predicted using the latest calibrated model (HydroSimulations 2018a, report HS2017/23). 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.

The groundwater model predictions described in this section and referred to elsewhere in this WMP were conducted for longer longwall lengths for Longwall 303 (1,788 m) and Longwall 304 (1,438 m). Accordingly, the groundwater predictions presented are more conservative than would be the case for the longwall layout presented in this WMP (Longwall 303 – 1,325 m; Longwall 304 – 1,286 m).

Catchment Yield[18]

Based on the period of record available for the Woronora Reservoir (1977 to 2018) at the time of the Project EA, the model predictions indicate a negligible reduction in catchment yield due to Longwall 304 extraction (i.e. 0.001% of the annual average yield to the reservoir)[19].

Mine Groundwater Inflows

The simulated groundwater inflow to Longwalls 301-304 is presented on Chart 4 for the updated groundwater model, from the start of Longwall 301 to the end of Longwall 304 (assuming no subsequent mining). The inflow is expected to lie in the range 3-140 kL/day. 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.

[17] The groundwater model predictions described in this section and referred to elsewhere in this WMP were conducted for longer longwall lengths for Longwall 303 (1,788 m void panel length) and Longwall 304 (1,438 m void panel length). Accordingly, the groundwater predictions presented are more conservative than would be the case for the longwall layout presented in this WMP (Longwall 303 void panel length of 1,325 m and Longwall 304 void panel length of 1,286 m).

[18] Total water flow from the catchment including surface and sub-surface contributions.

[19] 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 0.0008 ML/day reduction in catchment yield for Longwall 304 extraction.

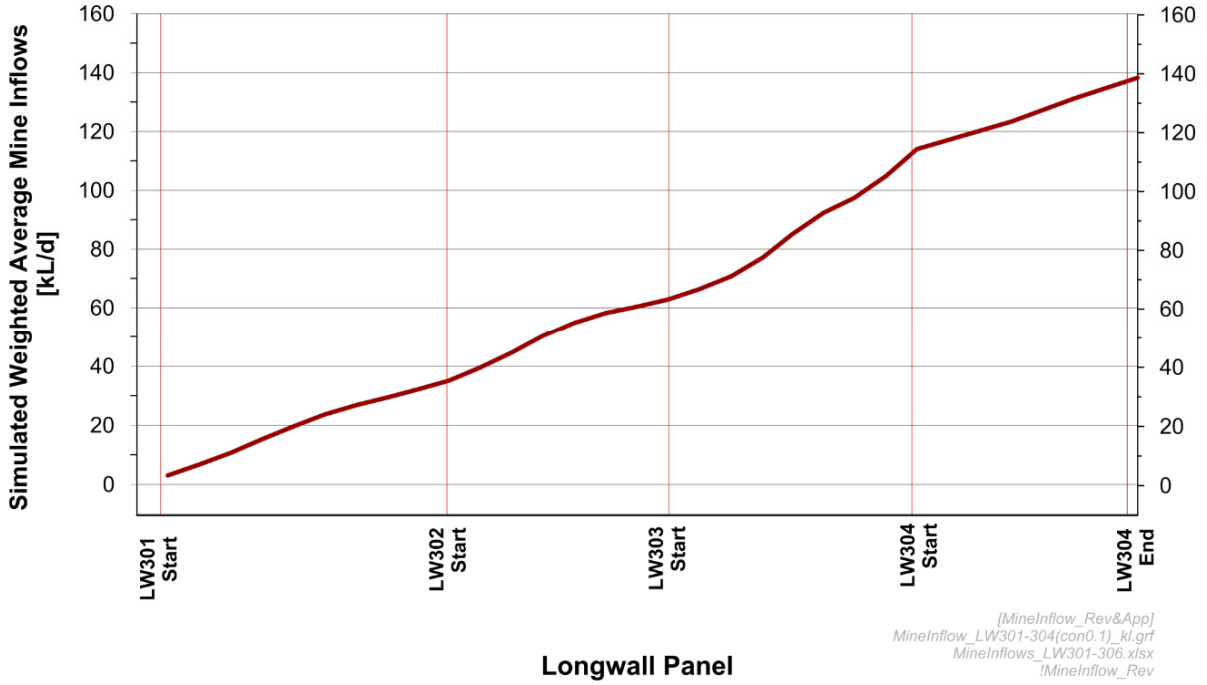


Chart 4 Predicted Groundwater Inflows to Longwalls 301-304 as Mining Proceeds

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 Longwall 304. The locations of these bores are shown on Figure 10.

Every bore shows some mining effect. The least affected bore is PM02, which is the furthest from active mining. Using the range in heads from the uppermost piezometer to the lowest head predicted at depth as a guide, the order of total predicted mining effect (from most to least) is: F6GW4A (410 m head range), 9GGW2B (385 m head range), F6GW3A (270 m head range), 9EGW1B (180 m head range), 9EGW2A (130 m head range), PM01 (9DGW1B) (130 m head range), PHGW2A (110 m head range), PHGW1B (90 m head range) and PM02 (80 m head range) (Figure 10).

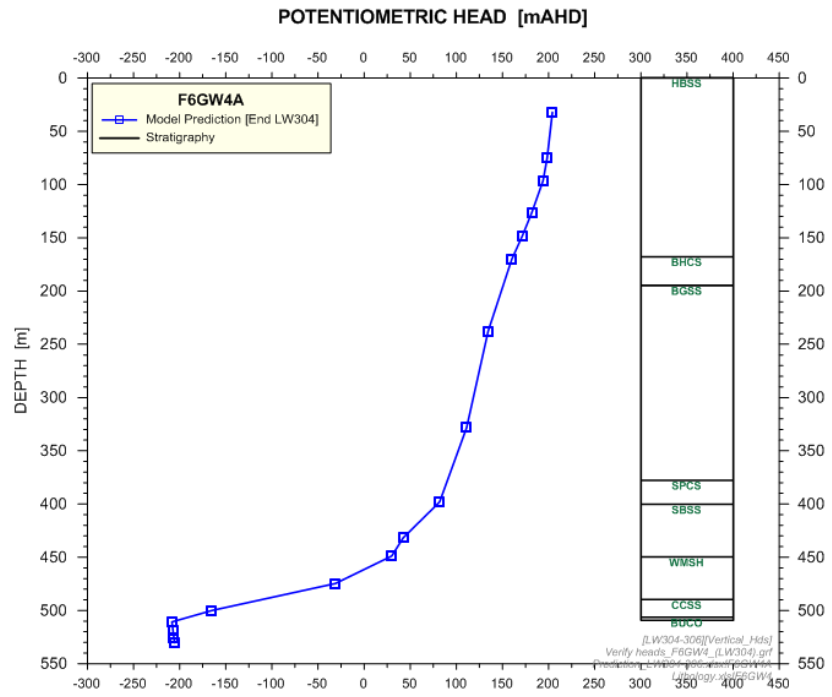


Chart 5 Predicted Vertical Head Profile at Bore F6GW4A at the end of Longwall 304

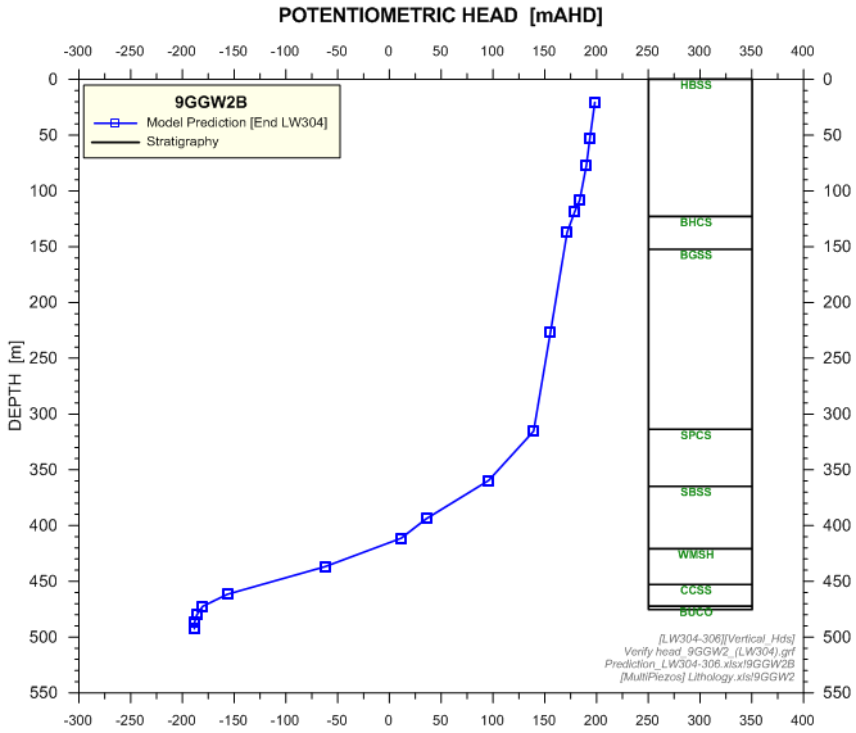


Chart 6 Predicted Vertical Head Profile at Bore 9GGW2B at the end of Longwall 304

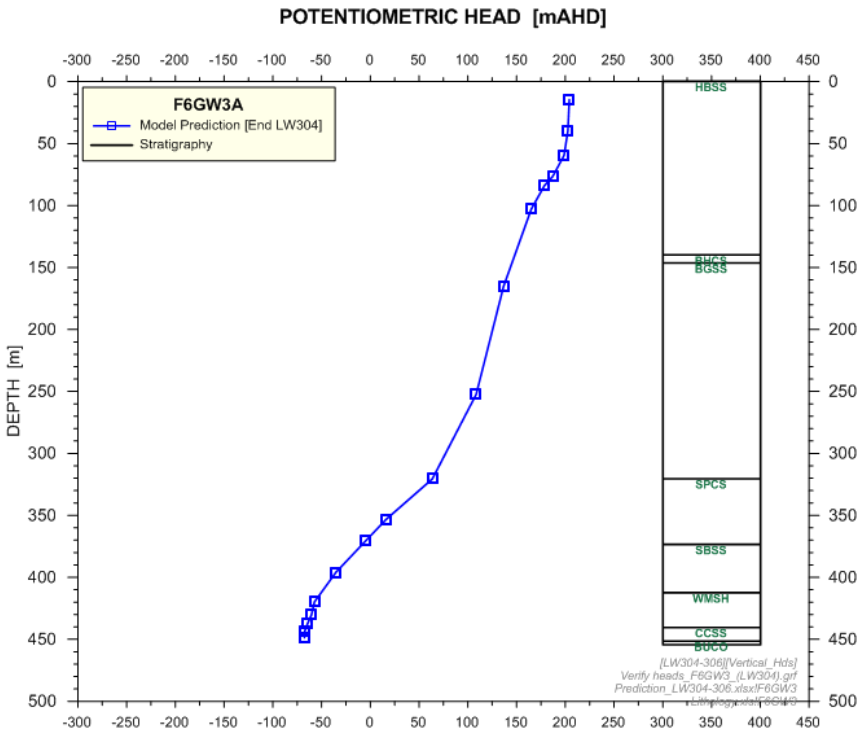


Chart 7 Predicted Vertical Head Profile at Bore F6GW3A at the end of Longwall 304

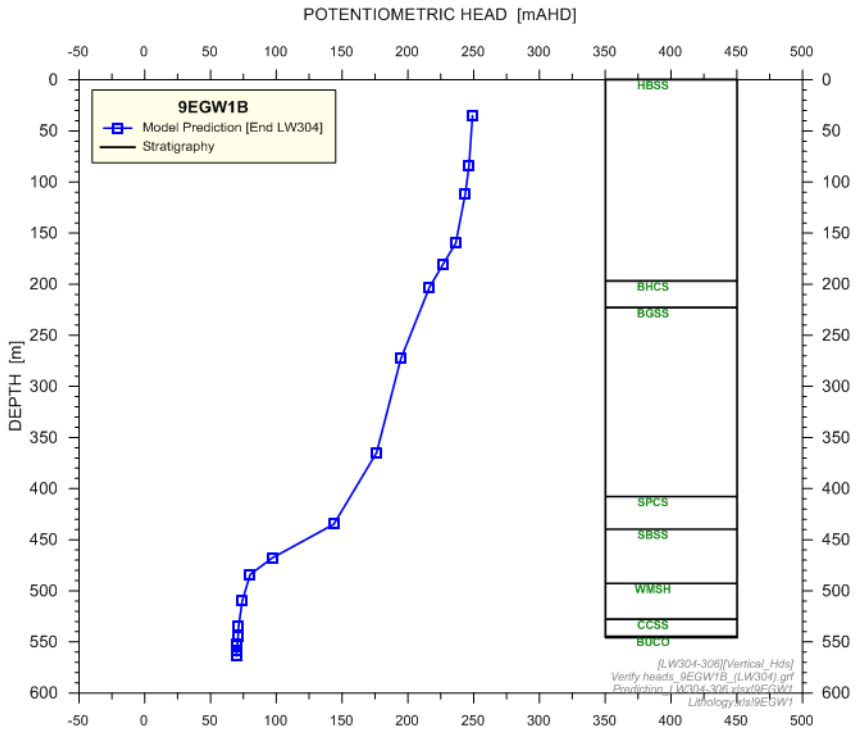


Chart 8 Predicted Vertical Head Profile at Bore 9EGW1B at the end of Longwall 304

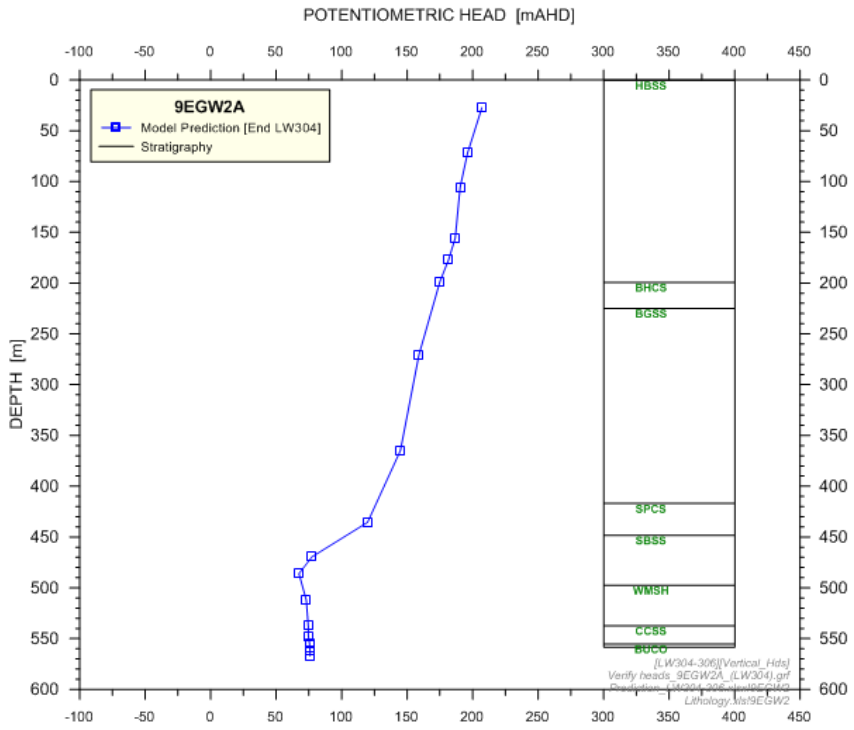


Chart 9 Predicted Vertical Head Profile at Bore 9EGW2A at the end of Longwall 304

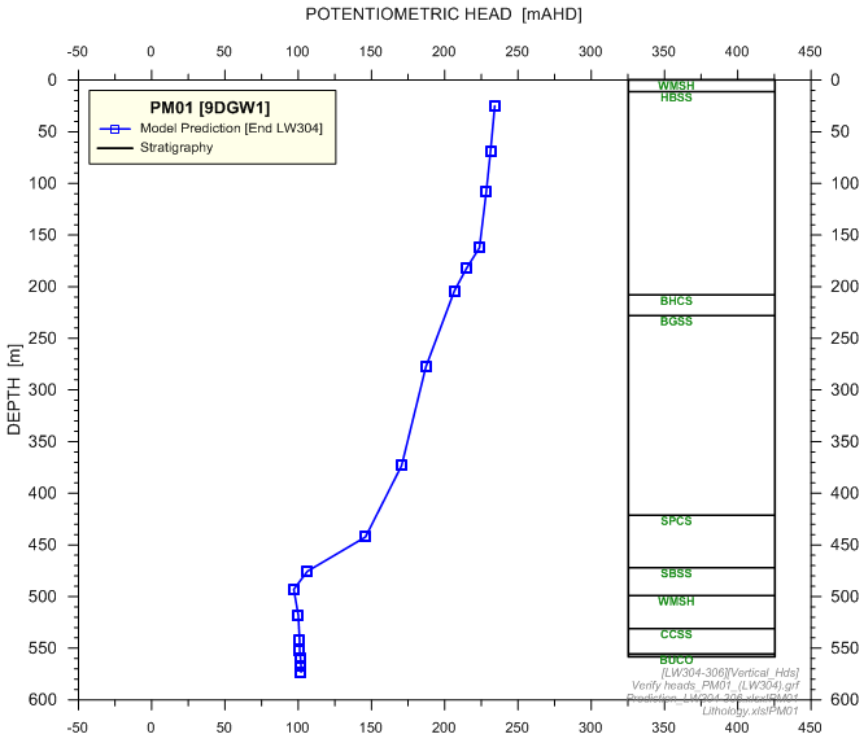


Chart 10 Predicted Vertical Head Profile at Bore PM01 (9DGW1B) at the end of Longwall 304

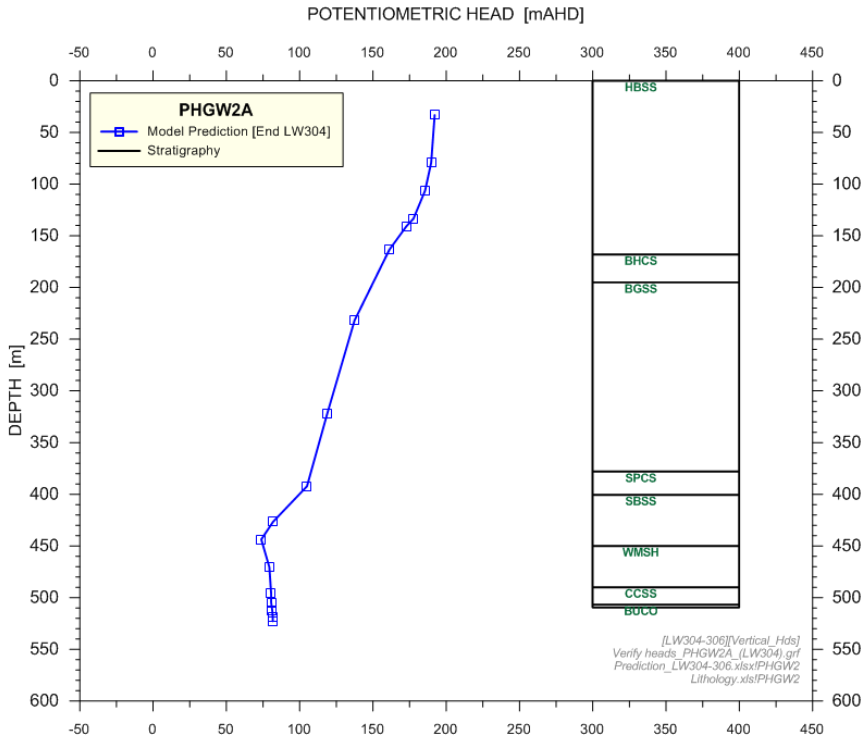


Chart 11 Predicted Vertical Head Profile at Bore PHGW2A at the end of Longwall 304

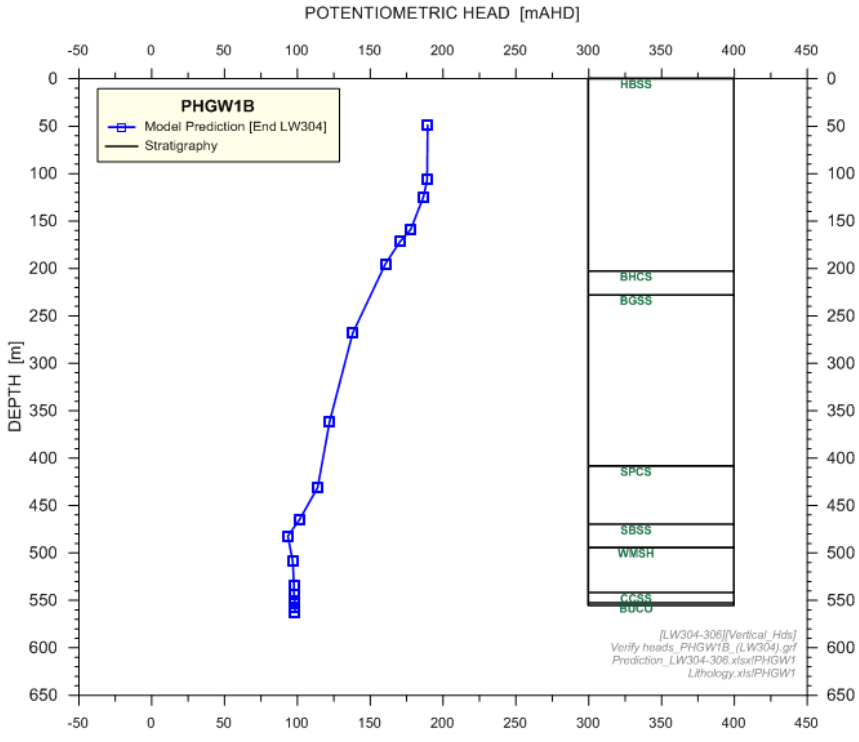


Chart 12 Predicted Vertical Head Profile at Bore PHGW1B at the end of Longwall 304

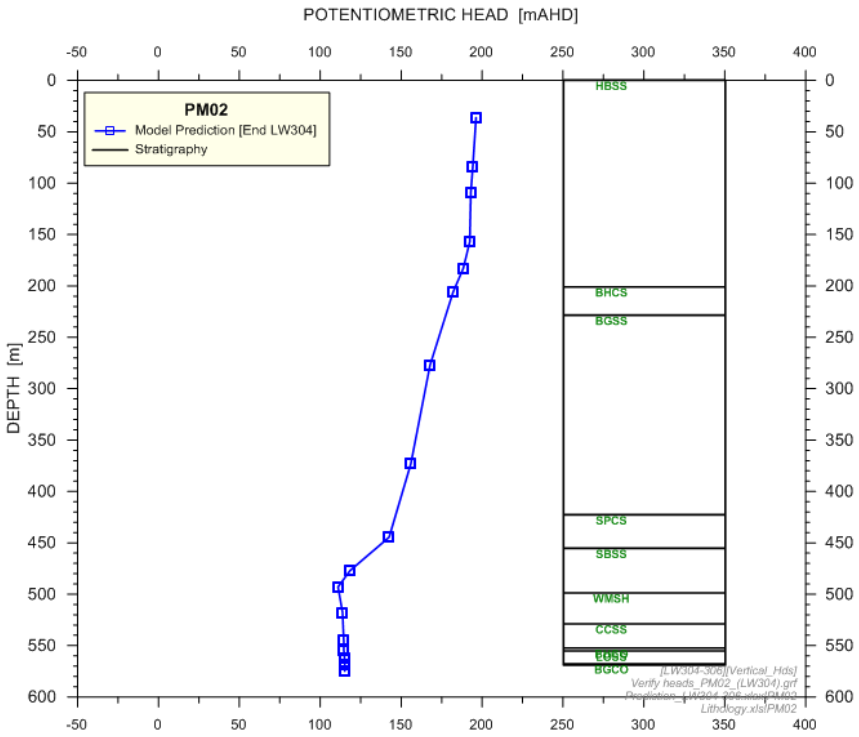


Chart 13 Predicted Vertical Head Profile at Bore PM02 at the end of Longwall 304

The performance measures, *No connective cracking between the surface and the mine* and *Negligible leakage from the Woronora Reservoir* are predicted to be not exceeded by the mining of Longwall 304.

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 8.

Table 8
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(s).*
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 9GGW2B does not occur.
	Significant departure from the predicted envelope of the vertical potentiometric head profile at Bore F6GW3A does not occur.
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 9GGW2B 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 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 T3 is reduced by no more than 10% from that measured on 30 June 2017.
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.*

Table 8 (Continued)
Summary of Water Resource and Watercourse Performance Indicators and Measures

Performance Measure	Performance Indicator(s)
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 P, Q, R, S, T, U, V and W.*
	Analysis of water level data for Pools P, T, U, V and W indicates the water level is at or above the pool's previous minimum.
	Analysis of water level data for Pools Q, R and S indicates the water levels are above that required to maintain water over the downstream rock bar.
	Visual inspection of the Waratah Rivulet from Pool P 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 P 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 (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. Section 8.10 provides the Longwall 304 Eastern Tributary TARP for subsidence movements.

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.

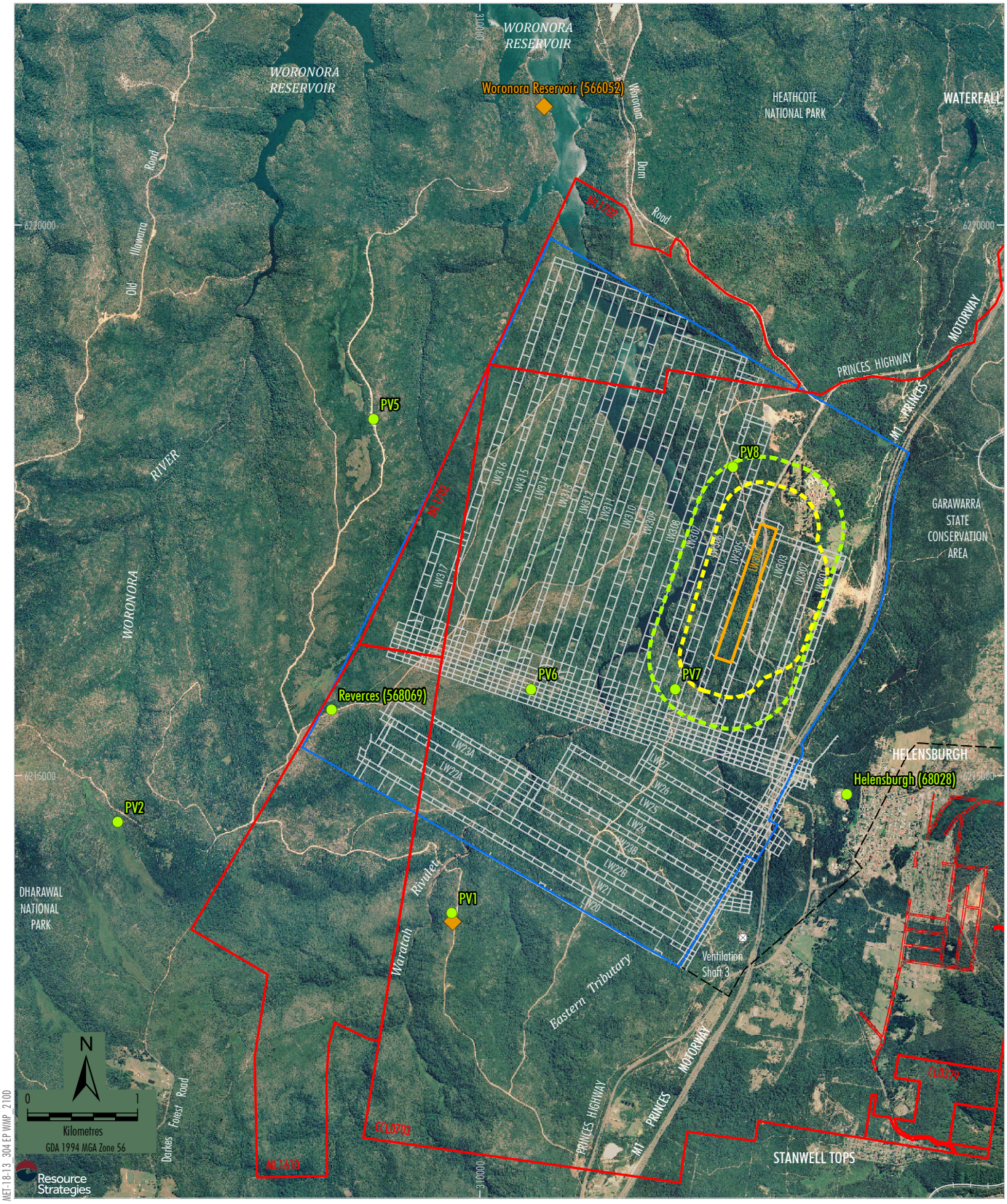
7.1 METEOROLOGY

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 9). 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 14).

Evaporation data is available from the WaterNSW station at the Woronora Dam (Table 9) and the Metropolitan Coal evaporimeter within the Waratah Rivulet catchment, at site PV1 (Table 9 and Figure 14).

Table 9
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



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwall 304 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwall 304
- 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); MSEC (2019)

Peabody

METROPOLITAN COAL

Meteorological Sites

Figure 14

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).

Gilbert & Associates (now Hydro Engineering & Consulting) conducted a visual inspection and photographic survey of streams in the vicinity of Longwalls 301-303 in July 2015 (Hydro Engineering & Consulting, 2016) (Appendix 5 of the Longwalls 301-303 Water Management Plan).

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, 2019). 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 10. 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 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.

Table 10
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.

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 DI – Water gaugings conducted over the period 1978 to 2003, as well as the known shape 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 and the Woronora River (Table 11).

The locations of the pools are shown on Figure 5. 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.

Table 11
Pool Water Level Sites (Manual and/or Continuous Water Level Data)

Site Number	Watercourse	Commencement Date
Pool A	Waratah Rivulet	29/9/2005
Pool B	Waratah Rivulet	29/9/2005
Pool C	Waratah Rivulet	29/9/2005
Pool E	Waratah Rivulet	29/9/2005
Pool F	Waratah Rivulet	29/9/2005
Pool G	Waratah Rivulet	29/9/2005
Pool G1	Waratah Rivulet	13/10/2005
Pool H	Waratah Rivulet	12/10/2005
Pool I	Waratah Rivulet	12/10/2005
Pool J	Waratah Rivulet	1/7/2010
Pool K	Waratah Rivulet	1/7/2010
Pool L	Waratah Rivulet	11/12/2008
Pool M	Waratah Rivulet	11/12/2008
Pool N	Waratah Rivulet	11/12/2008
Pool O	Waratah Rivulet	11/12/2008
Pool P	Waratah Rivulet	11/12/2008
Pool Q	Waratah Rivulet	20/1/2010
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 ETU	Eastern Tributary	18/05/2010
Pool ETW	Eastern Tributary	18/05/2010
Pool ETAF	Eastern Tributary	12/11/2010
Pool ETAG	Eastern Tributary	12/11/2010
Pool ETAH	Eastern Tributary	19/1/2011
Pool ETAI[1]	Eastern Tributary	19/1/2011
Pool ETAL	Eastern Tributary	3/10/2018

Table 11 (Continued)
Pool Water Level Sites (Manual and/or Continuous Water Level Data)

Site Number	Watercourse	Commencement Date
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[2]	Eastern Tributary	24/5/2018
Pool ETAU	Eastern Tributary	18/5/2010
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 WRP1[3]	Woronora River (Control Site)	11/12/2008
Pool WRP2[3]	Woronora River (Control Site)	1/7/2010
Pool WRP3[3]	Woronora River (Control Site)	1/7/2010
Pool WRP4[3]	Woronora River (Control Site)	1/7/2010

[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 situated in Pool ETAI is therefore considered to be representative of the water level in Pools ETAJ and ETAK.

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

[3] 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 12 and shown on Figure 7.

Table 12
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

Table 12 (Continued)
Stream Water Quality Sites

Site Number	Watercourse	Commencement Date
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
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

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.

Additional water quality data has also been collected at site ETAU[20] 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, 0 m (site ETFSL 0), 20 m (site ETFSL 20), 40 m (site ETFSL 40), 60 m (site ETFSL 60), 80 m (site ETFSL 80), 100 m (site ETFSL 100), 200 m (site ETFSL 200), 300 m (site ETFSL 300), 400 m (site ETFSL 400) and 500 m (site 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 downstream of ETFSL 0 (Figure 7). The additional sampling was conducted from August 2017 to 15 November 2018[21].

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).

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 13. The piezometer locations are shown on Figure 9.

As described in the Longwalls 301-303 WMP, the NSW Government's *Draft Policy Framework for Biodiversity Offsets for Upland Swamps and Associated Threatened Species* (May 2015) (Draft Upland Swamp Offsets Policy) and 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) were reviewed and considered in detail for swamps within 600 m of Longwalls 301-303 for the Longwalls 301-303 Biodiversity Management Plan. This review covered all swamps located within the Longwall 304 35° angle of draw and/or predicted 20 mm subsidence contour.

[20] 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.

[21] Sampling was suspended in November 2018, with the exception of sites ETAU (sampling recommenced on 12 December 2018; data available from site ETWQ AU in November), ETFSL 200 and ETFSL 500 in response to the reservoir water level.

Table 13
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		
S50	S50	312510	6217013	266.8	0.4	Hawkesbury Sandstone	27 June 2016
		312509	6217012	266.9	9.9		

Table 13 (Continued)
Swamp Substrate and Shallow Groundwater Level Sites

Site Number	Swamp	Easting (m)	Northing (m)	RL (m AHD)	Depth (m)	Lithology	Commencement Date
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		
S71a	S71a	312519	6217774	276.6	0.3	Hawkesbury Sandstone	27 June 2016
		312519	6217772	276.6	9.9		

[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.

Metropolitan Coal completed Surface Works Assessment Forms for the proposed installation of upland swamp piezometers in Swamps 38, 40, 41, 46, 47, 48, 49, 50, 51, 52, 53, 58, 69, 70 and 71a (Figure 9), which were submitted to WaterNSW and the DP&E. WaterNSW subsequently raised concerns regarding the amount of disturbance associated with the installation of the upland swamp piezometers. Following further consultation with WaterNSW and the DP&E, paired piezometers were proposed and approved to be installed in Swamps 40, 41, 46, 50, 51, 52, 53 and 71a (Figure 9). Piezometer sites 50, 51, 52 and 53 provide an extended transect which allows for monitoring of the Swamp 50 to 53 complex along the topographic gradient and over consecutive longwalls. The locations of the swamp groundwater piezometers are shown on Figure 9.

7.3.2 Shallow Groundwater Levels Near Streams

Shallow groundwater level data is available for a number of sites near streams, as summarised in Table 14. The piezometer locations are shown on Figure 10.

Table 14
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	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[1]	Waratah Rivulet	310685	6215353	184.3	~20	Hawkesbury Sandstone	September 2010
RTGW1A[2]	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

[1] 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.

[2] 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.

7.3.3 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 15 and Figure 10).

Table 15
Groundwater Transect

Site Number	Easting (m)	Northing (m)	Top of Collar (m AHD)	Depth (m)	Lithology	Commencement Date
T1	312048	6217168	174.106	21	Hawkesbury Sandstone	7 September 2016
T2	312092	6217209	195.118	35	Hawkesbury Sandstone	7 September 2016
T3	312201	6217246	225.450	61	Hawkesbury Sandstone	7 September 2016
T4[1]	312280	6217296	236.306	67	Hawkesbury Sandstone	7 September 2016
T5	312423	6217379	258.041	89	Hawkesbury Sandstone	7 September 2016
T6	311447	6217375	255.87	130	Hawkesbury Sandstone	18 December 2017

[1] 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 (HydroSimulations, 2018b).

Metropolitan Coal groundwater level and/or pressure data is also available from the multi-level piezometers and single-level piezometers listed in Table 16 and shown on Figure 10. Groundwater level/pressure data is also available at site S1997, courtesy of BHP Billiton Illawarra Coal (Table 16 and Figure 10).

Table 16
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 Goaf Hole on Fire Trail 9H	309762	6213480	274.5	35.0	239.5	Hawkesbury Sandstone	12-Apr-07
					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-Nov-08
					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	

Table 16 (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
9GGW1B[1]	Fire Trail 9G	310974	6214317	287.9	45.0	242.9	Hawkesbury Sandstone	14-Mar-09
					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	
9GGW1-80[1]	Fire Trail 9G	310974	6214317	287.0	~80.0	206.9	Hawkesbury Sandstone	21-Nov-13
9GGW2B	Fire Trail 9G at western end of Longwall 27	311734	6215359	240.8	55.0	185.8	Hawkesbury Sandstone	20-Apr-10
					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	

Table 16 (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
9FGW1A	Fire Trail 9F west of Longwall 22A	308556	6215537	310.2	55.0	255.2	Hawkesbury Sandstone	19-Feb-10
					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	
9EGW1B	Fire Trail 9E	309483	6216091	309.0	52.0	257.0	Hawkesbury Sandstone	1-Nov-09
					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	

Table 16 (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
9EGW2A	Fire Trail 9E	311331	6217099	276.9	60.0	216.9	Hawkesbury Sandstone	28-May-11
					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-Dec-17
					454.0	-178	Scarborough Sandstone	
					484.0	-208	Scarborough Sandstone	
					517.0	-241	Wombarra Shale	
					557.0	-281	Bulli Coal Seam	
F6GW3A	Old Princes Hwy east of LW 301	312855	6215539	242.6	50.0	192.6	Hawkesbury Sandstone	17-Jun-13
					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	

Table 16 (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
F6GW4A	Old Princes Hwy between LW303 and LW304	312531	6216694	265.0	50.0	215.0	Hawkesbury Sandstone	17-Jun-13
					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-Mar-11
					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 16 (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-Jun-10
					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-Feb-10
					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	

Table 16 (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
PM02	Fire Trail 9D	310650	6218509	267.4	35.0	232.4	Hawkesbury Sandstone	23-Dec-07
					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	
PM03	Woronora Dam Road	311664	6219773	265.0	64.0	201.0	Hawkesbury Sandstone	14-Feb-11
					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	

Table 16 (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
S1997*	North Cliff	306997	6212765	370.2	24.0	346.2	Hawkesbury Sandstone	10-Jun-09
					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	
302GW01[3]	Overlying Longwall 302	312952	6216553	305.1	80.0	225.1	Hawkesbury Sandstone	Commenced 23-Nov-17 End Date 25-May-18
					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-Oct-17 End Date 12 Jan-18
TBS02-90 (post-mining standpipe)	Overlying Longwall 302	312843	6216580	306.5	90.0	216.5	Hawkesbury Sandstone	13 Feb 19
TBS02-190 (post-mining standpipe)	Overlying Longwall 302	312837	6216583	305.7	190.0	115.7	Hawkesbury Sandstone	8 Feb 19

Table 16 (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
TBS02-250[5] (pre-mining hole)	Overlying Longwall 302	312852	6216598	306.1	192.0	114.1	Newport Formation	27-Oct-17 End Date 22 Oct 18
					243.0	63.1	Shale/ Sandstone	27-Oct-17 End Date 22 Oct 18
TBS02-250R (post-mining hole)	Overlying Longwall 302	312865	6216583	307.4	90.0	217.4	Hawkesbury Sandstone	24 Jan 19
					150.0	157.4	Hawkesbury Sandstone	VWP 245 failed during grouting
					180.0	127.4	Hawkesbury Sandstone	
					245.0	62.4	Upper Bulgo/ Sandstone	
TBS02A-15	Overlying Longwall 302	312837	6216577	304.2	15.5	288.7	Hawkesbury Sandstone	31-Oct-17
TBS03-230[6] Pre-Mining	Overlying Longwall 303	312652	6216685	281.9	162.0	119.9	Newport Formation	22-Feb-18 End Date 13 Dec 18
					213.0	68.9	Shale/ Sandstone	
TBS03-15	Overlying Longwall 303	312647	6216684	281.9	15.5	266.4	Hawkesbury Sandstone	23-Feb-18

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 80 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 to be reinstated 2019.

* Data courtesy of BHP Billiton Illawarra 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 9GGW2B, F6GW3A, F6GW4A, 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 22 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).

Bore 9GGW2B

Bore 9GGW2B is located at the western end of Longwall 27, approximately 1.5 km on the northern side of previously extracted Longwalls 6 and 7 which were mined in 2000-2001, and about 650 m south-west of Longwall 304 over the 300-series mains. Significant depressurisation appears to have occurred in 2000-2001 or earlier from the old Helensburgh workings to the east (Chart 14).

During the passage of Longwall 24 (>600 m away), minor drawdowns were observed in the Bulli Coal Seam and the Scarborough Sandstone, but other sensors exhibited no effect or a rise in head. The passage of Longwall 25 (>400 m away) caused distinct drawdowns in the Scarborough Sandstone, Wombarra Claystone, Stanwell Park Claystone and upper Bulgo Sandstone. The lower Bulgo Sandstone exhibited a rising head for Longwall 26 and Longwall 27 crossings, due to compression at that level. Sympathetic drawdowns were also exhibited in the three Hawkesbury Sandstone piezometers at the time of the Longwall 26 and Longwall 27 crossings.

As Longwall 302 mining progressed, the head profile at 30 June 2018 exhibited drawdowns at the lower two Hawkesbury Sandstone piezometers (P80 and P105, about 2 m and 5 m) compared with the 31 May 2017 head profile. On the contrary, the upper Hawkesbury Sandstone piezometer (P55) had a water level rise about 1 m. Similarly, water level rose about 16 m in the Wombarra Claystone Piezometer (P437) and it maintained a pressure head of about 230 m.

Deep vibrating wire piezometers P138, P162, P304, P393 and P474 have ceased to operate.

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 170 m AHD and the head in the Lower Bulgo Sandstone is about 100 m AHD. The recent two head profiles in Chart 14 show that the heads are varying with time as mining proceeds.

Bore F6GW3A

Bore F6GW3A is located adjacent to Longwall 301 about 150 m beyond its southern end, about 800 m from Longwall 27 and about 700 m from Longwall 304. Significant depressurisation has occurred from historical workings to the east about 500 m distant. The 450 m deep piezometer at the base of the Coal Cliff Sandstone displays significant depressurisation continuing from the mining of the first heading in the 300 mains in November 2013 (Chart 15).

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 182 m AHD and the head in the Lower Bulgo Sandstone is about 63 m AHD. The profiles at various times in Chart 15 show that the heads are not varying significantly with time as mining proceeds.

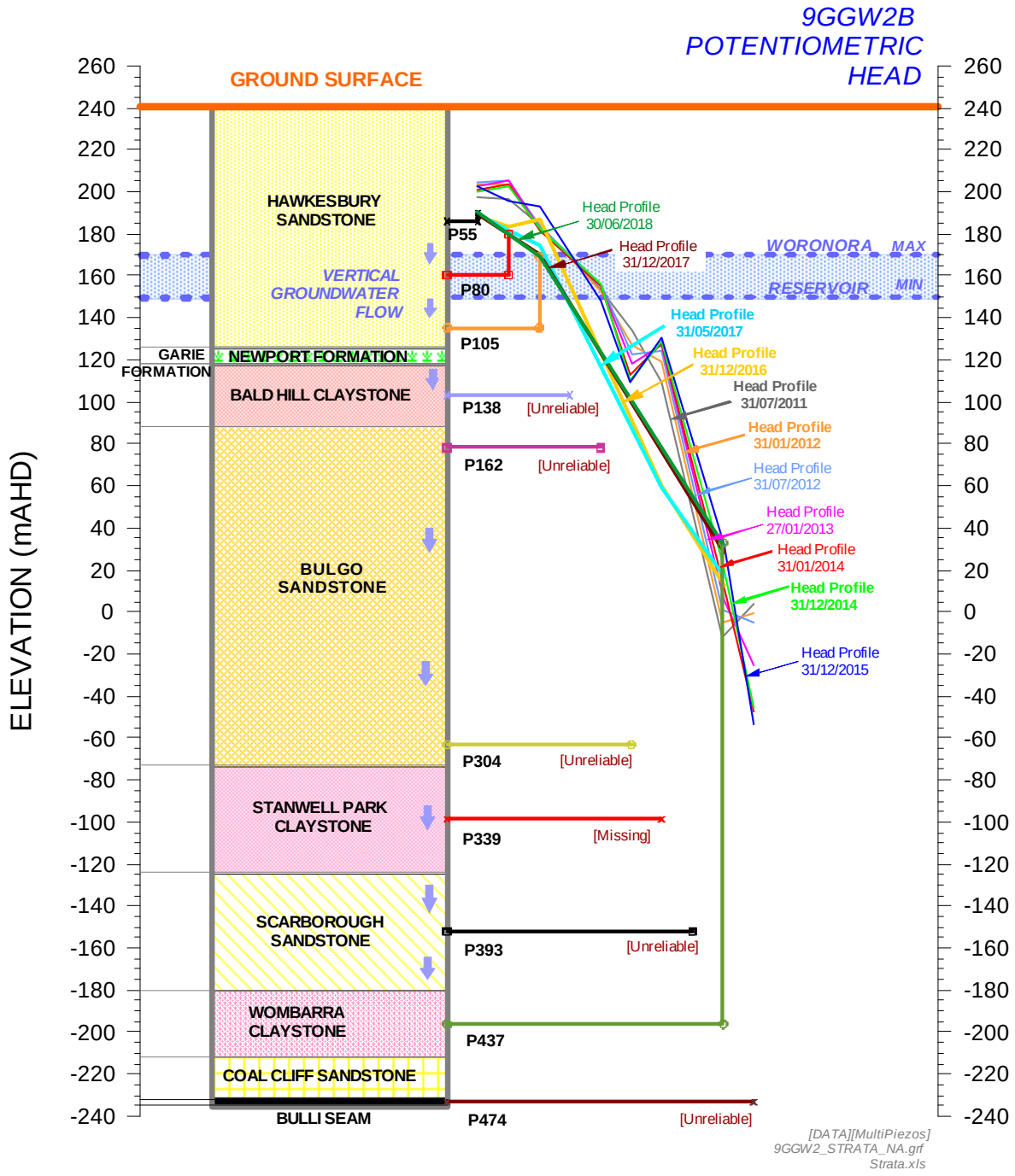


Chart 14 **Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore 9GGW2B**

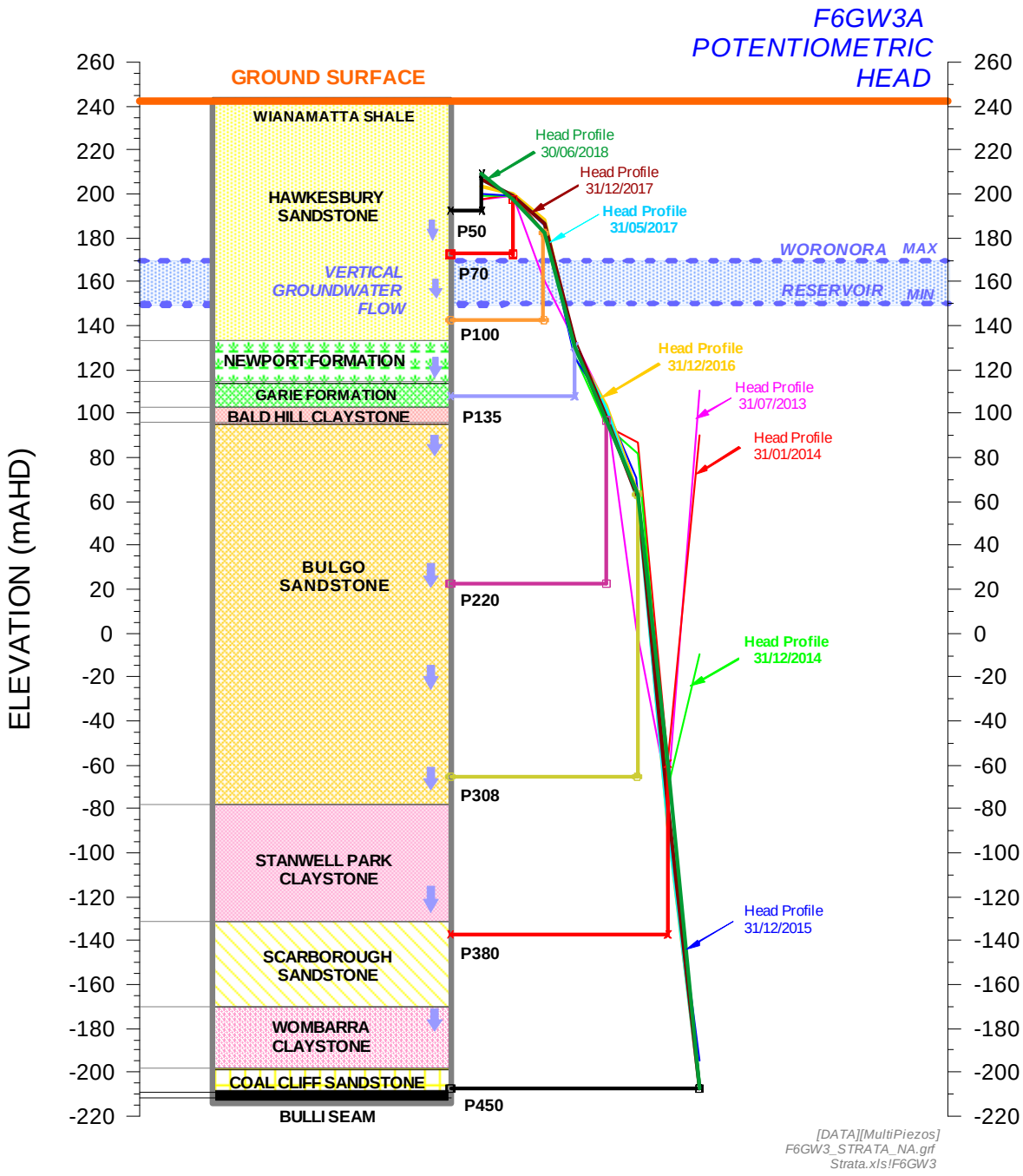


Chart 15 **Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore F6GW3A**

Bore F6GW4A

Bore F6GW4A lies above the coal pillar between Longwall 303 and Longwall 304. A significant amount of recent depressurisation is noted at the Lower Bulgo Sandstone (P362), Scarborough Sandstone (P440) and Bulli Seam (P512) (Chart 16). The pressure heads are about 170 m, 230 m and 50 m at these piezometers, respectively.

This bore is two panel widths from Longwall 301 and one panel width from Longwall 302. The respective mining faces came closest to the bore in late-September 2017 and late-May 2018, at which times distinct features are evident on all hydrographs. The passage of Longwall 301 caused mild responses, generally short-term increases in head, while the passage of Longwall 302 caused sharp cusp-like features on the Hawkesbury Sandstone hydrographs, sustained rises in the upper and mid Bulgo Sandstone, and strong declines in the three deepest piezometers. The rises in head are attributable to lateral and vertical compression.

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 75 m AHD. The recent two head profiles in Chart 16 show that the heads are varying significantly with time as mining proceeds.

Bore PHGW2A

As bore PHGW2A is located approximately 2.5 km north of Longwall 27 and the same distance from the historical workings to the east, no recent mining effect is evident (Chart 17). There is a mild downwards hydraulic gradient. This bore is about 500 m north-west of Longwall 304.

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 180 m AHD and the head in the Lower Bulgo Sandstone is about 125 m AHD. The profiles at various times in Chart 17 show that the heads are not varying with time as mining proceeds.

Bore PHGW1B

Bore PHGW1B is about 500 m due north of PHGW2A and about 1 km north-west of Longwall 304. It would be expected to have a similar vertical hydraulic profile to PHGW2A, but in fact it has a stronger gradient (Chart 18). 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 190 m AHD and the head in the Lower Bulgo Sandstone is about 110 m AHD. The profiles at various times in Chart 18 show that the heads are not varying with time as mining proceeds. The observed variations are stabilisation effects.

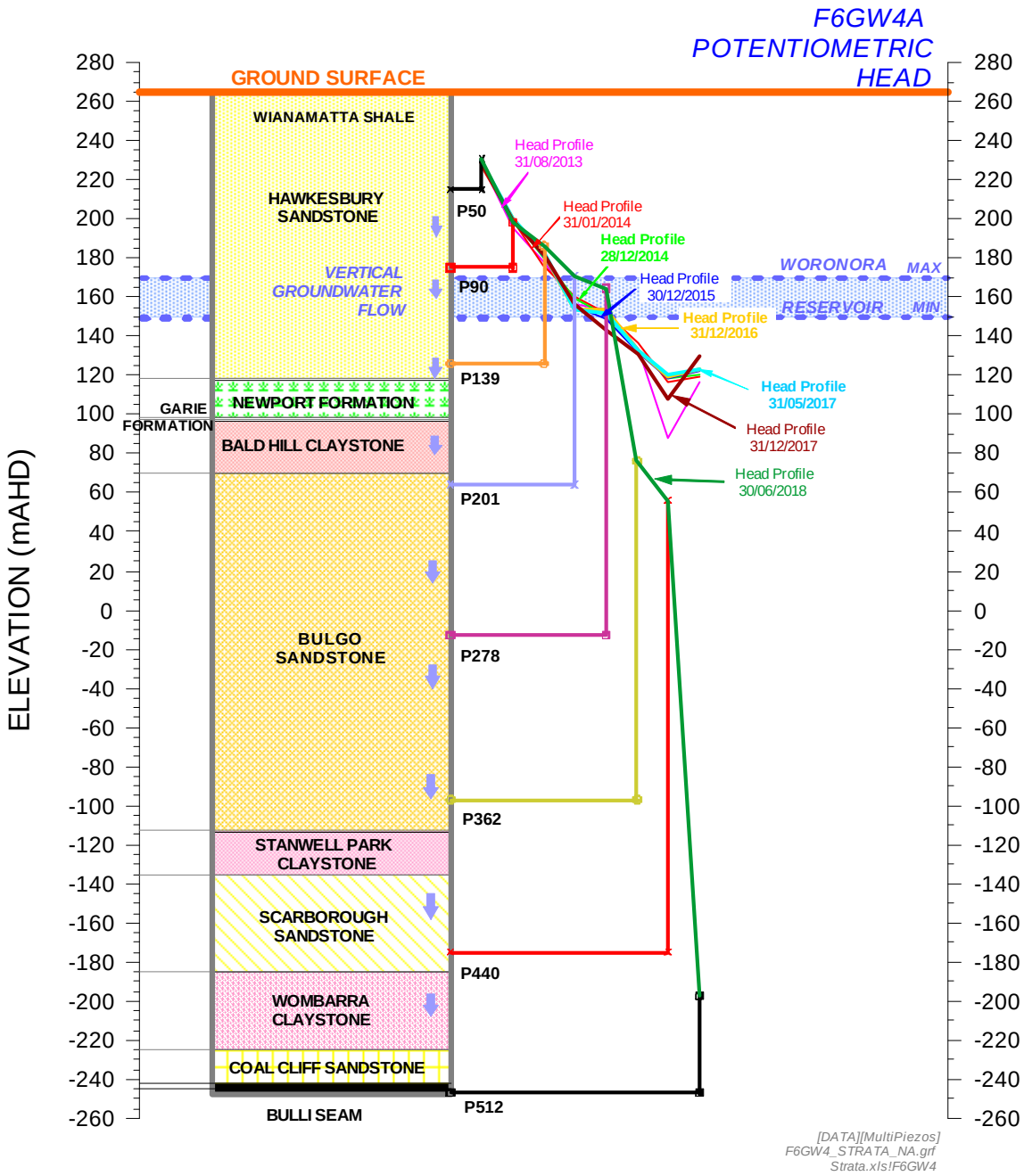


Chart 16 **Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore F6GW4A**

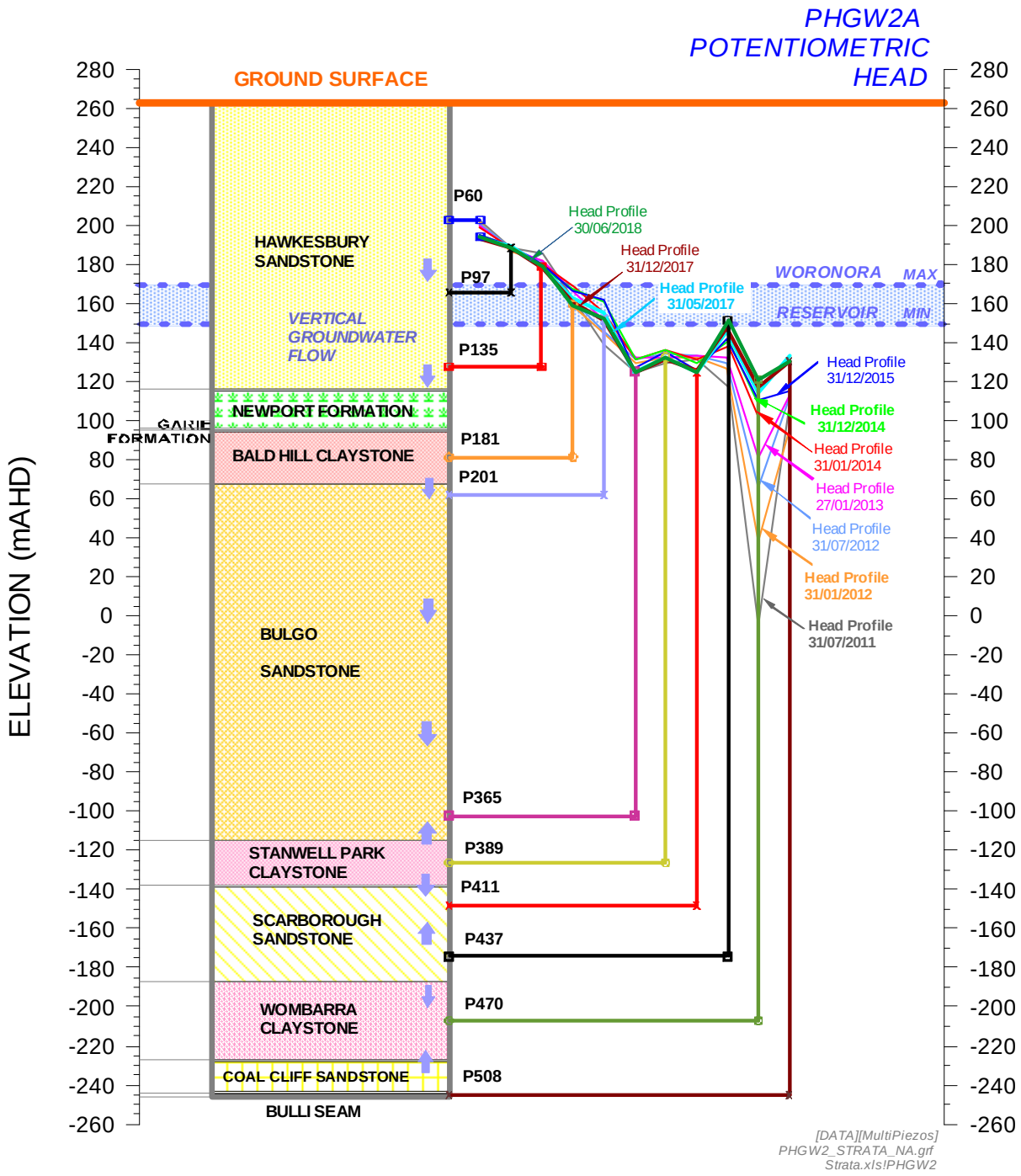


Chart 17 **Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore PHGW2A**

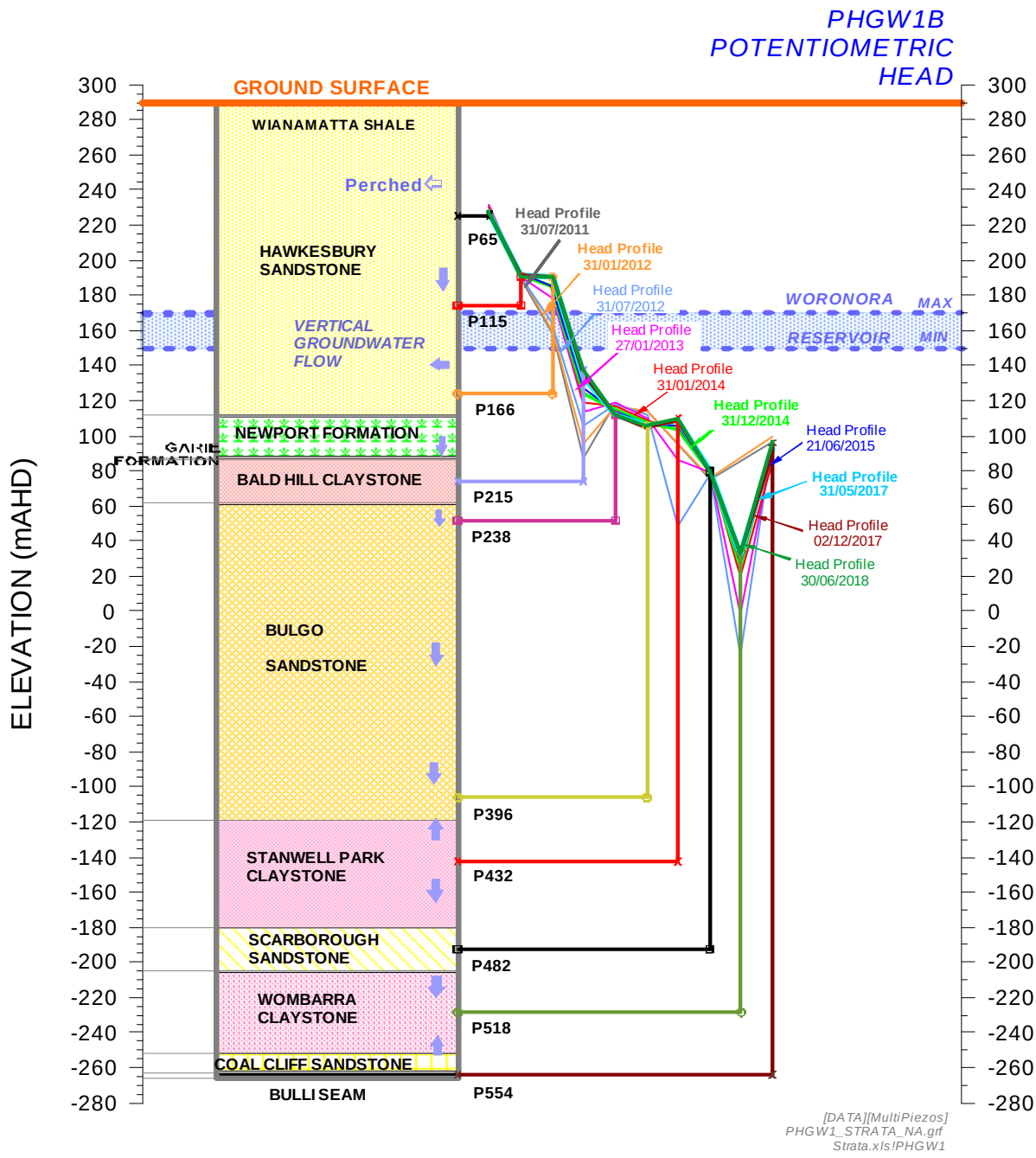


Chart 18 **Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore PHGW1B**

Bore 9EGW1B

Bore 9EGW1B is located approximately 500 m north of the western end of Longwall 23A and 2.6 km west of Longwall 304. Some depressurisation appears to have occurred in the Lower Bulgo Sandstone and lower formations due to mining to the south (Chart 19).

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 175 m AHD. The profiles at various times in Chart 19 show that the heads are not varying significantly with time as mining proceeds, but several piezometers have taken time to stabilise.

Bore 9EGW2A and 9EGW2-4

Bore 9EGW2A is located approximately 1.1 km due west of Longwall 304. The vibrating wire piezometers indicate substantial depressurisation at depth, but the records are erratic and not internally consistent (Chart 20). The vibrating wire piezometers at the lower Bulgo Sandstone and from the Scarborough Sandstone downwards had unreliable data from 14 October 2014.

An additional hole (9EGW2-4) with five piezometers (P407, P454, P484, P517 and P557) was installed proximal to 9EGW2A on 18 December 2017 at Lower Bulgo Sandstone and from the Scarborough Sandstone downwards.

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 170 m AHD and the head in the Lower Bulgo Sandstone is about 160 m AHD. The profiles at various times in Chart 20 show that there is no definitive reduction in heads with time as mining proceeds, but several piezometers have taken time to stabilise.

Bore PM01 (9DGW1B)

Bore PM01 (9DGW1B) is located approximately 2.4 km west of Longwall 304. This site has a similar vertical head gradient to that observed at PHGW1B, apparently due to the naturally higher lateral hydraulic gradient towards the north-east in deeper strata, but also due to mining effects from the south.

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 143 m AHD. The profiles at various times in Chart 21 show that the heads are not varying significantly with time as mining proceeds, but the Scarborough Sandstone piezometer (P482) has been unstable.

Bore PM02

Bore PM02 is located approximately 2.2 km north-west of Longwall 304. Being far from historical and recent mining, it would not be expected to show any dramatic response to mining but could show a slight slow decline in heads as the groundwater “cone of depression” extends radially away from the area of mining. Chart 22 indicates that all potentiometric heads are high and within 40 m of the maximum level of the Woronora Reservoir. As there is no 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 22 show that the heads are not varying significantly with time as mining proceeds.

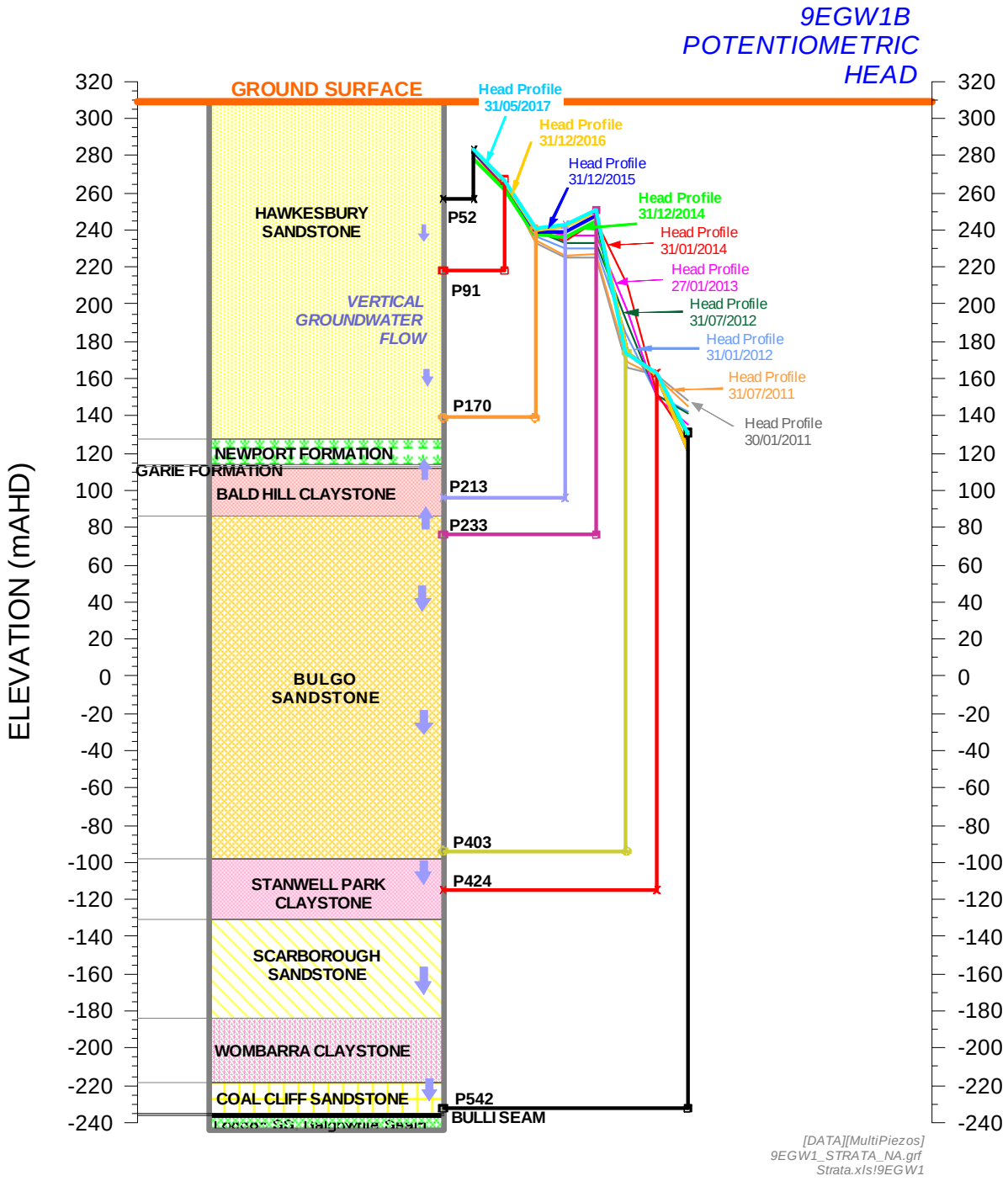


Chart 19 **Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore 9EGW1B**

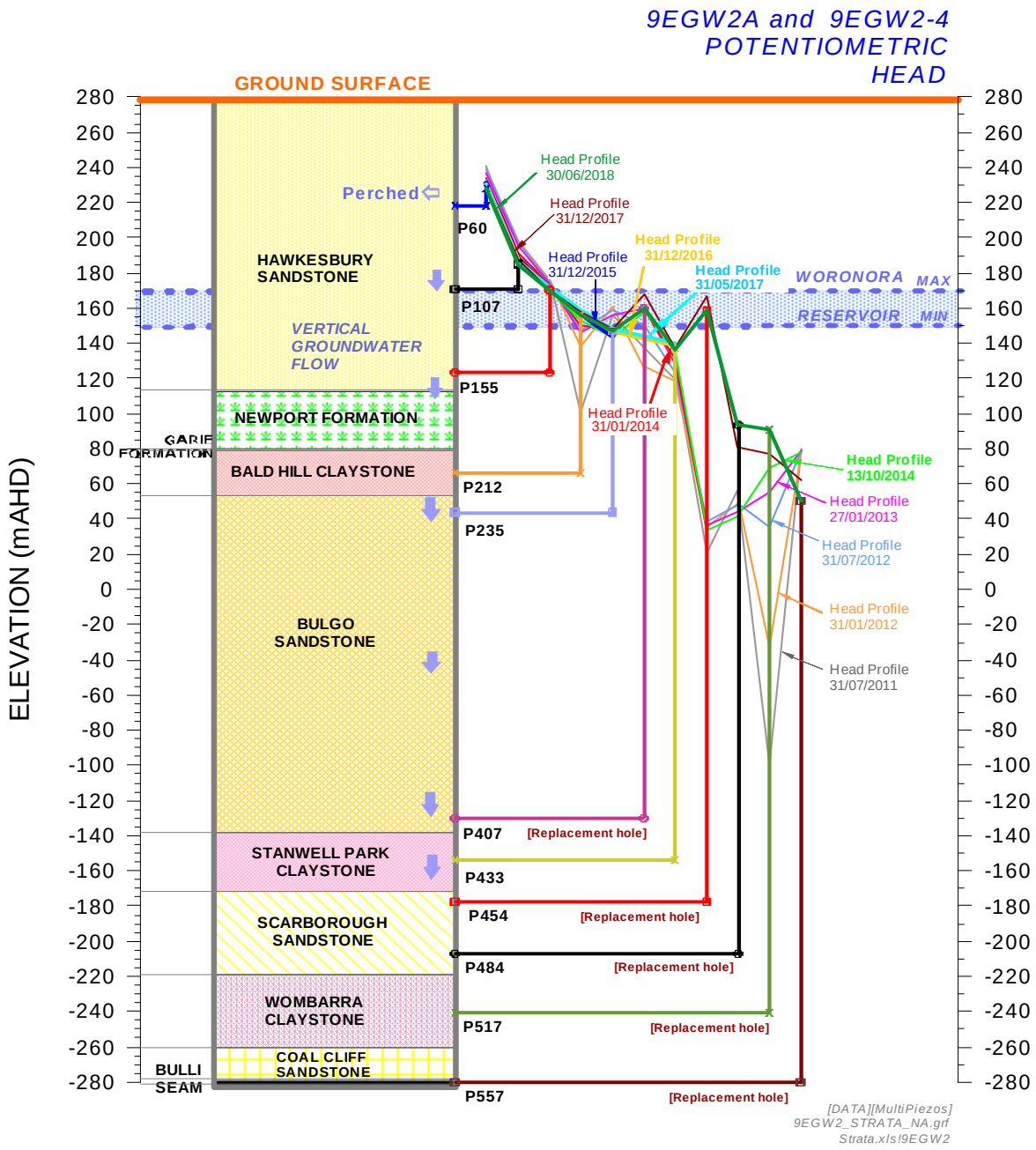


Chart 20 **Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bores 9EGW2A and 9EGW2-4**

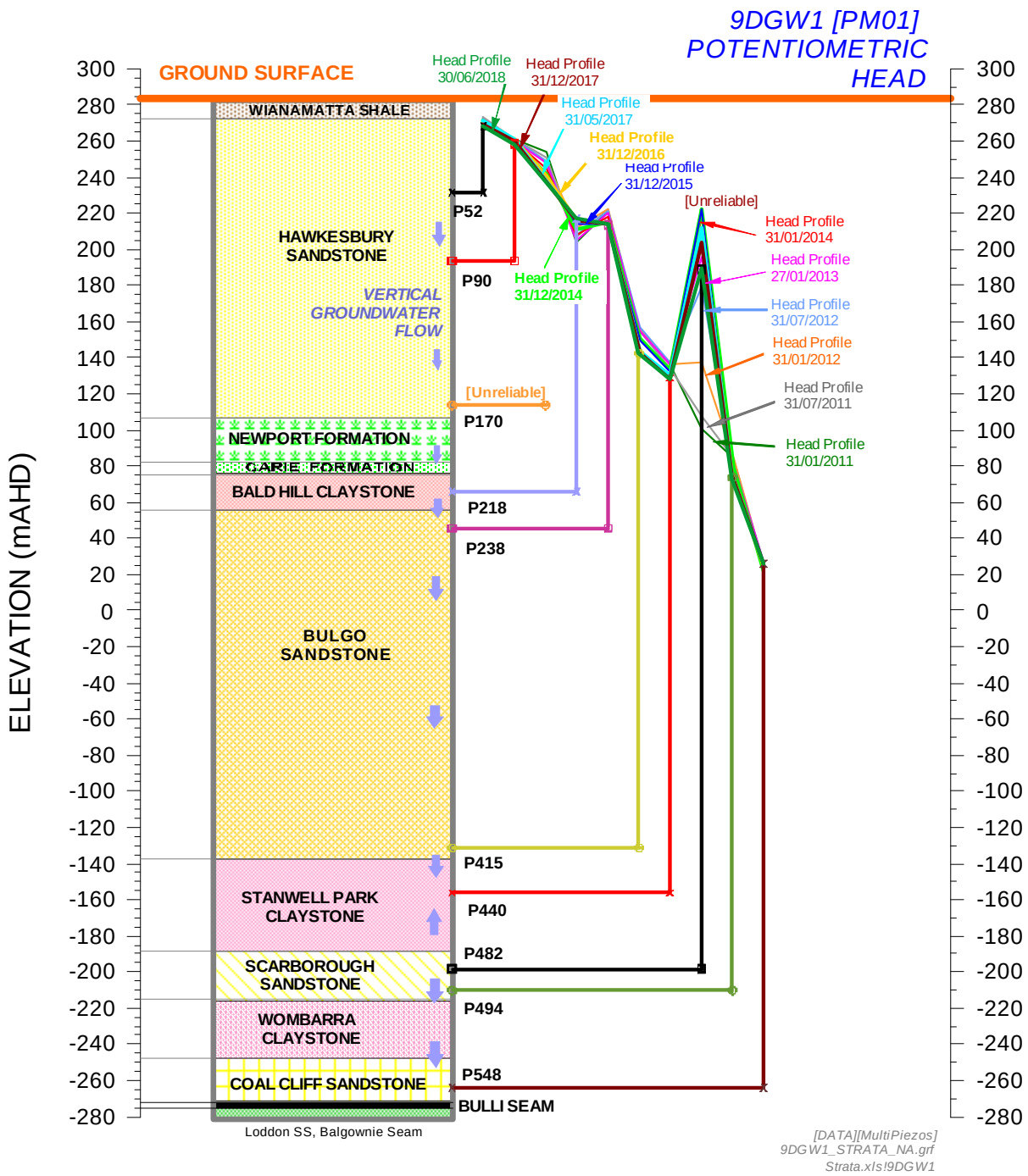


Chart 21 **Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore PM01 (9DGW1B)**

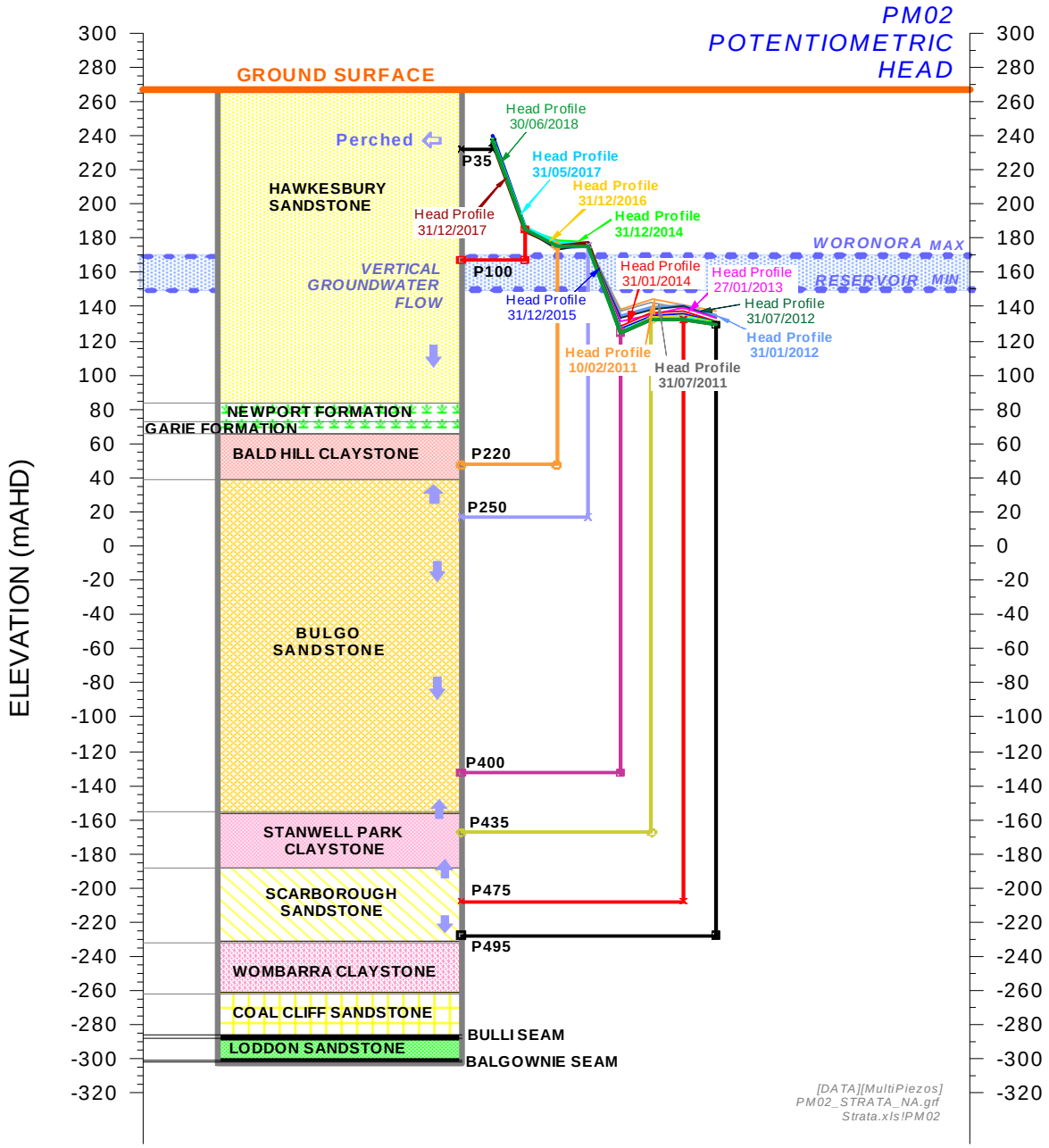


Chart 22 **Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore PM02**

7.3.4 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 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 shows the mine water make results to January 2019. The 20-day average daily mine water make has consistently been less than 0.5 ML/day (Chart 3a). Since 2009, the mine water make has averaged 0.09 ML/day, which is less than that predicted by groundwater modelling for the Project. The monitoring results are consistent with the predictions for mine water make.

7.3.5 Groundwater Quality

Groundwater quality data is available from a number of sites with installed piezometers, as summarised in Table 17. The locations of the groundwater quality sites are shown on Figure 11.

Table 17
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.

Groundwater quality is also sampled by Metropolitan Coal to meet its Dams Safety Committee Approval requirements. The groundwater quality sampling sites are detailed in Table 18 and shown on Figure 11.

Table 18
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
9F2-50C	9FGW2	308717.4	6217210.3	289.8	50	239.8	Upper Hawkesbury Sandstone	Chemical and Static Water Level	Operational
9F2-150C		308740.7	6217240.7	289.8	150	139.8	Lower Hawkesbury Sandstone	Chemical and Static Water Level	Operational (grout impacted)
9F2-250D		308720.5	6217223.8	289.8	250	39.8	Bulgo Sandstone	Chemical and Static Water Level	Operational (grout impacted)
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 (potentially grout impacted)
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 (potentially grout impacted)

Table 18 (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
9E1-80E					80	229.2	Upper Hawkesbury Sandstone	Chemical	Operational
9E1-108C					108	201.2	Lower Hawkesbury Sandstone	Chemical	Operational
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
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
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 18 (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 (grout impacted but clearing)
9G3-117C		311588.0	6215040.3	260.0	117	143.0	Lower Hawkesbury Sandstone	Chemical and Static Water Level	Operational (grout impacted but clearing)
9G3-216D		311609.7	6215024.9	260.0	216	44.0	Bulgo Sandstone	Chemical and Static Water Level	Operational (grout impacted)
F6GW3-85C	F6GW3	312849.0	6215533.9	243.5	85	158.5	Lower Hawkesbury Sandstone	Chemical and Static Water Level	Operational (grout impacted)
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.*

8 MONITORING PROGRAM

Subsidence parameters will be measured in accordance with the Metropolitan Coal Longwall 304 Subsidence Monitoring Program (Figure 3). In summary, surveys will be conducted to measure subsidence movements in three dimensions using a total station survey instrument. 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 Longwall 304. 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. Section 8.10 provides a detailed TARP to assess subsidence effects on the Eastern Tributary during the mining of Longwall 304.

8.1 METEOROLOGY

Rainfall data will be monitored using pluviometers at the following locations (Figure 14):

- 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 14) 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

As described in Section 5.4, the Waratah Rivulet is located over 1.1 km south-west of Longwall 304, at its closest point to Longwall 304 secondary extraction (Figures 1 and 4). At this distance, the Waratah Rivulet is not predicted to experience any measurable subsidence or valley related movements resulting from the extraction of Longwall 304 (MSEC, 2019). Notwithstanding, visual inspections and photographic surveys will be conducted along the Waratah Rivulet from Pool P to the full supply level of the Woronora Reservoir within three months of the completion of Longwall 304.

Visual and photographic surveys of the Eastern Tributary from the full supply level of the Woronora Reservoir to the maingate of Longwall 26 will be conducted monthly when mining is within 450 m of the stream and within three months of the completion of Longwall 304.

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 monthly visual inspections on the 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 Longwall 304 (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 DI – Water 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 (Sub-catchment I [GS 300092]); and
- the Metropolitan Coal owned gauging station on a tributary of the Woronora Reservoir (Sub-catchment K [GS 300093]).

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.

As reported in the *Woronora Reservoir Strategy Report - Stage 1* report, due to the sequence of development of the Longwall 300 series, the sub-catchments that drain westerly from the area above Longwalls 301-303 will be the only opportunity (except for sub-catchment C)[22] to monitor the effects of future longwall mining on the tributary flows entering the Reservoir. Tributaries entering the Woronora Reservoir from the western side would subside before there is any opportunity to monitor effects higher in the catchments. Streamflow monitoring stations were installed on sub-catchments I and K for this purpose.

It was noted that sub-catchment I (Figure 6) would potentially be affected by Longwalls 302 and 303, which would mean there would be little un-impacted streamflow data available for model calibration. Therefore, sub-catchment K was proposed to be monitored as a control catchment, allowing any progressive changes in sub-catchment I to be assessed. The results of monitoring to date are summarised in Section 4.3. It was recognised that sub-catchment K would also become progressively influenced as the 300 series longwalls advance. Notwithstanding, Metropolitan Coal will continue to monitor the sub-catchment I and K streamflow monitoring stations until such time that they are impacted by mine subsidence.

8.3.2 Eastern Tributary Gauging Station

Metropolitan Coal will monitor subsidence movements at the Eastern Tributary gauging station (in a similar manner to the monitoring undertaken for the Waratah Rivulet gauging station during the mining of Longwalls 25 and 26 and for the Eastern Tributary during the mining of Longwall 303) to assess the functionality of the gauging station.

Metropolitan Coal will monitor and assess subsidence in the vicinity of the Eastern Tributary gauging station in accordance with the Metropolitan Coal Longwall 304 Subsidence Monitoring Program. In the event differential survey data indicates vertical and horizontal movements have occurred at the Eastern Tributary gauging station, Metropolitan Coal will assess whether the movement has altered the stream flow rating curve.

In the event subsidence movements that alter the stream flow rating curve occur, Metropolitan Coal will update the stream flow rating curve to reflect the changes in surface levels resulting from subsidence. Metropolitan Coal will validate the updated stream flow rating curve and continue to monitor subsidence movements.

[22] Sub-catchment C is a small catchment draining to Eastern Tributary upstream of GS300078.

8.3.3 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 (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[23], ETAL, ETAM, ETAN, ETAO, ETAP, ETAQ, ETAR, ETAS/ETAT[24] and ETAU on the Eastern Tributary; and
- control Pools WRP1, WRP2, WRP3 and WRP4 on the Woronora River.

Data from these water level meters will be downloaded monthly. Data from Pools ETAS/ETAT and ETAU on the Eastern Tributary will be downloaded weekly when Longwall 304 extraction is within 450 m of the Eastern Tributary.

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) 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 weekly when mining of Longwall 304 is within 450 m of the Eastern Tributary. 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.

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.

[23] 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.

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

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;
- site UTWQ 1 on Tributary D;
- 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; 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:

- 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; and
- control site WOWQ 2 on the Woronora River.

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 20 (Section 8.9).

As described in Section 7.2.4, Metropolitan Coal increased the frequency of water quality sampling at sites ETWQ F, ETWQ N, ETWQ AF, ETWQ AG, ETWQ AH, ETWQ AI, ETWQ AK, ETWQ AQ and ETWQ AU on the Eastern Tributary and at site WOWQ2 on the Woronora Reservoir from monthly to weekly in response to the Eastern Tributary Incident in October 2016. At the commencement of Longwall 304, weekly monitoring at these sites will be discontinued and fortnightly monitoring will be conducted at sites ETWQ AQ, ETWQ AU and WOWQ2.

Metropolitan Coal will continue to monitor site ETAU and a minimum of three downstream sites (site ETFSL 0, site ETFSL 20, site ETFSL 40, site ETFSL 60, site ETFSL 80, 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 (Table 20, Section 8.9) for four consecutive assessment periods. The downstream sites will be selected in consideration of the Woronora Reservoir water level. Sampling of site ETAU and three downstream sites will continue fortnightly 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 will monitor WARARM5 at the same frequency described above when the sites downstream of site CONFLU can be accessed for sampling (i.e. when the Woronora Reservoir water levels are suitably low).

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 22 (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 Longwall 304 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 Swamps 20 and 25 for Longwalls 20-22, Swamps 28, 30, 33 and 35 for Longwalls 23-27, Swamps 40, 41, 46, 51, 52 and 53 for Longwalls 301-303 and in control Swamps 101, 137a, 137b, Bee Creek Swamp and Woronora River 1 (WRSWAMP 1) (Figure 9). Swamps 40, 41, 46, 51, 52 and 53 are located within the 35° angle of draw and/or predicted 20 mm subsidence contour for Longwall 304 (Figure 9).

Swamp 50 overlying Longwall 304 will be monitored for Longwall 304. Piezometers were not installed in Swamps 47, 48, 49 or 58 on the basis of consultation with WaterNSW and the DP&E in relation to baseline data collection for the Longwalls 301-303 Extraction Plan. It is noted that Swamp 48 is very small, approximately 0.1 hectares in area.

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 and WRGW7 along Waratah Rivulet; and
- site ETGW1 and site ETGW2 along the Eastern Tributary.

These shallow (20 m) boreholes contain a piezometer at the base of each hole. Data will be downloaded monthly.

Data from sites ETGW1 and ETGW2 on the Eastern Tributary will be downloaded weekly when Longwall 304 extraction is within 450 m of the Eastern Tributary.

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, T5 and T6)[25] located to the west of Longwall 304 (Figure 10). 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 Goaf Hole);
- site 9EGW1B;
- site 9FGW1A;
- site 9GGW2B;
- site 9HGW1B;
- site PM02;
- site 9GGW1-80;
- site PM01 (9DGW1B);
- site 9EGW2A;
- site 9EGW2-4;
- site PM03;
- site PHGW1B;
- site PHGW2A;
- site F6GW3A;
- site F6GW4A;
- site TBS02-250R; and
- site TBS03-230.

Data from the piezometers will be downloaded monthly.

[25] 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 (HydroSimulations, 2018).

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 nine bores[26] (those most relevant to Longwall 304, as listed in Section 7.3.3 and shown in Charts 14 to 22) 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 Vibrating Wire Piezometers (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. The water levels in Hawkesbury Sandstone at depths similar to reservoir level, measured at Bores PM02, 9GGW2B, 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.

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, T5 and T6) located to the west of Longwall 304. Data from the divers in the standpipes will be downloaded monthly. The water tables measured at transect bores T5 and T3 will be compared to assess the hydraulic gradient from bore T5 to bore T3 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. A weekly audit of the statutory inspections is conducted by the shift undermanager.

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.

[26] This includes bore site 9EGW2A; not site 9EGW2-4. It also excludes bore site F6GW4A.

Monitoring of the mine water balance will comprise:

- Metered water reticulated into the mine (recorded continuously and downloaded monthly).
- Backfill water used to assist pumping into the mine (recorded continuously and downloaded monthly).
- Metered water reticulated out of the mine (recorded continuously and downloaded monthly).
- Manual measurement of moisture content into and out of the mine through the mine ventilation system 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, fan maintenance, etc.) 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.
- Measurement of the moisture content of run-of-mine (ROM) coal conveyed out of the mine at the drift portal using an automated moisture scanner. A fully automated data acquisition system records and stores the data.

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, and the *in-situ* coal moisture content) and total mine outflows (reticulated water out of the mine, moisture in the exhaust ventilation, 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 also monitor the water balance for the 300 area (i.e. a localised water balance underground in and about the 300 series longwalls) using a series of underground water meters. Metropolitan Coal will provide the results of the localised water balance, with the results of the overall mine water balance to the Dams Safety Committee monthly.

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; and
- site ETGW2[27] along the Eastern Tributary.

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.

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

Unfiltered water quality samples will also be collected monthly at site WRGW7 on the Waratah Rivulet and site ETGW2 on the Eastern Tributary 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 19 to 24.

Table 19
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(s).*	WaterNSW gauging station on Waratah Rivulet (GS 2132102) DI – Water gauging station on O'Hares Creek at Wedderburn (GS 213200) (control site) WaterNSW owned gauging station on Woronora River (GS 2132101) (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. Baseline data is available from the gauging station on Woronora River from January 2008. The Woronora River ceased flowing several times at the gauging station during the baseline period.	Level 1	The median of the ratios does not fall below the 35th percentile of the baseline data	Continue monitoring. Six monthly 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). Six monthly 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 catchments, 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 a control catchment, continue monitoring and six monthly reporting. If the same has not occurred in a 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 DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. • Consider the need for management measures, in accordance with Sections 8 and 9.

[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 20-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
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 20-B. • Adjusted baseline mean plus one standard deviation[4, 5] has been calculated for each water quality parameter and are provided in Table 20-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 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 monthly (until such time that data analysis indicates a return to Level 1). Six monthly 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 monthly (until such time that data analysis indicates a return to Level 1). Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.

[1] 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.

[2] 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.

[3] 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).

[4] 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 calculated 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.

[5] 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).

[6] Results reported as < (detection limit) have been set equal to nominated detection limit.

Table 20-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**	Dissolved Iron	0.544	0.706	0.284	0.337
		Dissolved Aluminium	0.097	0.100	0.041	0.047
		Dissolved Manganese	0.092	0.117	0.055	0.066
	WOWQ2 (using same baseline period as WRWQ9 to allow comparison)	Dissolved Iron	0.741	0.961	0.324	0.385
		Dissolved Aluminium	0.244	0.250	0.094	0.109
		Dissolved 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**	Dissolved Iron	0.543	0.543	0.336	0.336
		Dissolved Aluminium	0.094	0.188	0.065	0.106
		Dissolved Manganese	0.029	0.030	0.017	0.020
	WOWQ2 (using same baseline period as ETWQ AU to allow comparison)	Dissolved Iron	1.657	1.657	0.555	0.555
		Dissolved Aluminium	0.075	0.151	0.061	0.100
		Dissolved Manganese	0.090	0.094	0.052	0.058

Table 21
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	*Visual inspection does not identify abnormal water flow from the goaf, geological structure, or the strata generally.*	Underground.	Inspections of development workings for water accumulation.	Weekly.	Identification of abnormal water flow from the goaf, geological structure, or the strata generally.	N/A	No abnormal water flow from the goaf, geological structure, or the strata generally	Level 1	Normal water flow identified from the goaf, geological structure, or the strata generally.	Continue monitoring. Six monthly reporting.
								Level 2	Abnormal water flow identified from the goaf, geological structure, or the strata generally, however consistent with expected operational conditions.	Increase the frequency of data analysis to daily (until such time that data analysis indicates a return to Level 1). Six monthly reporting.
								Level 3	Abnormal water flow identified from the goaf, geological structure, or the strata generally, inconsistent with expected operational conditions.	Increase the frequency of data analysis to daily (until such time that data analysis indicates a return to Level 1). Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.
No connective cracking between the surface and the mine	*The 20-day average mine water make does not exceed 1 ML/day.*	Underground	• Metered water reticulated into the mine (mine inflow). • Backfill water used to assist pumping into the mine. • Metered water reticulated out of the mine (mine outflow). • Moisture content into and out of the mine through the mine ventilation system (mine inflow and outflow). • *In-situ* moisture content of the coal (mine inflow). • Moisture content of ROM coal conveyed out of the mine at the drift portal (mine outflow).	• Continuous monitoring, downloaded monthly. • Continuous monitoring, downloaded monthly. • Continuous monitoring, downloaded monthly. • Moisture content will be monitored: - every hour over a 9 hour period on two occasions during a 12 month period; - daily (week day) when possible; - minimum once per week. • Measured during routine channel sampling for coal quality. • Continuous monitoring using an automated moisture scanner, downloaded monthly.	Water make[1, 2] calculated from the difference between total mine inflows and total mine outflows, within one month of download.	Instrumentation precision.	The modelled daily mine inflow to Longwall 304 is predicted to be less than 0.14 ML/day on average.	Level 1	20-day average mine water make is less than or equal to 0.5 ML/day.	Continue monitoring. Six monthly reporting.
								Level 2	20-day average mine water make is between 0.5 ML/day and 1 ML/day.	Increase the frequency of data analysis to fortnightly (until such time that data analysis indicates a return to Level 1). Six monthly reporting.
								Level 3	20-day average mine water make is greater than or equal to 1 ML/day.	Increase the frequency of data analysis to fortnightly (until such time that data analysis indicates a return to Level 1). Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.

[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] A new gas drainage plant is anticipated to come online in April 2019. Additional monitoring will be conducted to measure moisture outflow.

Table 21 (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
No connective cracking between the surface and the mine	*Significant departure from the predicted envelope of the vertical potentiometric head profile at Bore 9GGW2B does not occur.*	Bore 9GGW2B	Groundwater pressures/levels	Monthly download of continuous datalogging.	Analysis of vertical head profiles, six-monthly, within one month of download	Datalogger instrumentation precision to 1mm; error is +/- 0.5 mm	Predicted profile for longwall panel relevant to longwall status	Level 1	9GGW2B Head Profile is consistent with the shape and magnitude of the predicted Model Curve[3]	Continue monitoring. Six monthly reporting.
								Level 2	9GGW2B Head Profile is consistent with the shape of, and does not lie significantly to the left of the predicted Model Curve[3]	Increase the frequency of data analysis to quarterly (until such time that data analysis indicates a return to Level 1). Six monthly reporting.
								Level 3	9GGW2B Head Profile is inconsistent with the shape of, or lies significantly to the left of the predicted Model Curve[3]	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 DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.
	Significant departure from the predicted envelope of the vertical potentiometric head profile at Bore F6GW3A does not occur.	Bore F6GW3A	Groundwater pressures/levels	Monthly download of continuous datalogging.	Analysis of vertical head profiles, six-monthly, within one month of download	Datalogger instrumentation precision to 1mm; error is +/- 0.5 mm	Predicted profile for longwall panel relevant to longwall status	Level 1	F6GW3A Head Profile is consistent with the shape and magnitude of the predicted Model Curve[3]	Continue monitoring. Six monthly reporting.
								Level 2	F6GW3A Head Profile is consistent with the shape of, and does not lie significantly to the left of the predicted Model Curve[3]	Increase the frequency of data analysis to quarterly (until such time that data analysis indicates a return to Level 1). Six monthly reporting.
								Level 3	F6GW3A Head Profile is inconsistent with the shape of, or lies significantly to the left of the predicted Model Curve[3]	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 DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.
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[6].*	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 1mm; error is +/- 0.5 mm.	PHGW2A > 186.92 m AHD[4]	Level 1	PHGW2A[5] >= 186.92 m AHD	Continue monitoring. Six monthly reporting.
								Level 2	PHGW2A[5] < 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). Six monthly reporting.
								Level 3	PHGW2A[5] =< 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 DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.

[3] 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).

[4] Minimum measurement to 30 June 2017.

[5] 7-Day Average Potentiometric Head at the mid Hawkesbury Sandstone Piezometer

[6] 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.

Table 21 (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 9GGW2B is reduced by no more than 40% from that measured to 30 June 2017[6].*	Bore 9GGW2B (80.3 m)	Groundwater pressures/levels.	Monthly download of continuous datalogging.	Analysis of water tables, quarterly, within one month of download.	Datalogger instrumentation precision to 1mm; error is +/- 0.5 mm.	9GGW2B > 181.38 m AHD[4]	Level 1	9GGW2B[5] >= 181.38 m AHD	Continue monitoring. Six monthly reporting.
								Level 2	9GGW2B[5] < 181.38 m AHD and > 176.38 m AHD	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Six monthly reporting.
								Level 3	9GGW2B[5] =< 176.38 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 DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.
	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[6].	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 1mm; error is +/- 0.5 mm.	9EGW2A > 186.32 m AHD[4]	Level 1	9EGW2A[5] >= 186.32 m AHD	Continue monitoring. Six monthly reporting.
								Level 2	9EGW2A[5] < 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). Six monthly reporting.
								Level 3	9EGW2A[5] =< 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 DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.
	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[6].	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 1mm; error is +/- 0.5 mm.	PM02 > 183.86 m AHD[4]	Level 1	PM02[5] >= 183.86 m AHD	Continue monitoring. Six monthly reporting.
								Level 2	PM02[5] < 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). Six monthly reporting.
								Level 3	PM02[5] =< 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 DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.
	The hydraulic gradient from transect bore T5 to bore T3 is reduced by no more than 10% from that measured on 30 June 2017.	Bores T3 and T5	Groundwater levels	Monthly download of continuous datalogging.	Analysis of water tables quarterly, within one month of download.	Datalogger instrumentation precision to 1mm; error is +/- 0.5 mm	T5-T3 = 17.92 m[7]	Level 1	T5-T3 >= 17.92 m	Continue monitoring. Six monthly reporting.
								Level 2	T5-T3 < 17.92 m and > 16.13 m	Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Six monthly reporting.
								Level 3	T5-T3 =< 16.13 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 DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.

4 Minimum measurement to 30 June 2017.

5 7-Day Average Potentiometric Head at the mid Hawkesbury Sandstone Piezometer

6 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.

7 30 June 2017 measurement.

Table 22
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).	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. Report to DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.

[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. 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 23
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 P, Q, R, S, T, U, V and W.*	Pools P 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 P to W for streambed cracking and changes to the natural drainage behaviour.	Limitations of visual observations.	No mine-induced surface cracking present at Pools P, Q, R, S, T, U, V or W within the stream bed or rock bar. Pools P and T flow through and below rock bars. Pools Q, R and S terminate at rock bars. 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 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 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 Pools P or T prior to flowing through/below the rock bars; - surface flow is not evident along the length of Pools Q, R or S prior to flowing over 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 DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.
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 P, T, U, V and W indicates the water level is at or above the pool's previous minimum.*	Pools P, 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 P, 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 30 June 2018[1]	Level 1	The water level in Pools P, T, U, V or W has not been below the pool's previous minimum.	Continue monitoring. Six monthly reporting.
								Level 2	The water level in Pools P, 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). Six monthly reporting.
								Level 3	The water level in Pools P, 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 DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.

[1] Hydro Engineering & Consulting (2018) Metropolitan Coal Surface Water Review 1 January to 30 June 2018.

Table 23 (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
No Diversion of Flows, No Change in the Natural Drainage Behaviour (Continued)										
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 Q, R and S indicates the water levels are above that required to maintain water over the downstream rock bar.*	Pools Q, R and S on Waratah Rivulet. Control pools on the Woronora River.	Pool water level.	Monitored continuously, with a data logger and downloaded monthly.	Analysis of Pools Q, R and S water level data against the level required to maintain water over the downstream rock bar, quarterly, within one month of download.	Water level sensor precision, data logger malfunction and download error.	Pool water level hydrographs to 30 June 2018[1]	Level 1	The water level in Pools Q, R or S has been above that required to maintain water over the downstream rock bar.	Continue monitoring. Six monthly reporting.
								Level 2	The water level in Pools Q, R or S has been below that required to maintain water over the downstream rock bar, however, appears 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). Six monthly reporting.
								Level 3	The water level in Pools Q, R or S has been below that required to maintain water over the downstream rock bar 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 DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.
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 P 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 P 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 P to the full supply level of the Woronora Reservoir has not changed.	Continue monitoring. Six monthly reporting.
								Level 2	The extent or nature of iron staining in the Waratah Rivulet from Pool P 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 reporting.
								Level 3	The extent or nature of iron staining in the Waratah Rivulet from Pool P 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 DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.

[1] Hydro Engineering & Consulting (2018) Metropolitan Coal Surface Water Review 1 January to 30 June 2018.

Table 23 (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 P 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 P 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[3]. Methane (mg/L) ALS Method EPO33: Methane Detection limit is 0.01 mg/L[4].	No gas releases observed in Waratah Rivulet from Pool P to the full supply level of the Woronora Reservoir prior to the mining of Longwall 20. Pool P - gas releases observed in February 2014; May 2014 to February 2015; May and June 2015; September 2015 to June 2017. 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[1] in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir. Methane concentrations are equal to or less than 0.159 mg/L[1] in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir.	Continue monitoring. Six monthly reporting.
								Level 2	Free carbon dioxide concentrations are above 4 mg/L and equal to or less than 13 mg/L[2] in Waratah Rivulet pools from Pool P 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[2] in Waratah Rivulet pools from Pool P 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). Six monthly reporting.
								Level 3	Free carbon dioxide concentrations are above 13 mg/L in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir. Methane concentrations are above 0.478 mg/L in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir.	Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.

[1] 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).

[2] 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).

[3] 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.

[4] 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.

Table 24
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 when Longwall 304 is not within 450 m of the Eastern Tributary. Weekly when Longwall 304 is within 450 m of the Eastern Tributary.	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 2m 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 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 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 DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.
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 against the level required to maintain water over the downstream rock bar, quarterly (within one month of download) when Longwall 304 is not within 450 m of the Eastern Tributary. Analysis of Pool ETAS/ ETAT and Pool ETAU water level data against the level required to maintain water over the downstream rock bar weekly when Longwall 304 is within 450 m of the Eastern Tributary.	Water level sensor precision, Data logger malfunction and download error.	Pool water level hydrographs to 30 June 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 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). Six monthly 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.

[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 (2018) Metropolitan Coal Surface Water Review 1 January to 30 June 2018.

[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.

Table 24 (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[1]	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	Monthly when Longwall 304 is within 450 m of the Eastern Tributary. Within three months of the completion of Longwall 304.	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 DP&E 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 Longwall 304. Metropolitan Coal to implement stream remediation in accordance with the Metropolitan Coal Stream Remediation Plan[2].

[1] 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 Longwall 304.

[2] The Draft Metropolitan Coal Stream Remediation Plan is currently subject to stakeholder consultation. The Stream Remediation Plan will be appended to the Metropolitan Coal Water Management Plan when approved.

Table 24 (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 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). Six monthly 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.	Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, DI – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9.

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.

8.10 EASTERN TRIBUTARY 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 Eastern Tributary during the extraction of Longwall 303 so that additional mining of Longwall 303 would have no further exceedance of the Eastern Tributary performance measure. The same monitoring and adaptive management program will be implemented for the extraction of Longwall 304, as described below.

As Longwall 304 mines towards the Eastern Tributary, Metropolitan Coal will implement the Longwall 304 Eastern Tributary Valley Closure TARP (Table 25) designed to detect the development of subsidence effects on the Eastern Tributary. The Eastern Tributary Valley Closure TARP defines three status levels. Level 1 status represents no measurable movement, Level 2 status represents measurable movement and Level 3 status represents increasing rates of movement.

Subsidence monitoring for the Longwall 304 Eastern Tributary Valley Closure TARP will be conducted in accordance with the Metropolitan Coal Longwall 304 Subsidence Monitoring Program.

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 the DP&E, WaterNSW and Metropolitan Coal General Manager within 24 hours of Technical Committee review if the results are at TARP Level 1 or Level 2 status.

In the event the results are at TARP Level 3 status, the Technical Committee will report immediately to the Metropolitan Coal General Manager, consider whether an increase in monitoring frequency is required, and notify the DP&E and WaterNSW of Level 3 status and associated actions within 24 hours of becoming aware of the Level 3 TARP status. The Metropolitan Coal General Manager will determine the need to cease longwall mining operations.

Table 25
Longwall 304 Eastern Tributary Valley Closure Trigger Action Response Plan

	Monitoring method	Measurement	Baseline[1]	Frequency TARP measurement	Level 1 Baseline condition	Level 2 Measurable change in observation from Level 1	Level 3 Measurable change in observation from Level 2
Monitoring	Closure prisms	Closure – high resolution	Fortnightly up to 900 m void length, then weekly until 1,230 m	3 Surveys in pillar 7 c/t to 1,230 m void length Beyond 1,230 m surveys at no greater than 3-day intervals	• Measurable movement no greater than **±1 mm**	Measurable movement greater than Level 1 and no greater than **±2 mm** Measured in two consecutive epochs	Measurable movement greater than Level 2 and no greater than **±4 mm,** or • rate of change **0.5 to 1.0 mm/week** Measured in two consecutive epochs at two or more survey lines
	Ground survey ETAU	Relative 3D movement, closure and strain			• Measurable movement no greater than **±2 mm**	Measurable movement greater than Level 1 and no greater than **±3 mm** Measured in two consecutive epochs	Measurable movement greater than Level 2 and no greater than **±4 mm** Measured in two consecutive epochs
	GNSS network	Absolute 3D movement and closure	Daily Real Time	Daily real time	• Measurable horizontal movement no greater than **±10 mm**	Measurable horizontal movement greater than Level 1 and no greater than **±15 mm** Measured over three consecutive epochs (days) and where supported by closure prism data	Measurable horizontal movement greater than Level 2 and no greater than **±20 mm** Measured over three consecutive epochs (days) and where supported by closure prism data
Reporting	Technical Committee meeting / review[2,3]	-	Meeting/review at 900 m void	-	Meeting/review data at 1,230 m then subsequent reviews within 24 hours of closure prism and ground survey monitoring	Meeting/review within 24 hours of closure prism and ground survey monitoring	Meeting/review within 24 hours of closure prism and ground survey monitoring, or as otherwise determined by the Technical Committee
	Key outcomes of Technical Committee meeting / review[4,5]	-	Review baseline measurements.	-	Reporting within 24 hours of Technical Committee review	Reporting within 24 hours of Technical Committee review	Immediate reporting to MC General Manager Increase in monitoring frequency as determined by the Technical Committee Notification of the DP&E and WaterNSW of Level 3 status and associated actions as soon as practicable MC to determine need to cease longwall mining operations at Level 3 status. Exceedance of Level 3 upper bound parameters over two consecutive epochs would initiate cessation of mining by MC

[1] Measurements prior to distance of 2 x depth of cover from Eastern Tributary

[2] Members of the Technical Committee may attend a meeting in person or remotely via screen sharing. Where this is not possible, the Committee member will be provided with the information presented in the meeting and outcomes of the meeting for review and comment. Participation will be noted in the key outcomes reporting to the DP&E and WaterNSW.

[3] The Technical Committee will be informed at a weekly frequency with ETAU and ETAS/ETAT pool water level monitoring, ground water monitoring at ETGW1 and visual inspections of ETAS, ETAT and ETAU.

[4] The key outcomes of the Technical Committee Meeting will be reported to the DP&E, WaterNSW and Metropolitan Coal (MC) General Manager.

[5] Measurements prior to distance of 2 x depth of cover from Eastern Tributary at fortnightly intervals, then weekly within 2 x depth of cover until reaching IEPMC recommended 450 m radius from Eastern Tributary, and then as per TARP. Baseline will be reset at commencement of Longwall 304 for incremental monitoring at same trigger levels as Longwall 303.

9 MANAGEMENT MEASURES

9.1 SUBSIDENCE MANAGEMENT APPROACH

Potential environmental consequences during the mining of Longwall 304 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 Longwall 304 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 304 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 and 304 were shortened to reduce potential subsidence effects at the Garrawarra Centre Complex.
- The finishing ends of Longwall 303 and Longwall 304 were shortened to reduce predicted valley closure on the Eastern Tributary.

Assessment of longwall geometry on predicted valley closure has indicated that potential environmental impacts to the Eastern Tributary can be managed through stand-offs from the Eastern Tributary. Metropolitan Coal has also developed a monitoring and adaptive management approach for the Eastern Tributary 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 P 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 8.3.3, Pools B, C, E, G, G1, H and I will be manually monitored on a daily basis, 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. Stream remediation campaigns using polyurethane (PUR) were completed at Pool A in June 2012, at Pool F in July 2015 and at Pool G in August 2016. 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 the event stream remediation activities are required at any additional pools/rock bars, Metropolitan Coal will prepare stream remediation plans in consultation with the DP&E, DRG and WaterNSW and include the plans in the Metropolitan Coal Stream Remediation Plan.

Stream remediation will be triggered at Pools H or I on the Waratah Rivulet if the water level in a pool falls below the water level 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 DP&E, DRG, WaterNSW, Office of Environment and Heritage (OEH), DI – 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 8.3.3).

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. To date (June 2018), 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. Monitoring of Pool N will continue to be conducted.

Stream remediation will be triggered at Pools J, K, L, M or O 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 DP&E, DRG, WaterNSW, OEH, DI – Water and DPI - Fisheries if the stream remediation process has been triggered.

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 P to W will be monitored continuously with water level sensors and data loggers (Section 8.3.3).

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 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 DP&E 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.

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 will commence stream remediation at Pools ETAH, followed by ETAK.

Metropolitan Coal will conduct stream remediation works in accordance with the Metropolitan Coal Stream Remediation Plan. The Draft Metropolitan Coal Stream Remediation Plan was provided to the DP&E and relevant agencies in November 2018. Once finalised, the Metropolitan Coal Stream Remediation Plan will be appended to the Metropolitan Coal Water Management Plan.

Upstream of the Reach Subject to the Eastern Tributary Performance Measure

Metropolitan Coal will also conduct stream remediation at Pool ETO on the Eastern Tributary (Figure 5). Metropolitan Coal will conduct stream remediation at Pool ETO prior to commencing remediation at Pools ETAH and ETAK.

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 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 DP&E, DRG 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 site COH17 will be monitored to record evidence of potential subsidence impacts in accordance with the Metropolitan Coal Longwall 304 Land Management Plan (Figure 3). 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 Longwall 304 Land Management Plan (Figure 3).

9.4.2.4 Swamp Remediation Measures

In accordance with the Metropolitan Coal Longwall 304 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 DP&E, OEH, WaterNSW, DPI - Fisheries and DRG.

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 Longwall 304 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.

Section 8.10 details the monitoring and adaptive management approach that will be implemented as Longwall 304 mines towards the Eastern Tributary. A Technical Committee, comprising industry and technical representatives, will review the monitoring data in accordance with the TARP. The TARP will be used to determine the need to cease longwall mining operations.

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 Manager – Technical Services and/or the Environment & Community Superintendent within 24 hours of assessment completion.
- The Manager – Technical Services 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 DP&E, DI - Water, WaterNSW and OEH 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 DP&E for approval.
- Metropolitan Coal will implement the approved course of action to the satisfaction of the DP&E.

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 DP&E if either the contingency measures implemented by Metropolitan Coal have failed to remediate the impact or the Secretary of the DP&E 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 DP&E.
- 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

In accordance with Condition 7, Schedule 3 of the Project Approval, Metropolitan Coal will collect baseline data for the next Extraction Plan (Longwall 305 on). The collection of baseline data for water resources and watercourses is described below.

11.1 SURFACE WATER

Meteorological data for the next Extraction Plan is available from the existing pluviometers, pan evaporimeter and climate stations described in Section 8.1.

Streams relevant to the next Extraction Plan include the Waratah Rivulet, Eastern Tributary and the first and second order streams that flow into the Woronora Reservoir.

The results of visual and photographic surveys of the Waratah Rivulet and Eastern Tributary prior to the commencement of Longwall 20 (provided in Appendices 1 and 2 of this WMP) and during the mining of Longwalls 20-27 and Longwalls 301-303 provide information on these streams.

Gilbert & Associates (now Hydro Engineering & Consulting) conducted a visual inspection and photographic survey of streams in the vicinity of Longwalls 301-303 in July 2015 (Hydro Engineering & Consulting, 2016) (Appendix 5 of the Longwalls 301-303 Water Management Plan).

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, 2019). Hydro Engineering & Consulting's (2019) visual inspection and photographic survey report is provided in Appendix 5 of this WMP.

Prior to the commencement of Longwall 305, Metropolitan Coal will investigate the potential to install:

- a pool water level meter in the large pool mapped on the lower reaches of the stream that overlies Longwalls 309 to 311, downstream of Swamp 92 (Appendix 5; Figures 4 and 9); and
- a pool water level meter in two of the large pools mapped on the lower reaches of the stream that overlies Longwall 311, downstream of Swamp 77 (Appendix 5; Figures 4 and 9).

Metropolitan Coal will also investigate the potential to install a small flow measuring flume immediately downstream of Swamp 92, Swamp 77 and Swamp 76 (Figure 9) prior to the commencement of Longwall 305:

- A small flow measuring flume immediately downstream of Swamp 92 - while no pools have been mapped on the stream immediately downstream of Swamp 92 by Hydro Engineering & Consulting (2019), there may be potential to direct flow from the upland swamp toward a flume (Appendix 5).
- A small flow measuring flume immediately downstream of Swamp 77 - at the first small pool mapped on the stream by Hydro Engineering & Consulting (2019) (Appendix 5).
- A small flow measuring flume immediately downstream of Swamp 76 – the first order stream which overlies Longwalls 313 to 315 has not been subject to detailed stream mapping.

Consideration of the environmental performance and management of this WMP will also inform the appropriate type and frequency of monitoring of water resources and watercourses relevant to the next Extraction Plan.

Surface water quality data for the Woronora Reservoir (site DW01, measurements taken from 0 to 9 m below the water surface level), Nepean Reservoir and Cataract Reservoir will continue to be sourced from WaterNSW.

11.2 GROUNDWATER

Paired swamp piezometers were installed in Swamp 71a in June 2016. In accordance with the Longwall 304 Biodiversity Management Plan, Metropolitan Coal will install paired piezometers in Swamp 72 prior to the commencement of Longwall 305 and will assess the logistics and access to Swamps 62, 81, 82 and 89 for the installation of piezometers prior to the commencement of Longwall 306.

Metropolitan Coal will also install soil moisture probes at various depth intervals to monitor the vertical profile of soil moisture in the swamp substrate. Soil moisture probes (linked to a datalogger) will be installed in a selection of Swamps 62, 72, 81, 82 and/or 89 adjacent to paired piezometers. Soil moisture probes will also be installed in control Swamps 101, 137a and 137b. To inform the water holding capacity of the swamps installed with soil moisture probes, a log of the soil profile will be taken at the location of the piezometers/soil moisture probes, and the depth of the swamp substrate across the swamp will be sampled and recorded.

While not subject to the next Extraction Plan, a program to collect baseline data will be specifically designed for the three larger swamps (Swamps 76, 77 and 92) located further to the west using groundwater piezometers and swamp soil moisture probes prior to the commencement of Longwall 306.

Metropolitan Coal will install a post-mining multi-level bore over Longwall 305. The bore will extend to the fracture zone and will assess permeability below the Bald Hill Claystone.

Metropolitan Coal does not anticipate that any additional groundwater monitoring sites will be required for the next Extraction Plan; however, consideration of the environmental performance and management of this WMP will inform the appropriate type and frequency of groundwater monitoring relevant to the next Extraction Plan, and additional groundwater bores may be installed on the basis of the monitoring and modelling results.

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;
- 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 DP&E 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 Manager – Technical Services 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 DP&E 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 DP&E 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 DP&E 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 DP&E.

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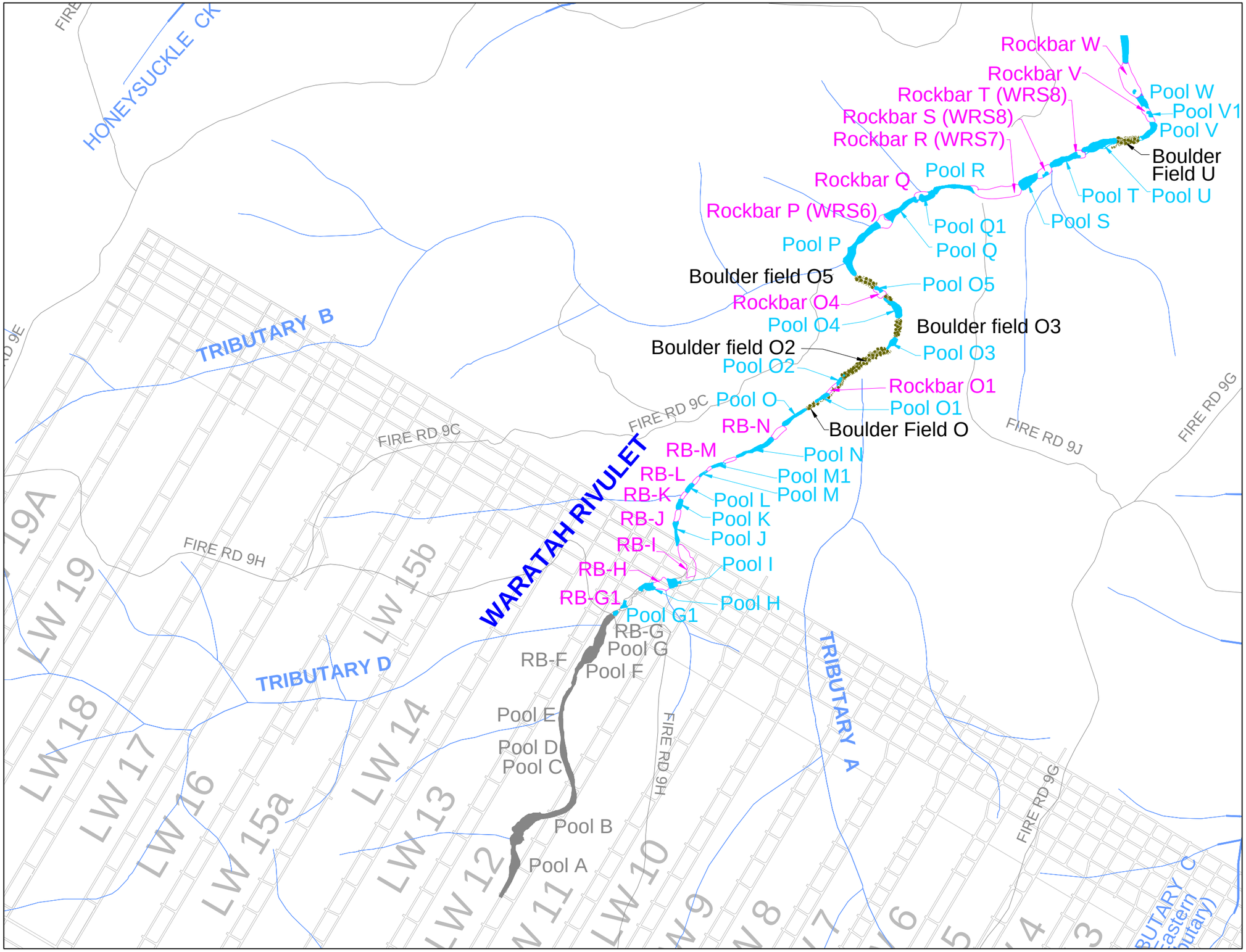
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APPENDIX 1

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.

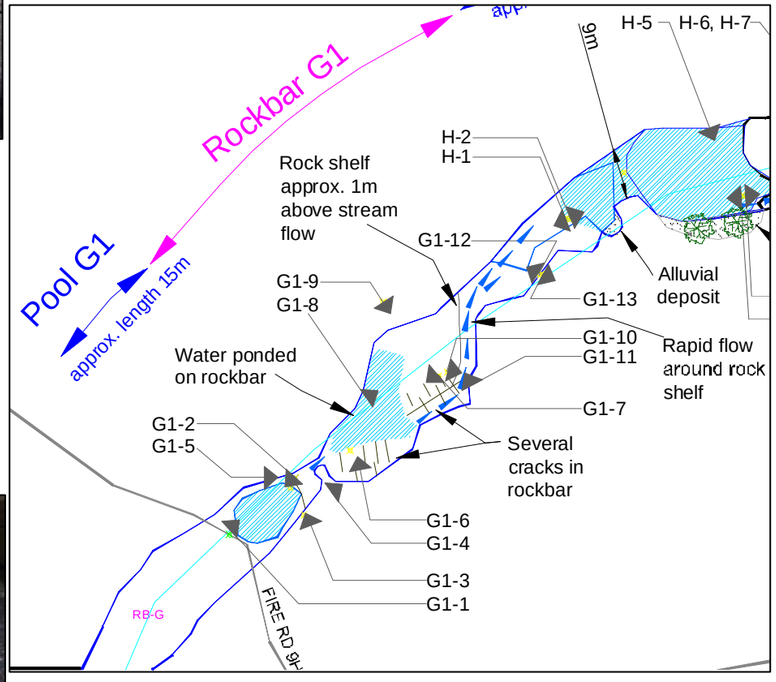


Photo Details

Photo ID	Easting	Northing	Bearing
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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.

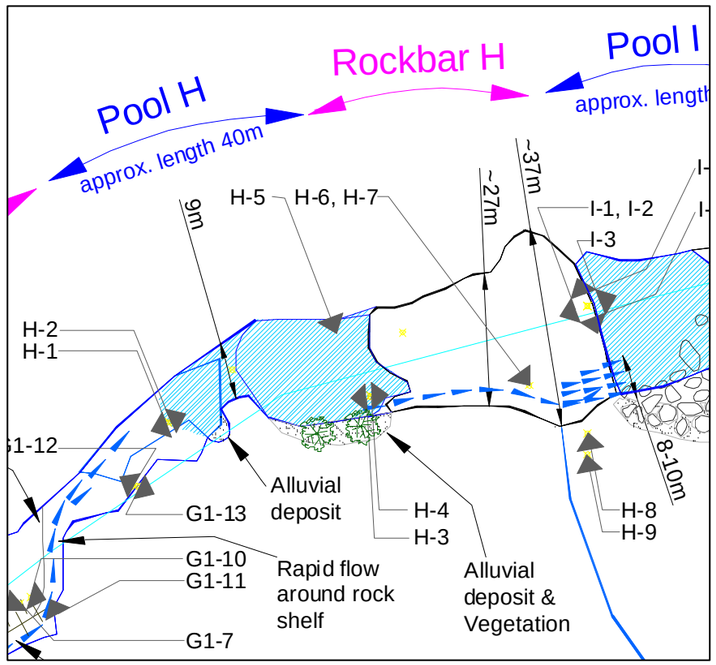


Photo Details

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



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-6 Downstream end of Pool I looking downstream



I-5 Southern bank at u/s end of pool

Pool I notes (as at 16 Dec 2008)

- 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.

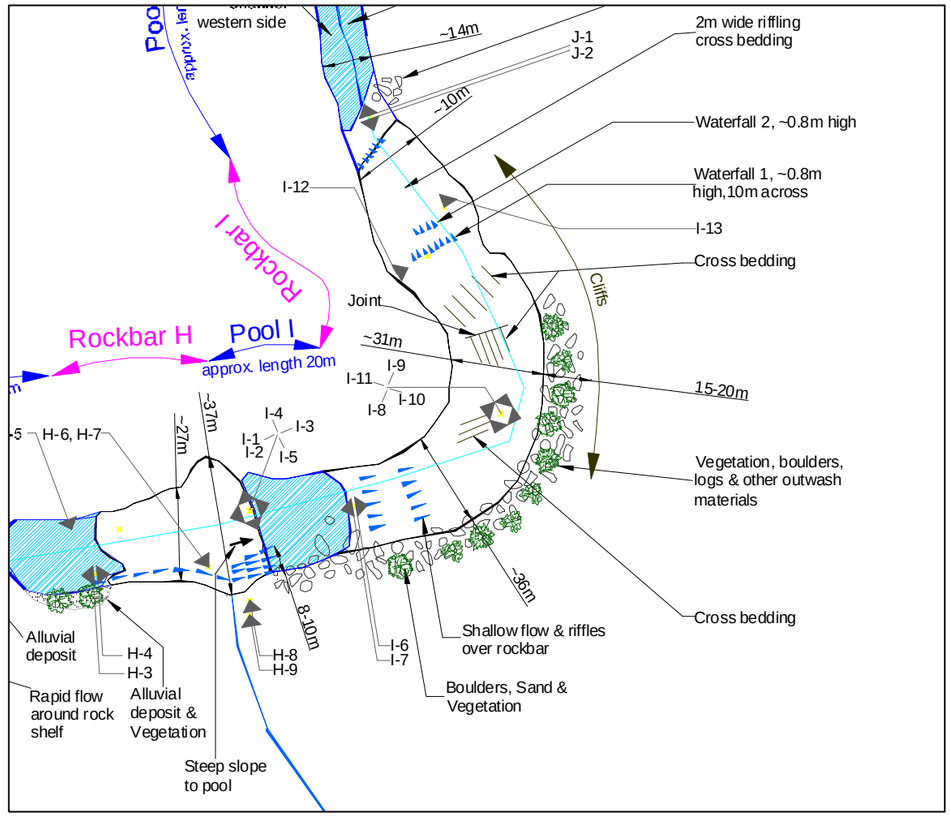


Photo Details

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.

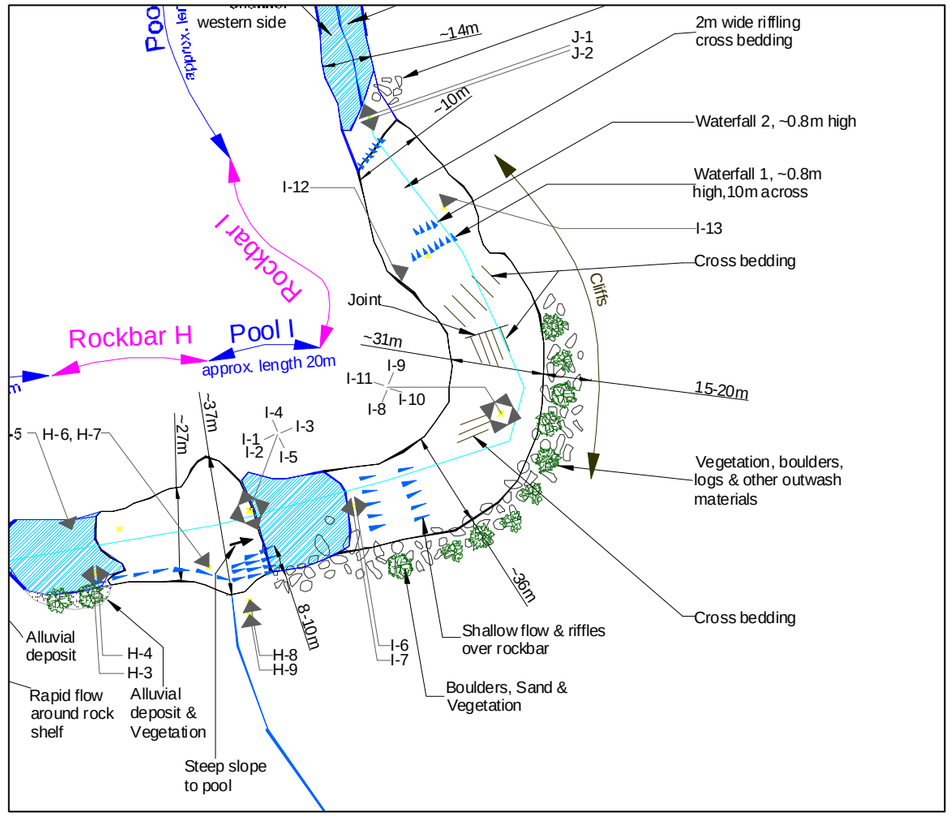


Photo Details

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

Pool J and Rockbar J notes (as at 16 Dec 2008)

- 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.

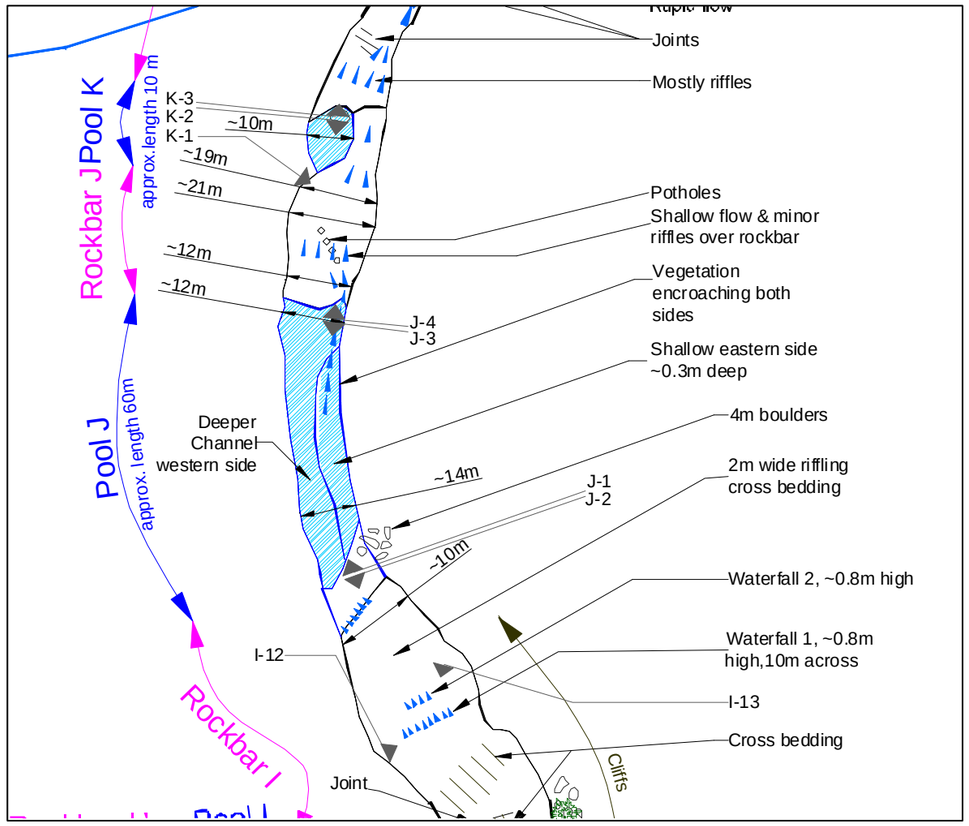


Photo Details

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

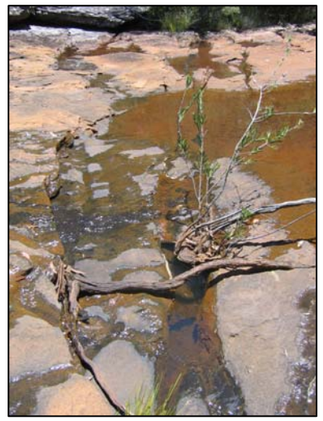
POOL K - STREAM MAPPING SUMMARY



K-1 Pool K upstream end looking towards west bank



K-4 Joints across Rockbar K



K-5 Joints across Rockbar K

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.



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

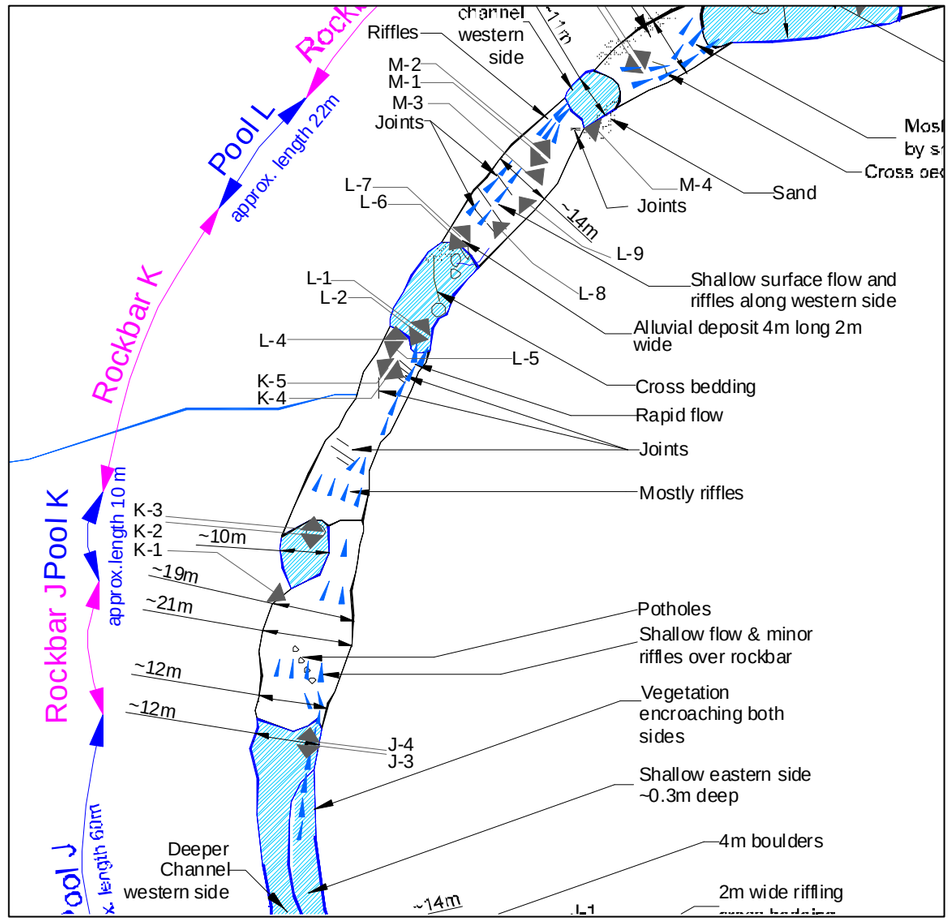


Photo Details

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.

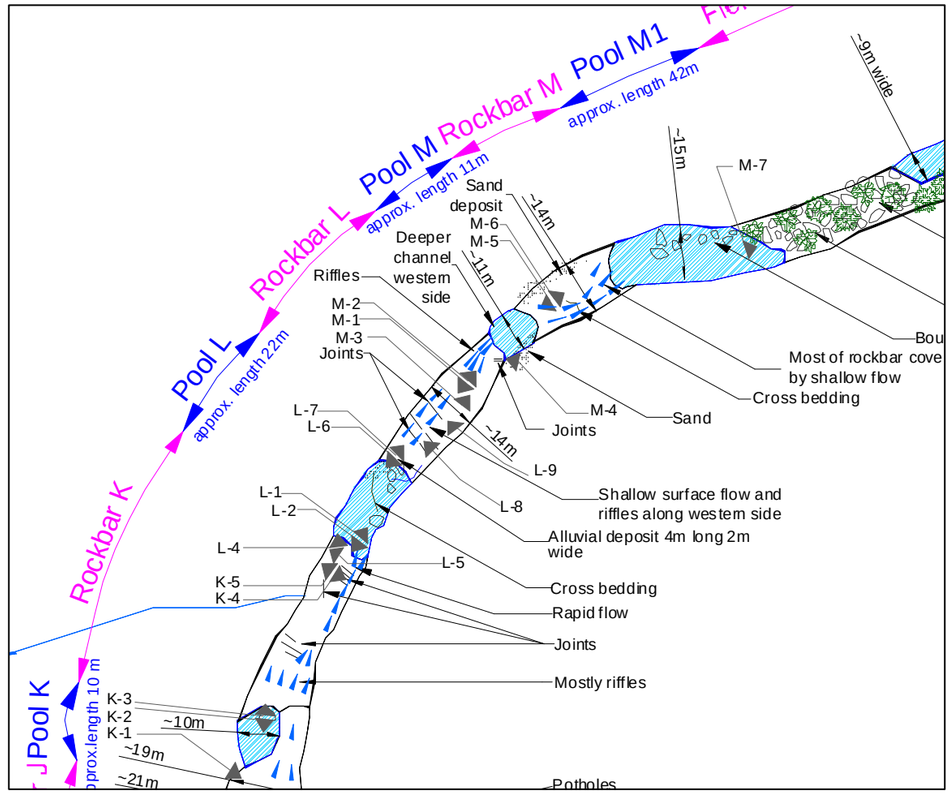


L-2 Upstream end of Pool L looking upstream





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)

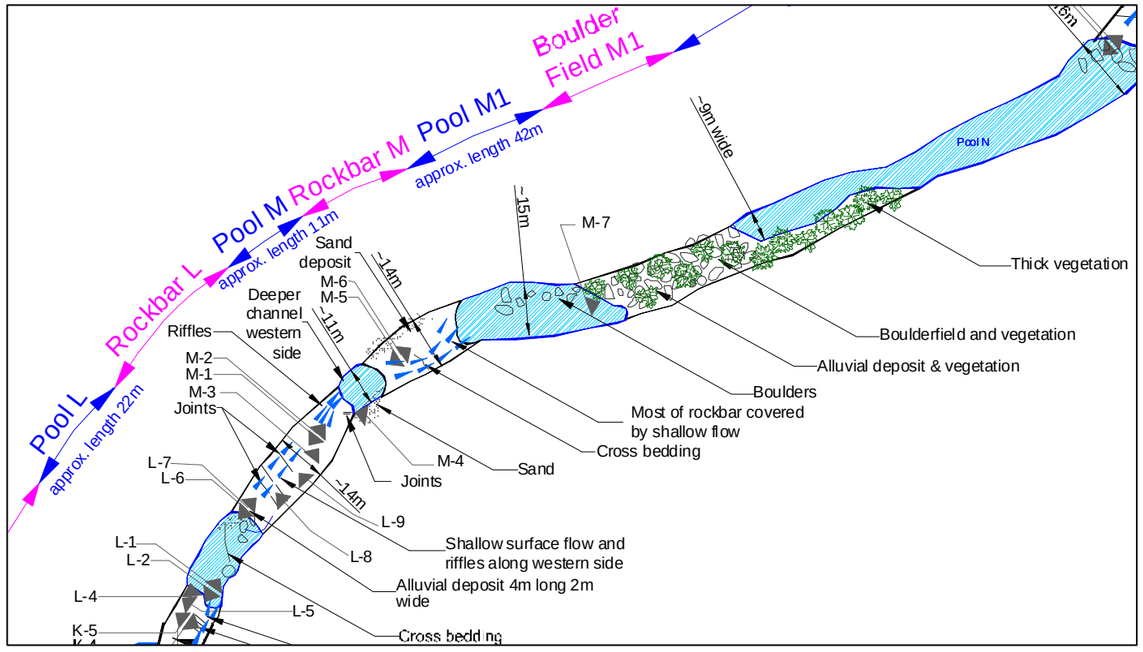
- Pool M1 is approximately 42m long and width varies from approximately 9m to 15m. Water depth varies from 0.3m to 1m with an average of approximately 1m.
- Base of Pool M1 is sandstone, covered with sediment.
- Boulders and detached blocks located along the north western side of the pool, approximately 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.

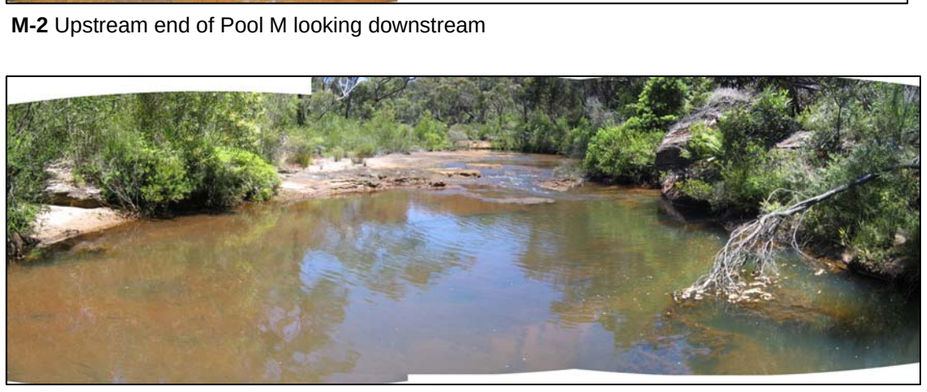


M-2 Upstream end of Pool M looking downstream



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-2 Downstream end of Pool N looking downstream



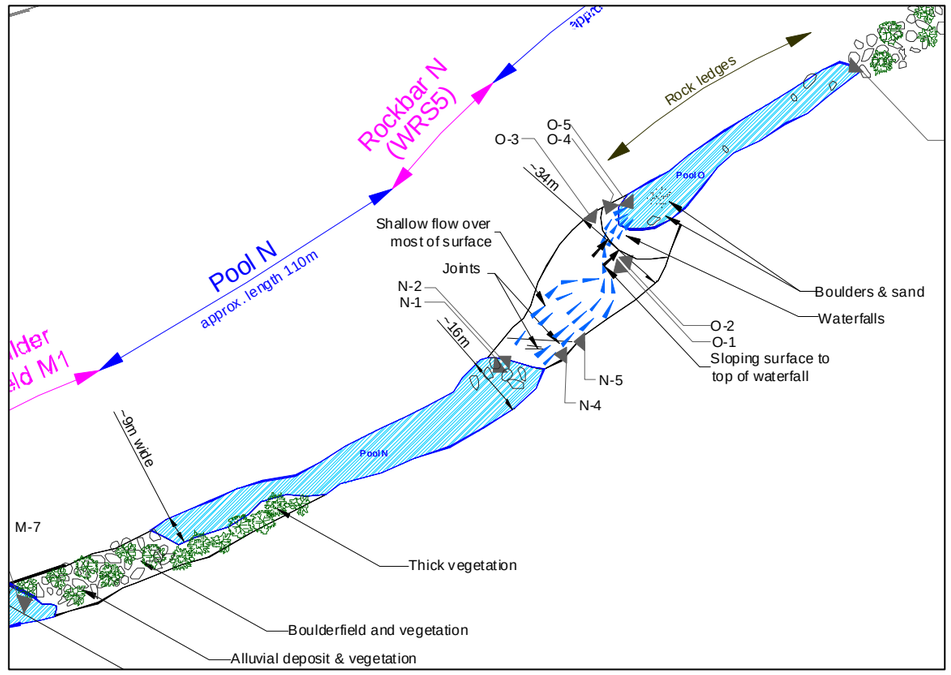
N-4 Joints in rockbar N



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

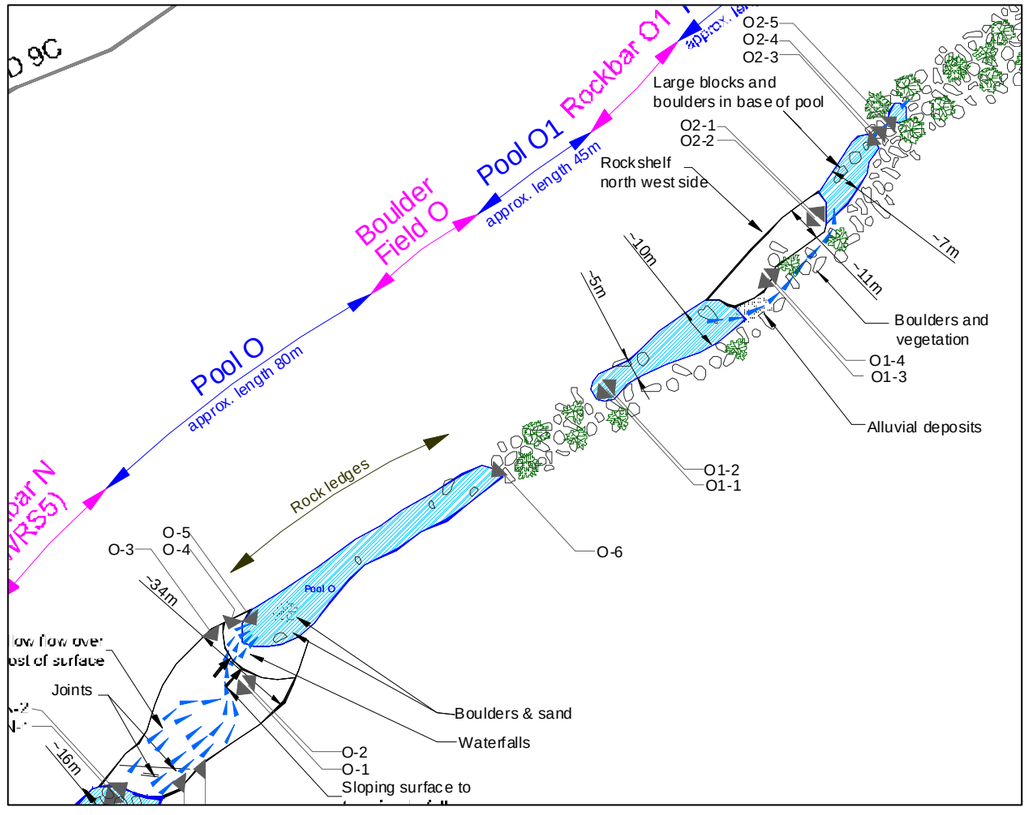


Photo Details

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

Pool O1 notes (as at 17 Dec 2008)

- 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

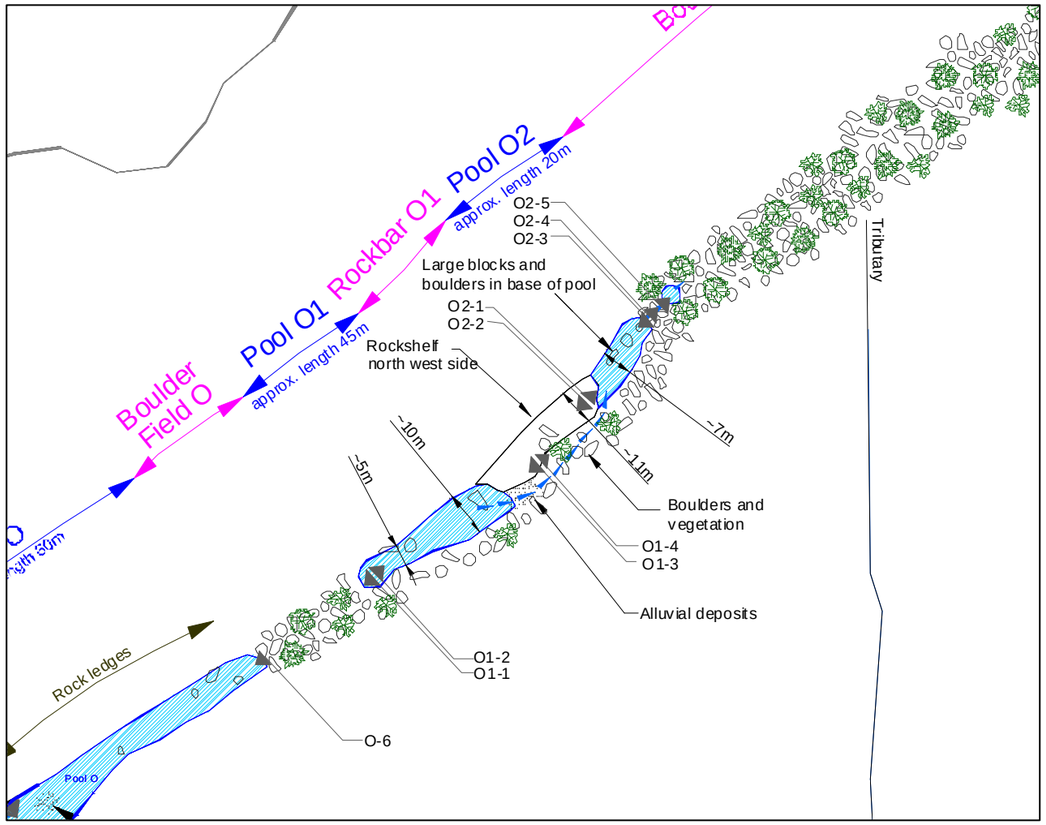


Photo Details

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

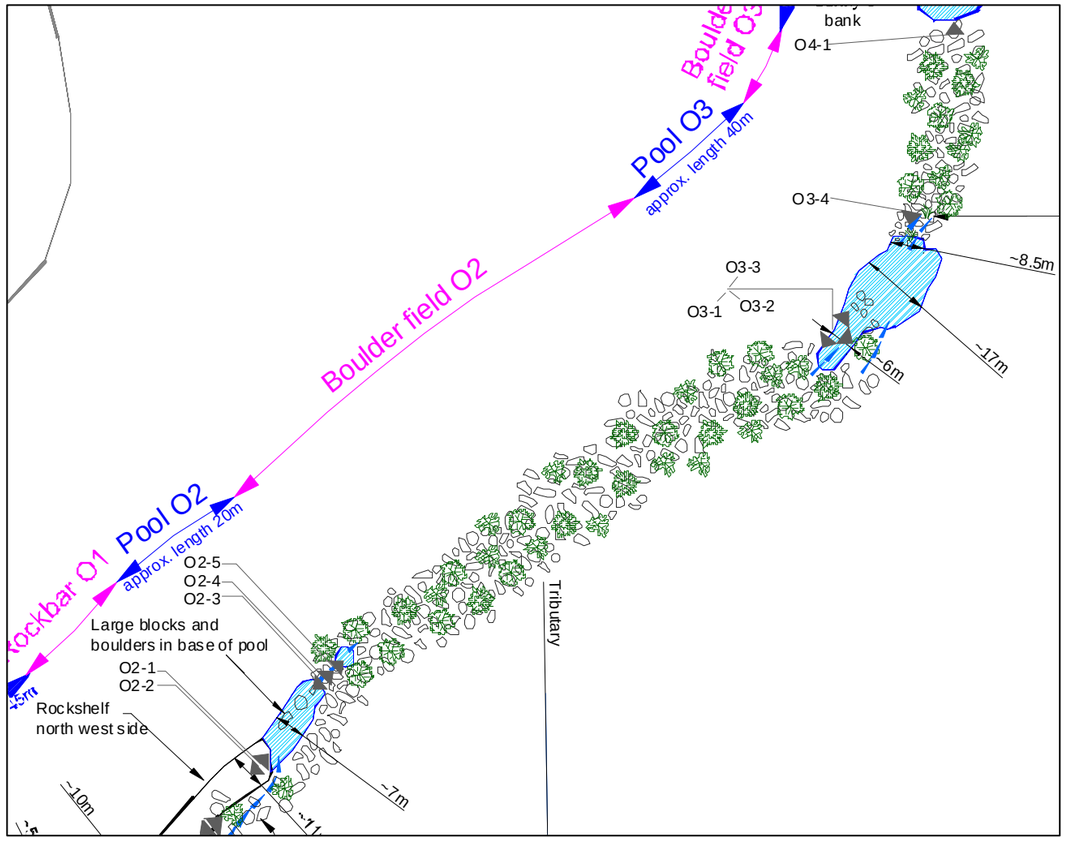


Photo Details

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

Pool O3 notes (as at 17 Dec 2008)

- 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.

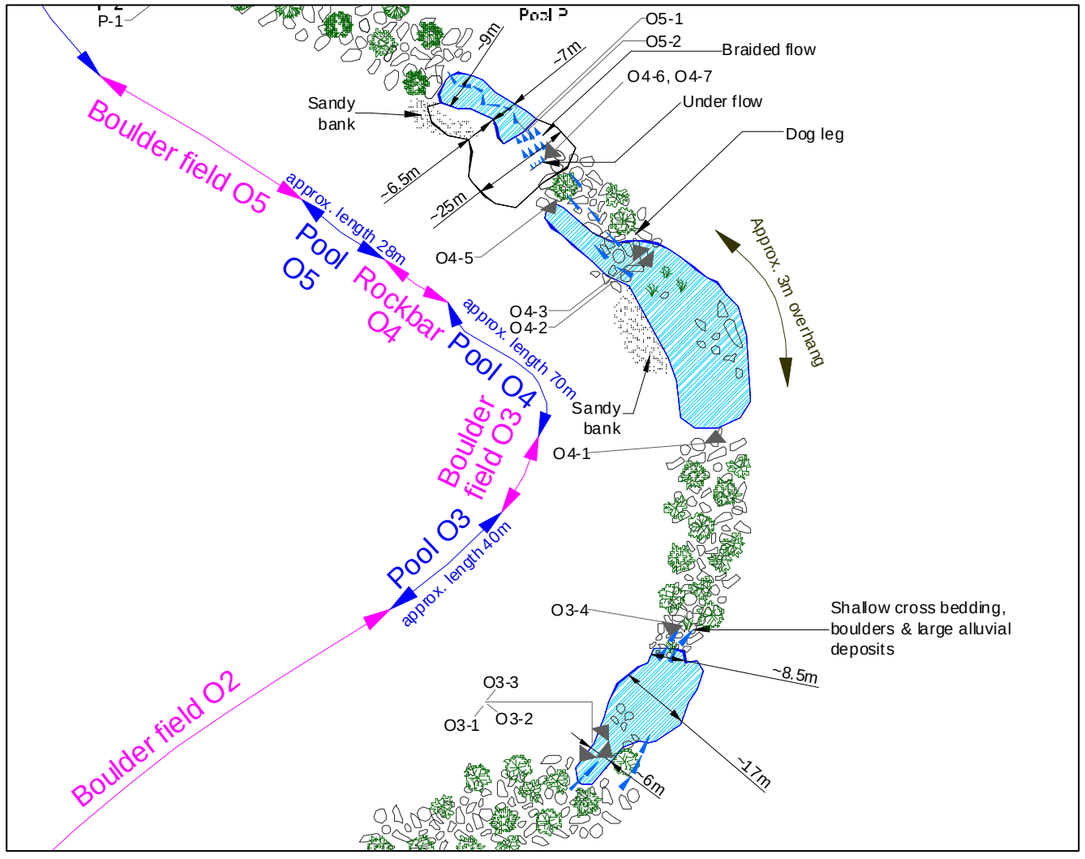


Photo Details

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)

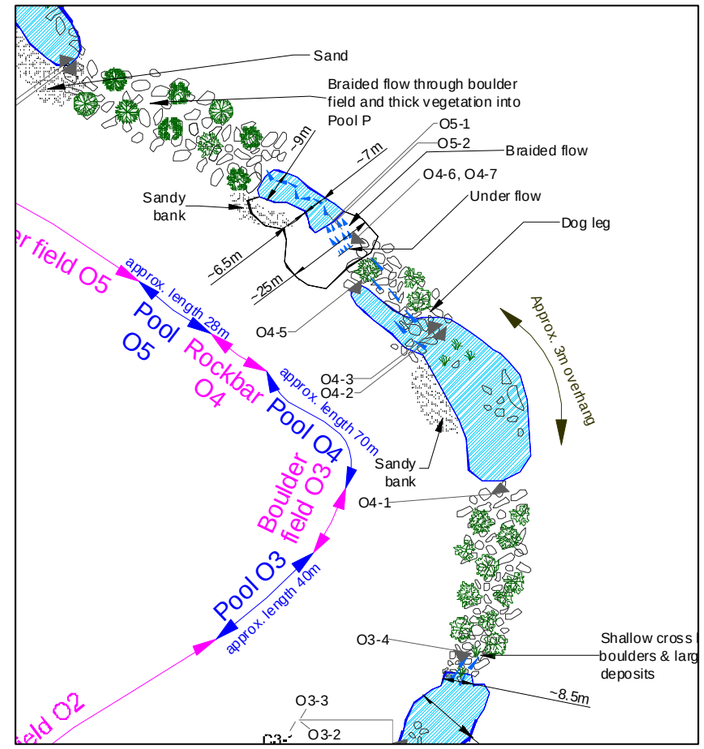
- Pool O4 is approximately 70m long overall. The main section of the pool is approximately 55m long and 15m to 20m wide. A narrow section extends downstream of a dog leg, measuring approximately 15m long and 5m wide. Water depth varies from approximately 0.1m to 1m.
- Pool bed is sandstone with alluvial 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

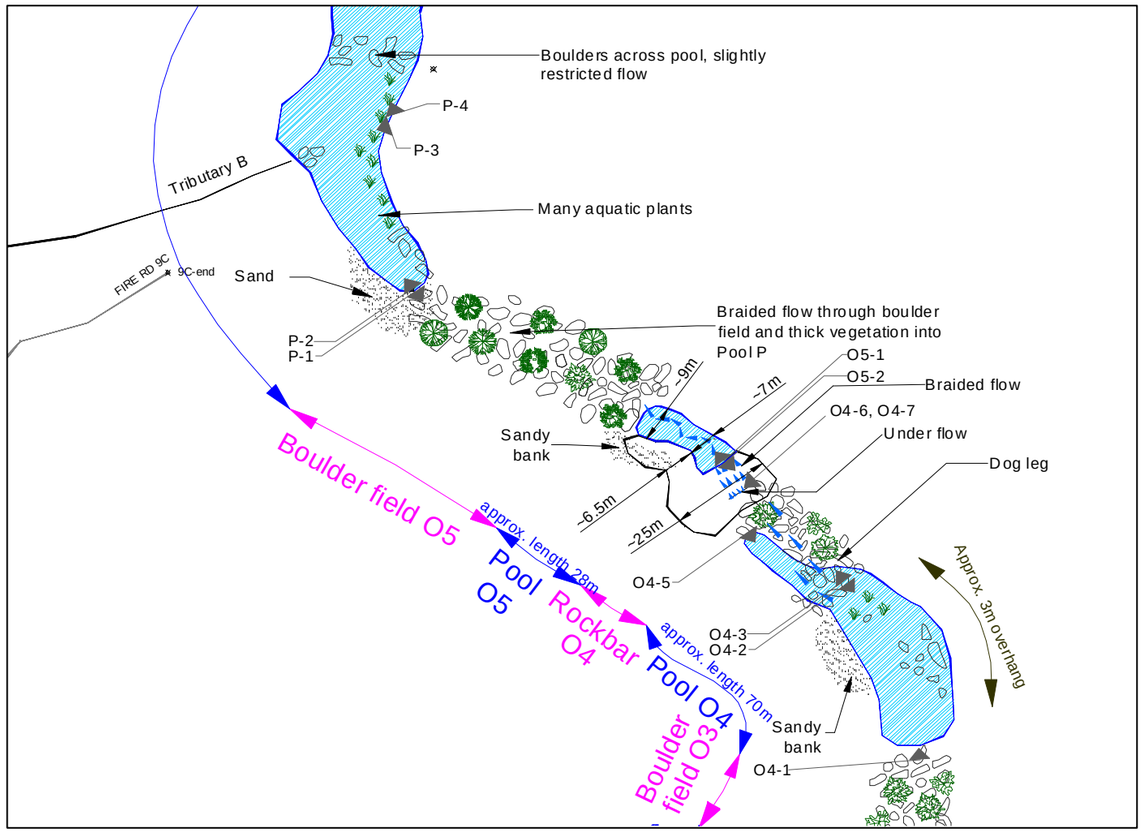
Photo Details

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

Pool P and Rockbar P (WRS6) notes (as at 17 Dec 2008)

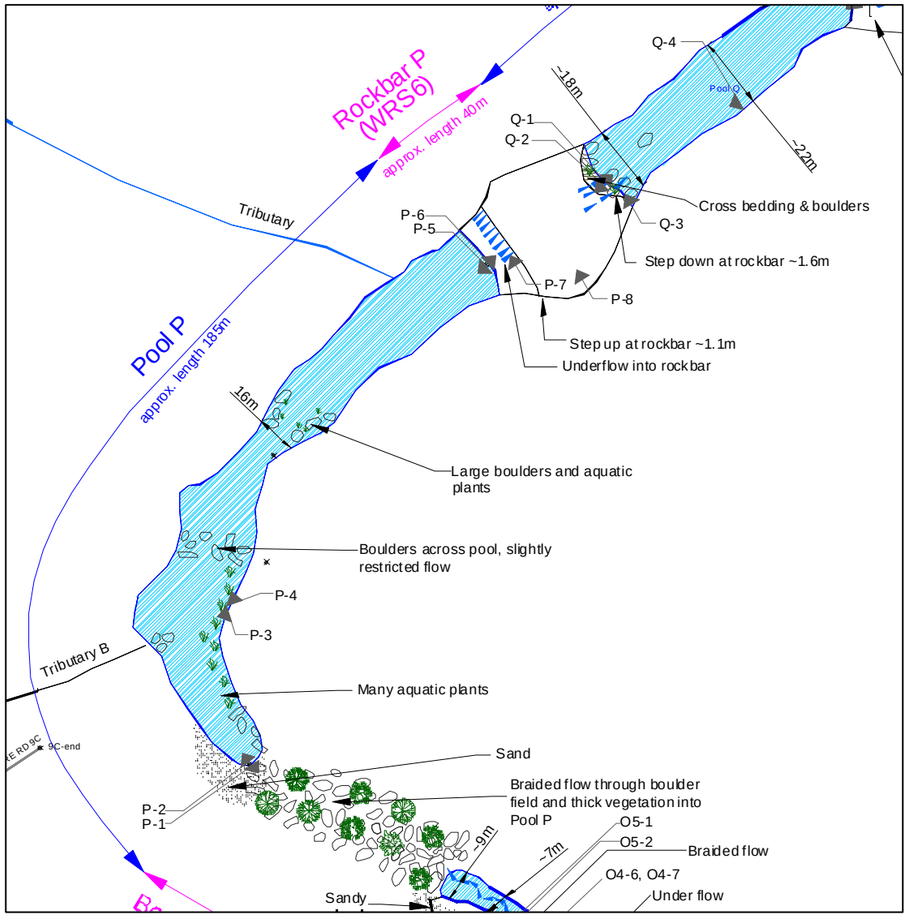
- Width varies from approximately 12m to 20m with an average of approximately 15m
- Water depth varies from approximately 2m (u/s end) to 0.2m with an average of approximately 0.6m
- Base of the pool is sandstone with several boulders and large detached blocks. Flow is restricted by boulders just downstream 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 approximatlely 9m from the d/s end of Pool P at a 1.1m step up in the rockbar. Flow below the rockbar is audible .



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

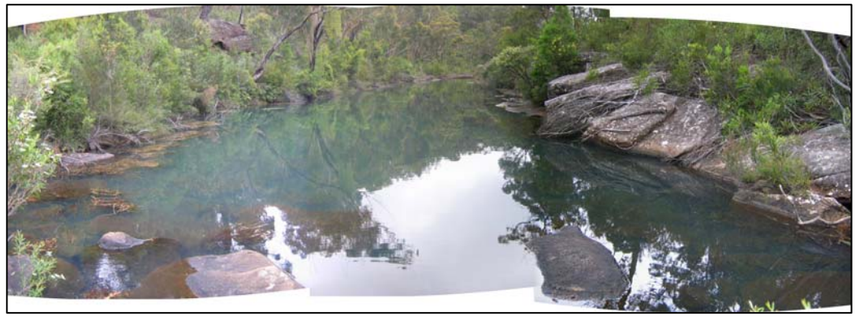


P-8 Looking north west across Rockbar P (WRS6)

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.

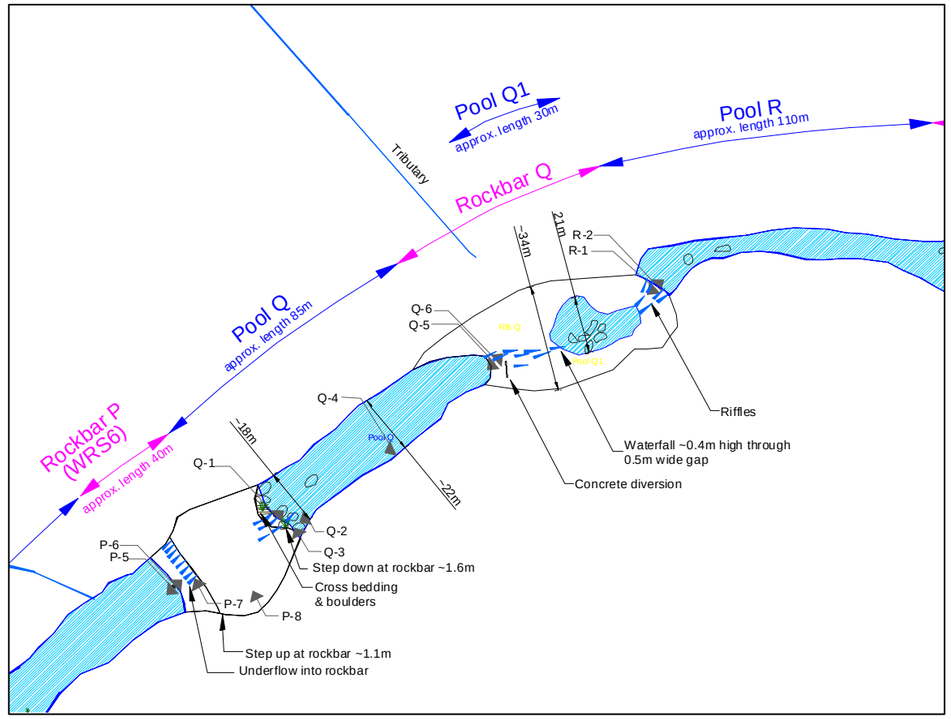


Photo Details

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



R-4 Downstream end of Pool R looking Downstream

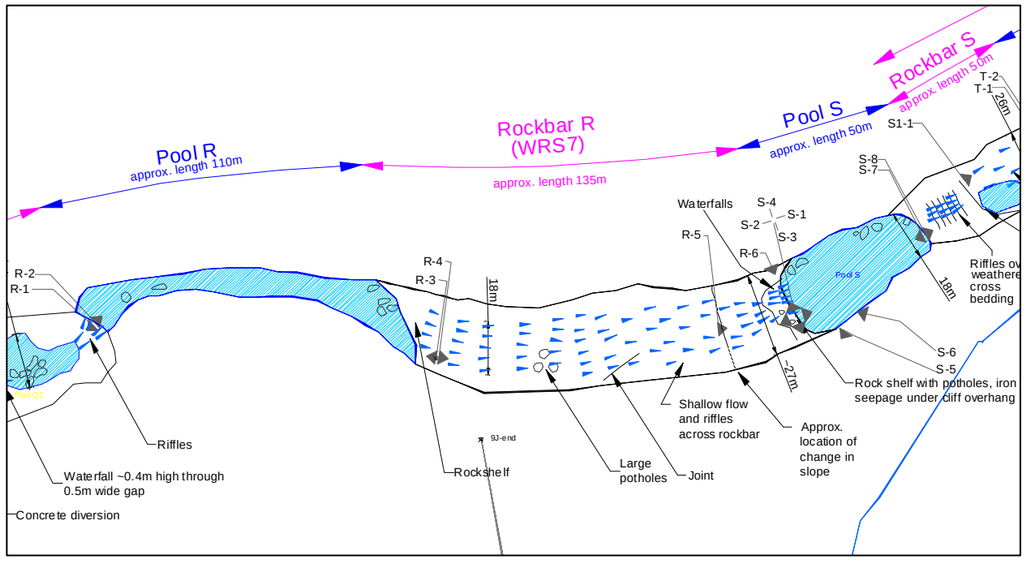


Photo Details

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-5 Rockbar R change of slope looking Downstream

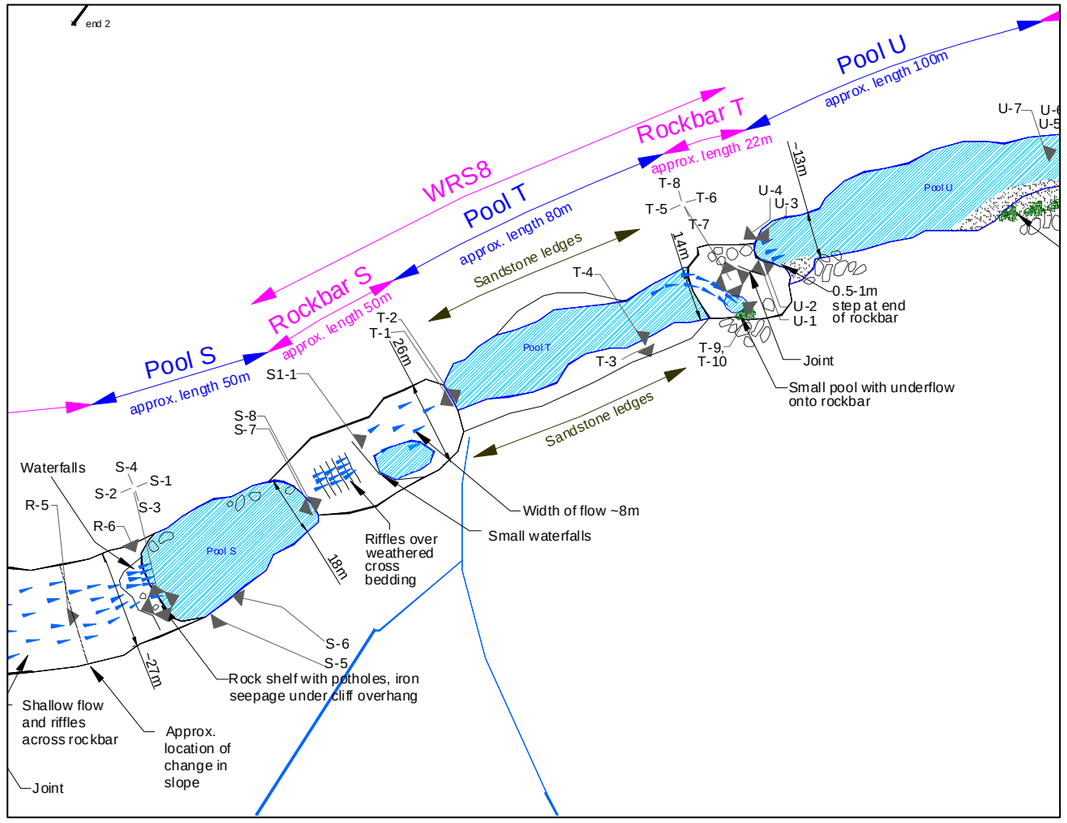


R-6 Downstream end of Rockbar R looking at south east bank

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)

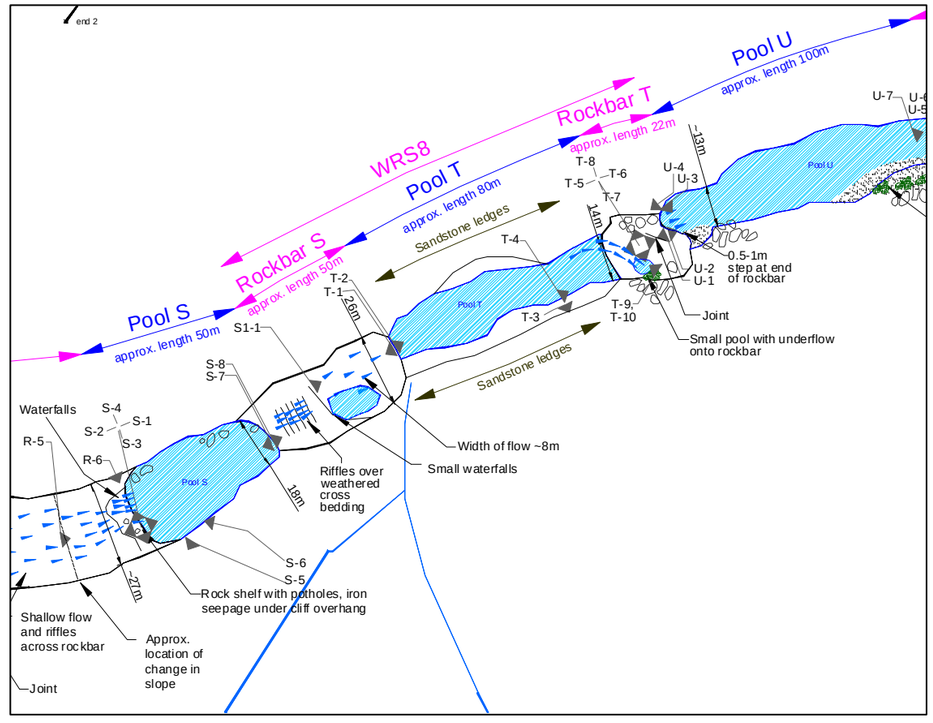
- Width is approximately 18m. Water depth at the upstream end of Pool S is 4.7m. Averge depth appears to be approximately 1.5m. Length of Pool S is approximately 50m.
- Base of the pool is sandstone.
- Estimated total height of waterfalls at upstream end of Pool S is approximately 1.9m.
- Some boulders 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

Pool T and Rockbar T (WRS8) notes (as at 24 Dec 2008)

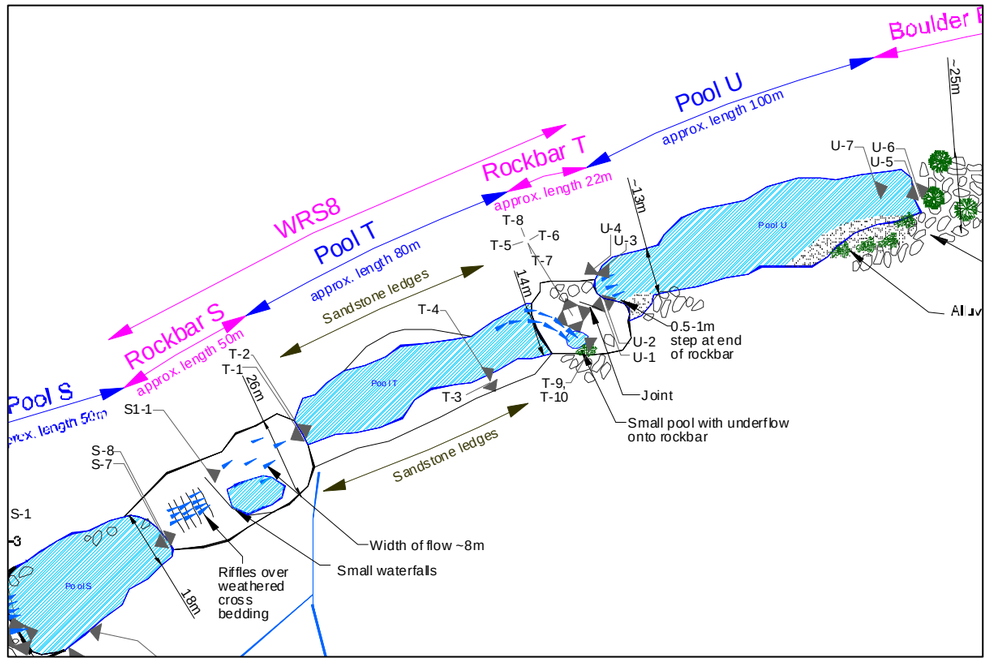
- Average width is approximately 14m. Depth varies from approximately 0.1m to 0.5m with an average of approximately 0.3m. The length of Pool T is approximately 80m.
- Base of the pool is sandstone with pot holes at about the middle of the pool and sediment at the upstream end.
- Sandstone ledges with 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



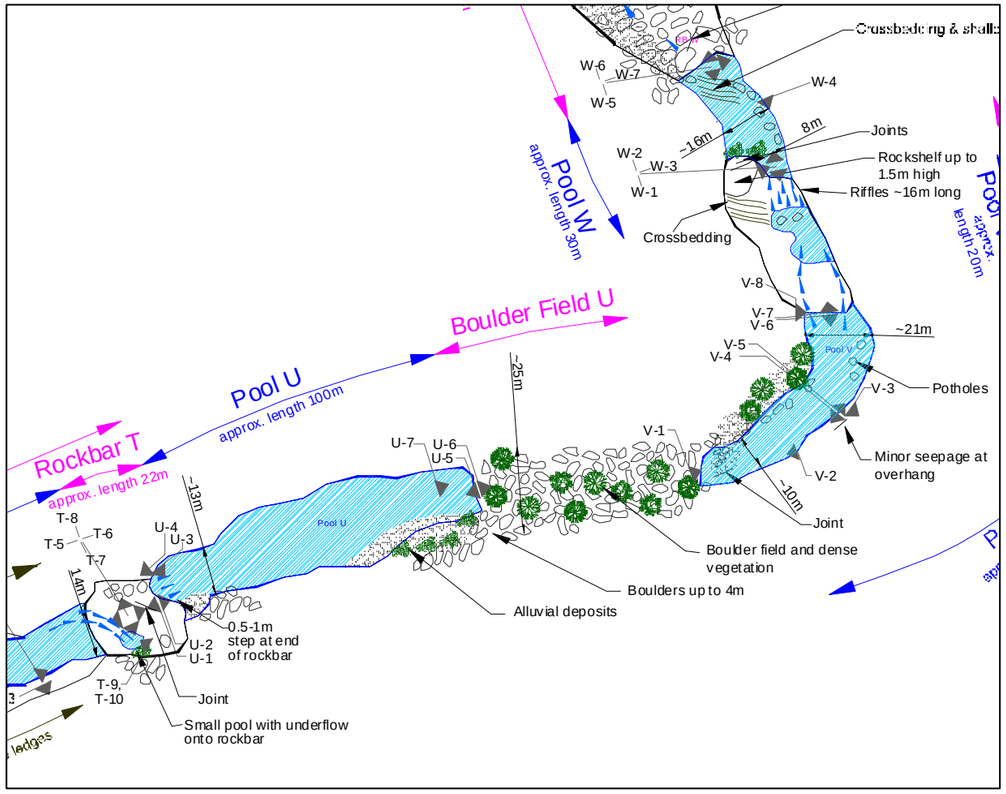
U-3 Potholes and flow emerging



U-2 Upstream end of Pool U looking Downstream

Pool U notes (as at 24 Dec 2008)

- 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-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)

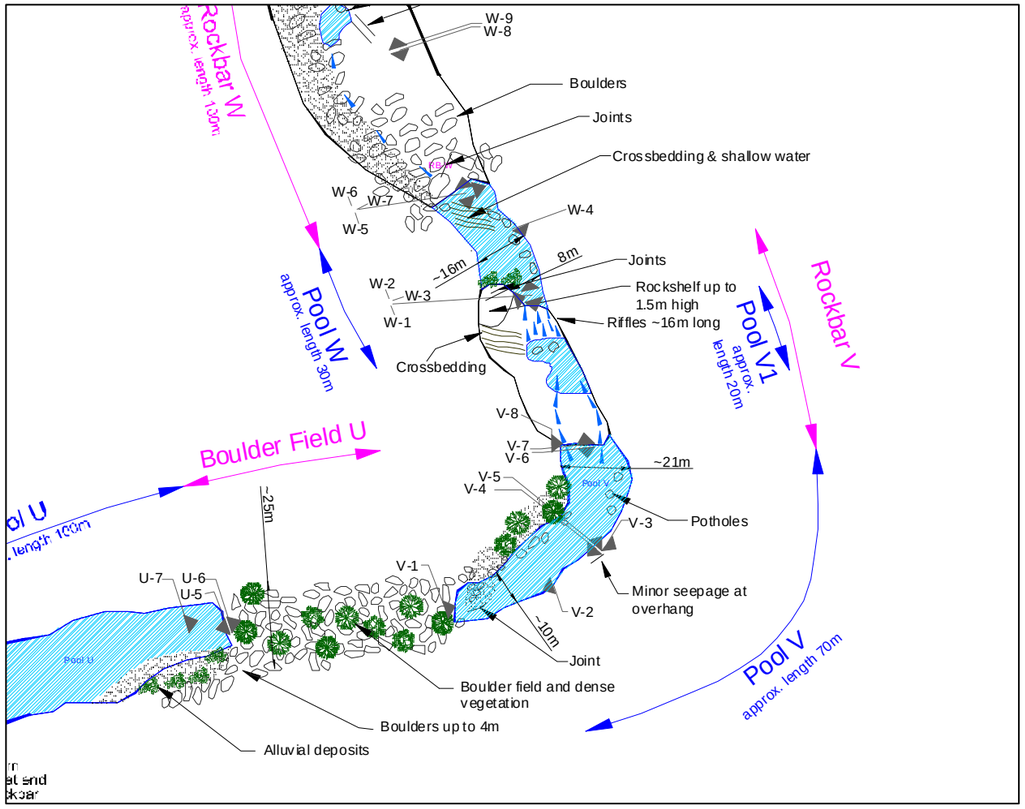
- Width varies from approximately 10m to 21m. Water depth varies from approximately 0.1m (u/s end) to 1.2m (d/s end)
- Base of the pool is sandstone with scattered boulders, minor alluvial deposits at the upstream end and aquatic vegetation at the upstream end.
- Minor seepage observed from sandstone 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



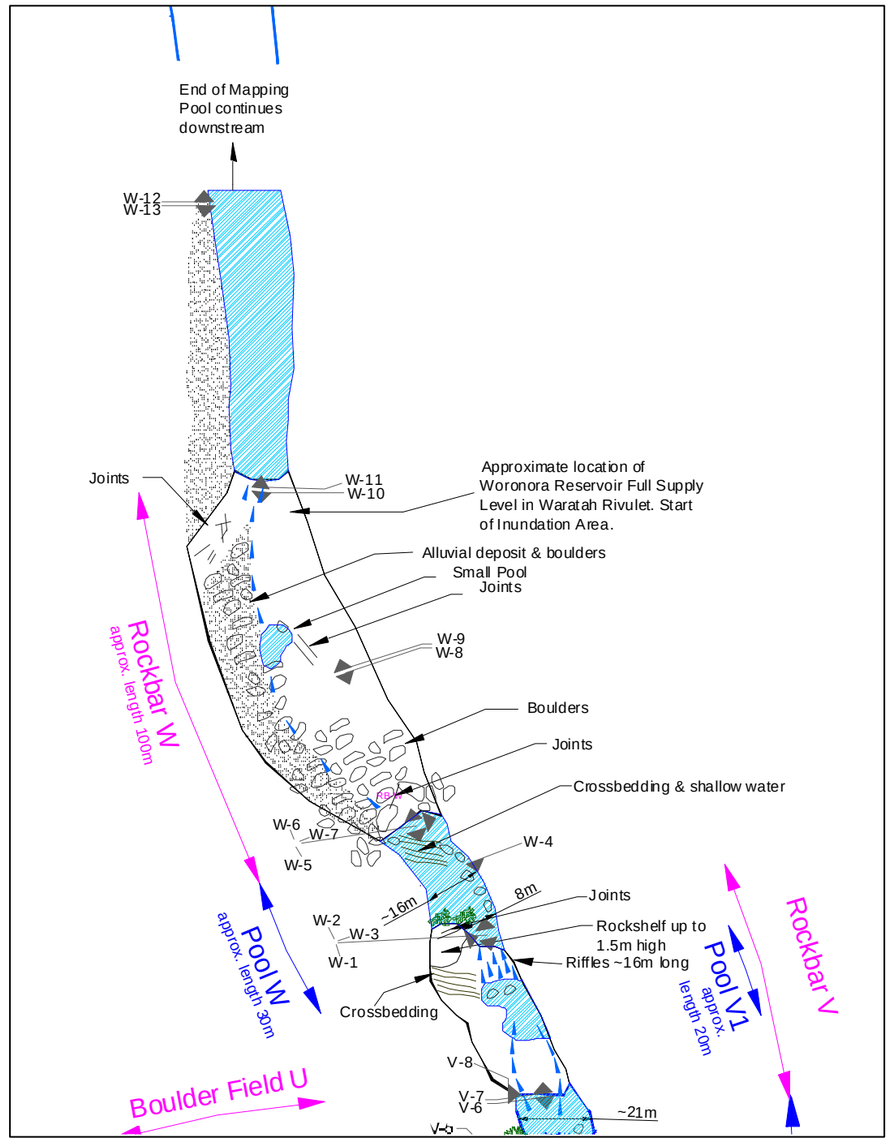
W-6 Downstream end of Pool W looking Downstream

Pool W notes (as at 24 Dec 2008)

- 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



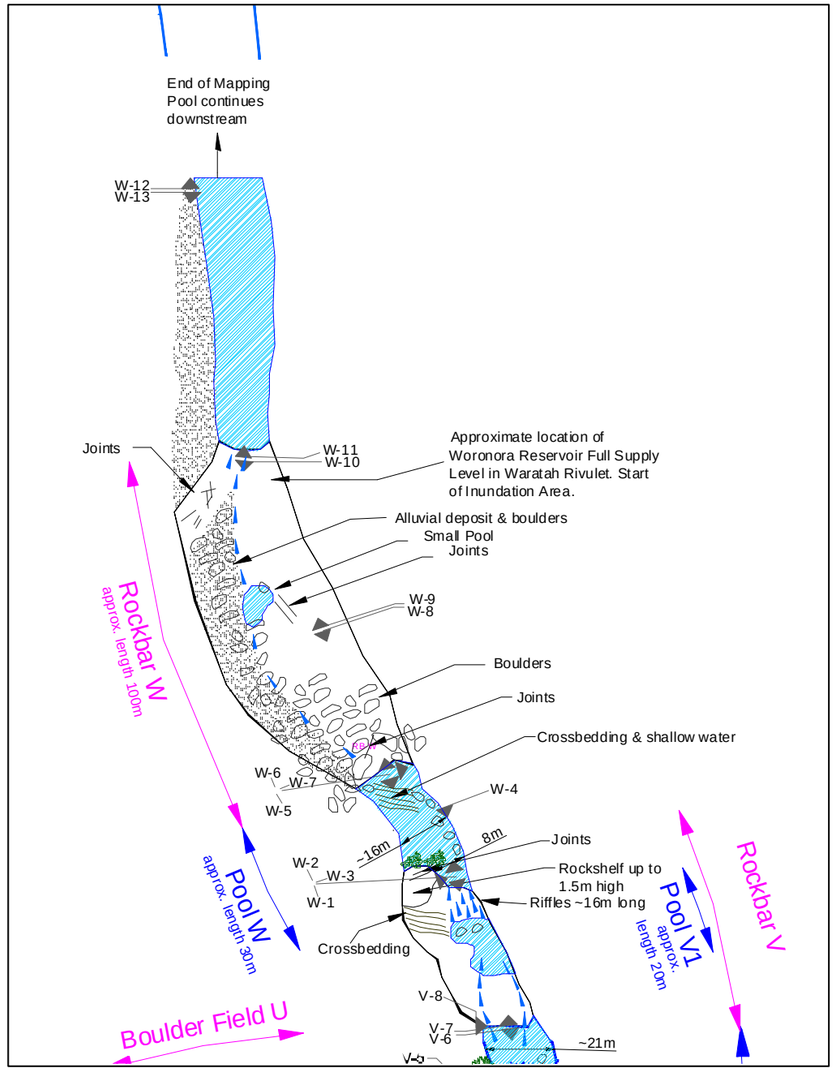
W-12 End of mapping (Pool X) looking Downstream



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)



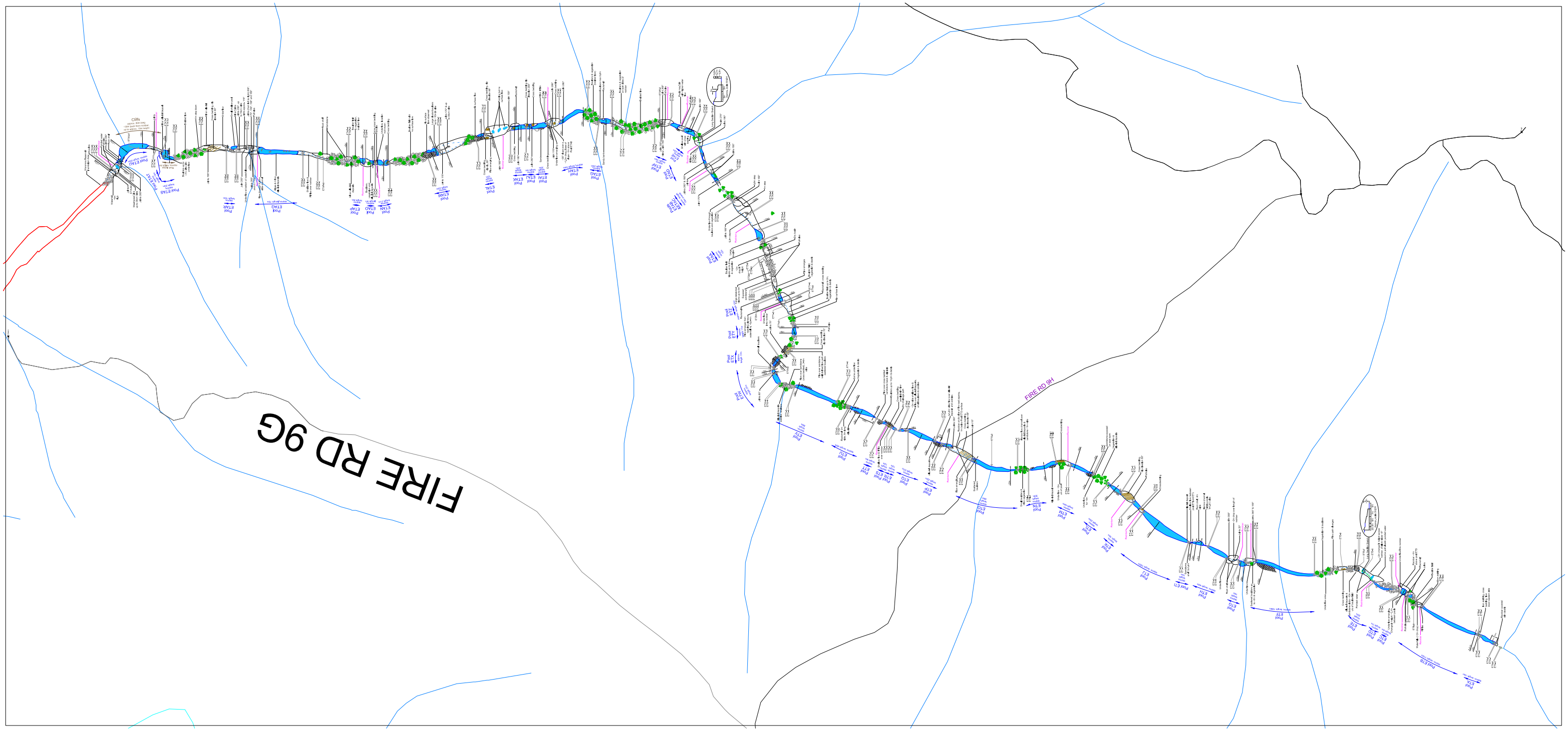
W-13 End of mapping (Pool X) looking Upstream

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-4 Rockbar Upstream of Pool ETA looking Downstream



ETA-2 Upstream end of Pool ETA looking Downstream



ETA-5 Downstream end of Pool ETA looking Upstream



ETA-3 Rockbar Upstream 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.

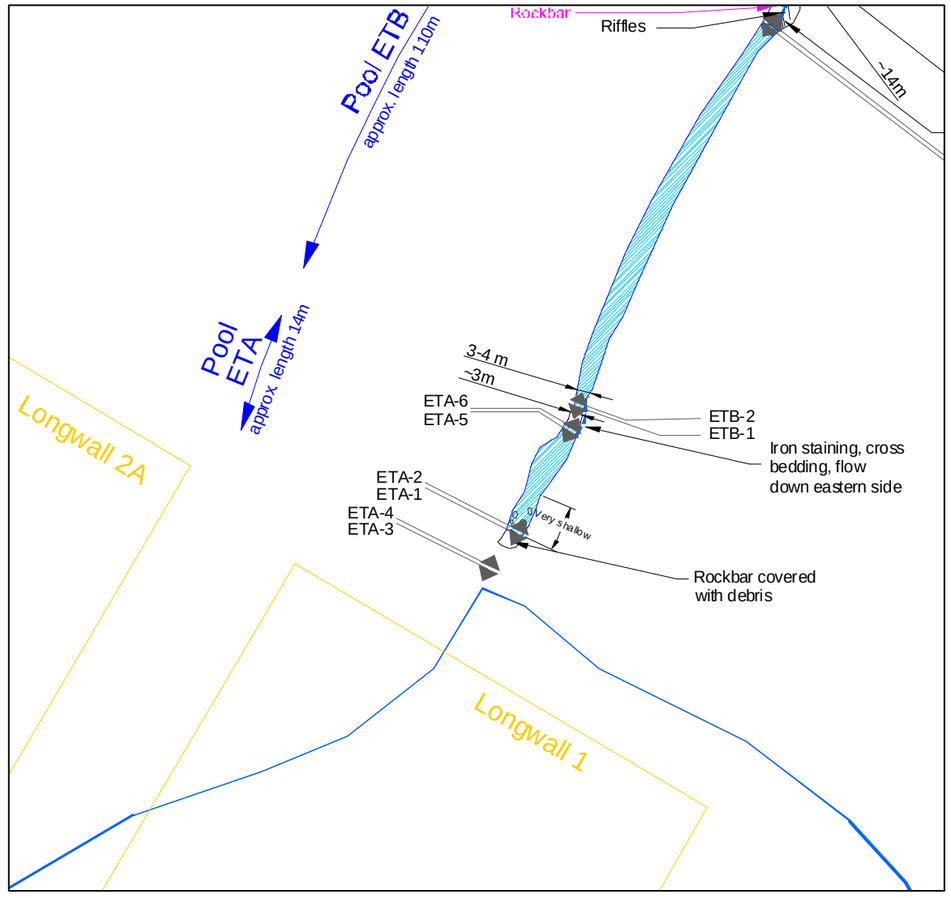


Photo Details

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



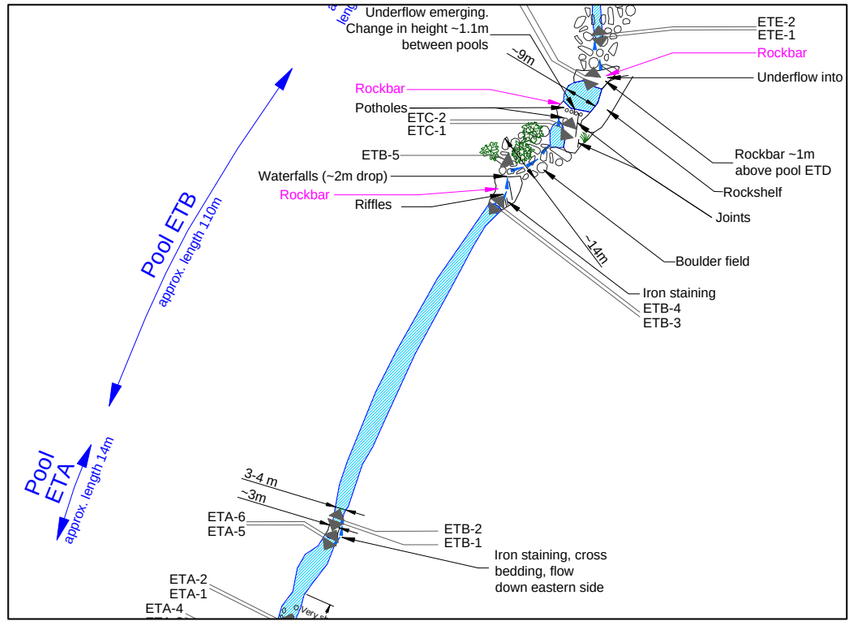
ETB-3 Downstream end of Pool ETB looking Upstream

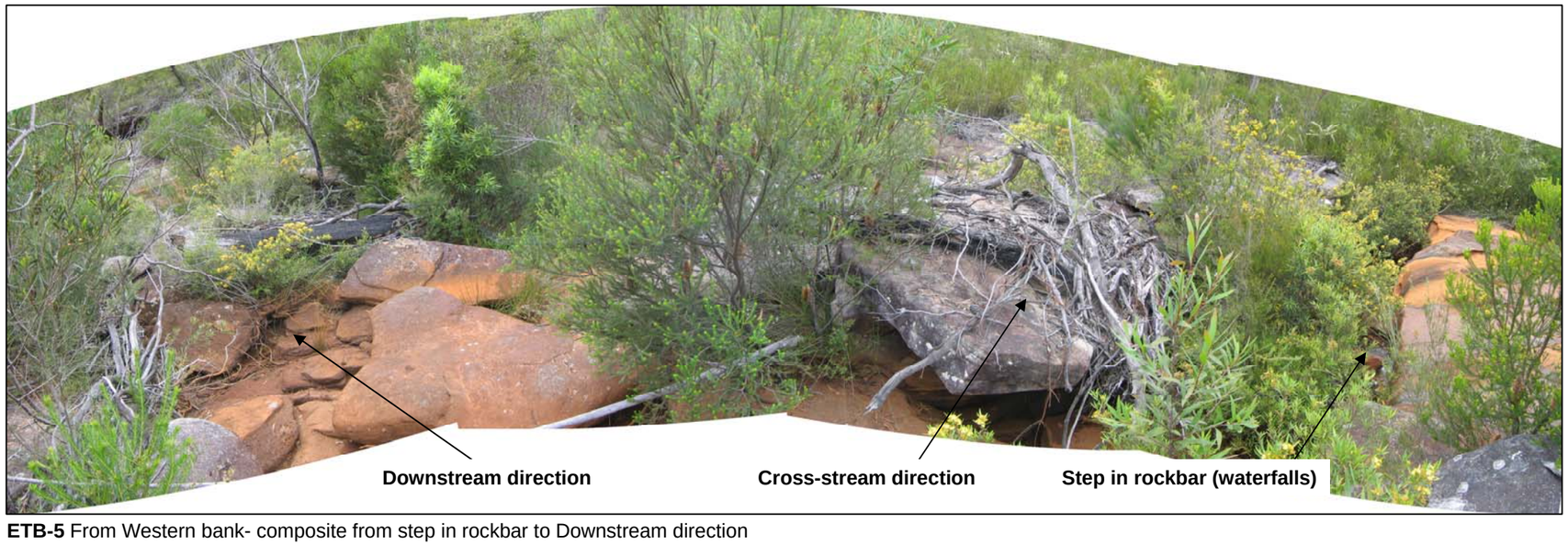


ETB-4 Downstream end of Pool ETB looking Downstream

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-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

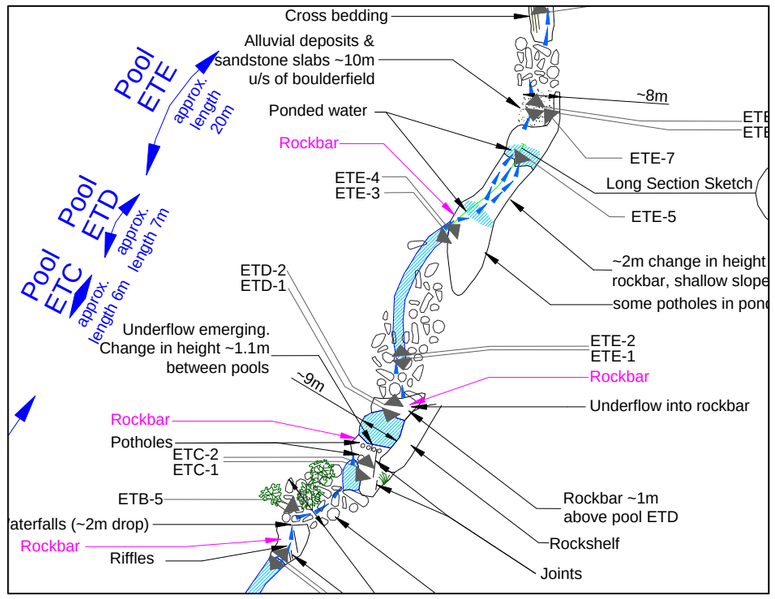
POOL ETC STREAM MAPPING SUMMARY



ETC-1 Downstream end of Pool ETC looking Upstream

Pool ETC notes (as at 29 Dec 2008)

- 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.

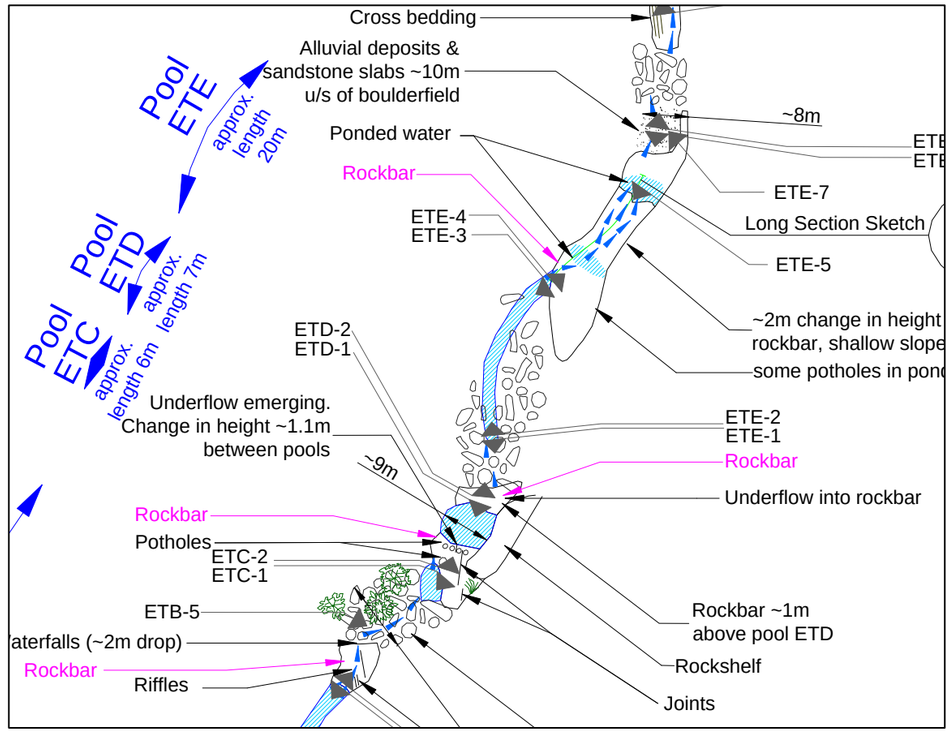


Photo Details

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



ETE-3 Downstream end of Pool ETE looking Upstream



ETE-4 Downstream 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)

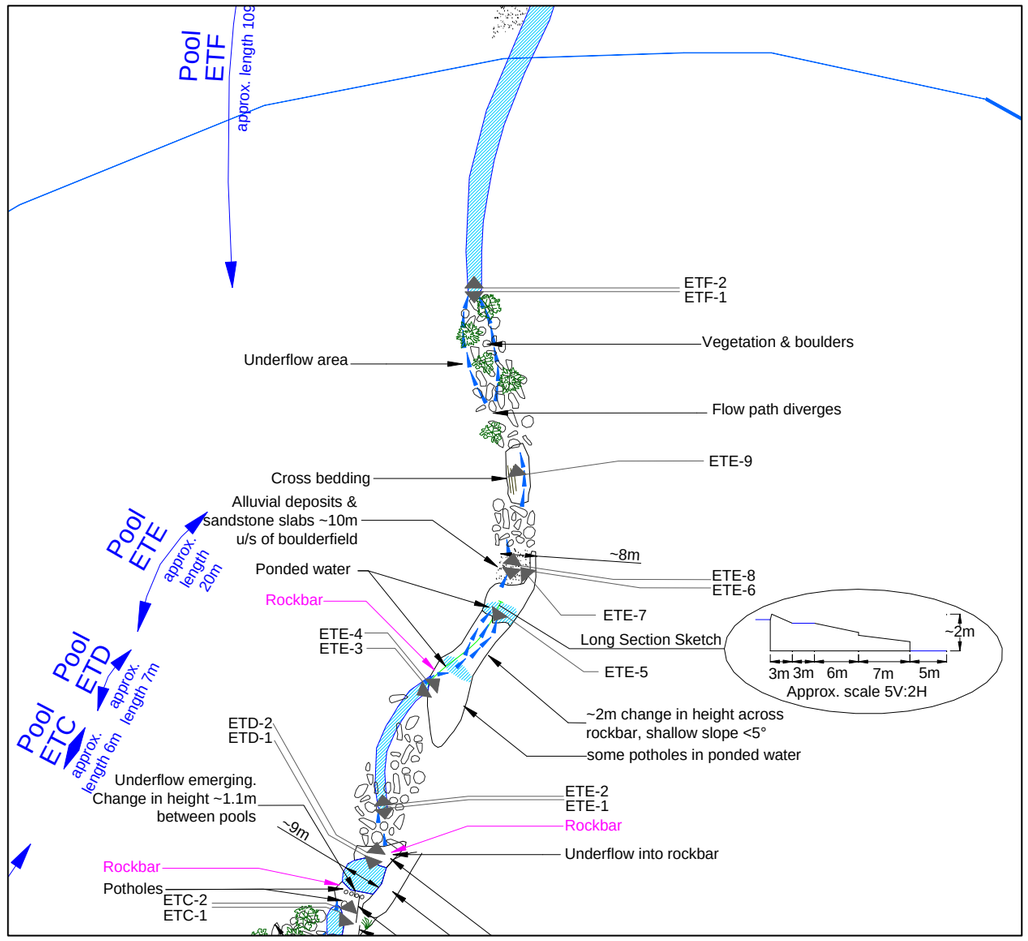


Photo Details

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

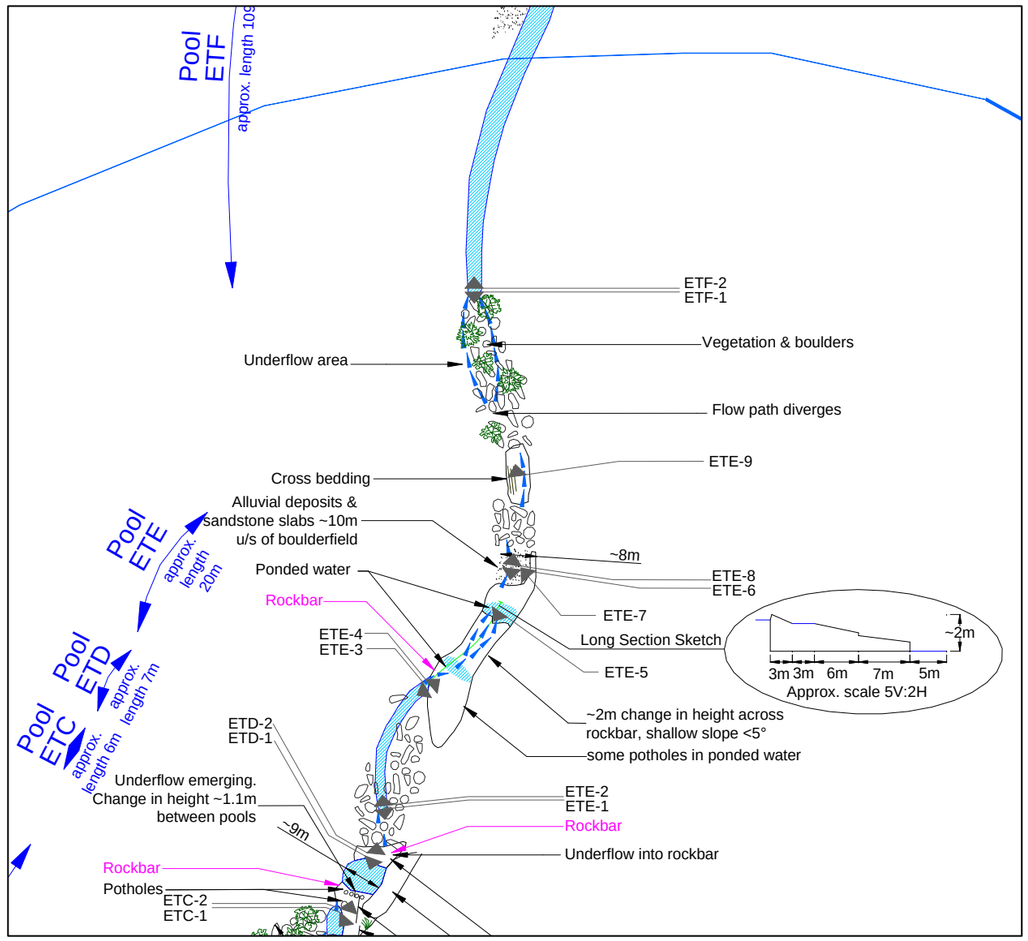


Photo Details

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.

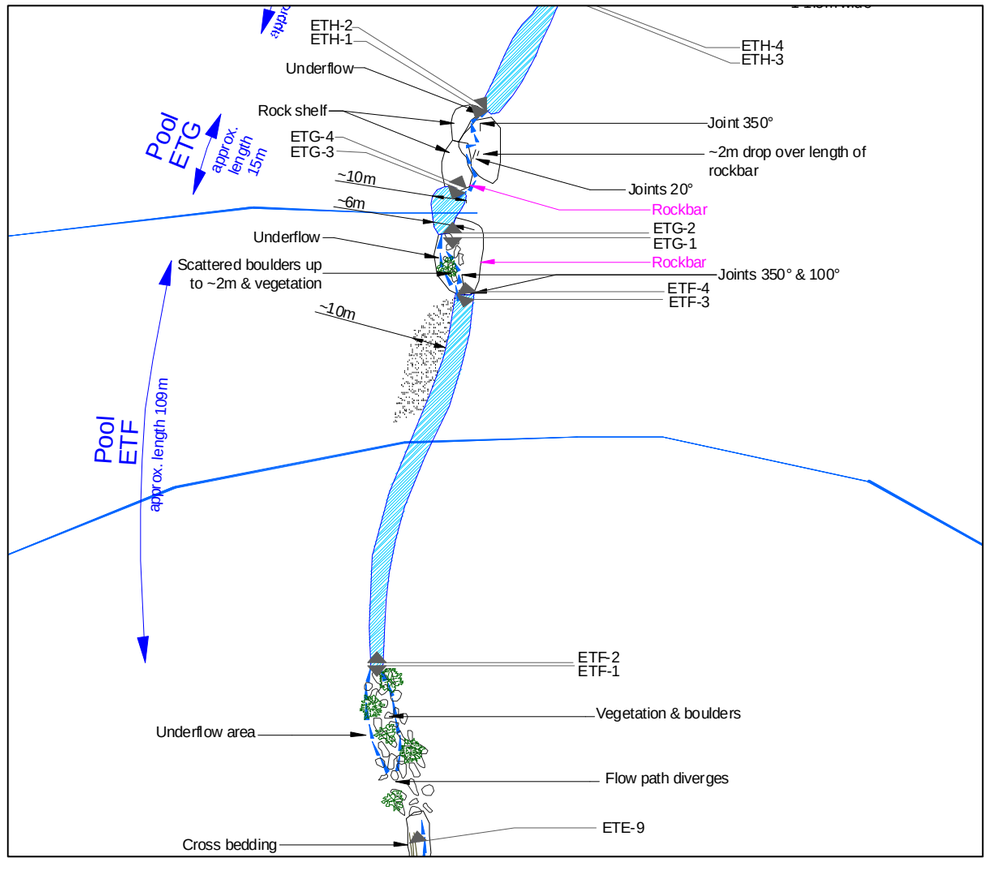


Photo Details

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.

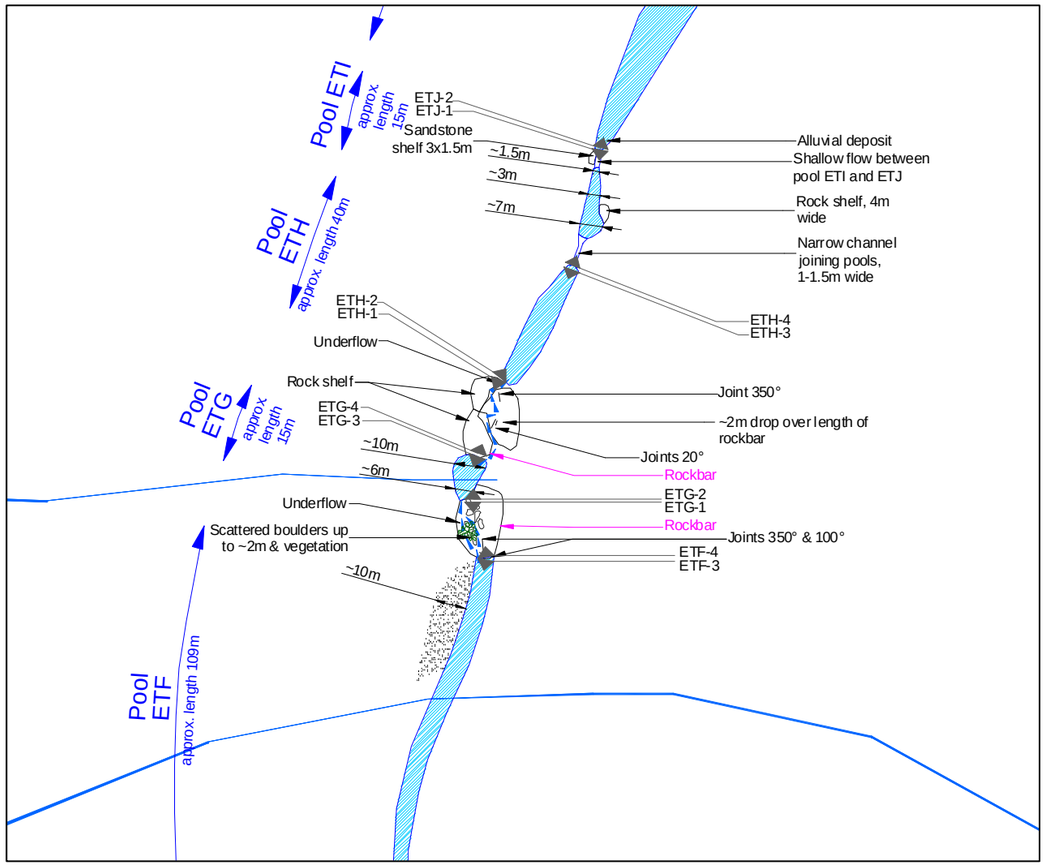


Photo Details

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



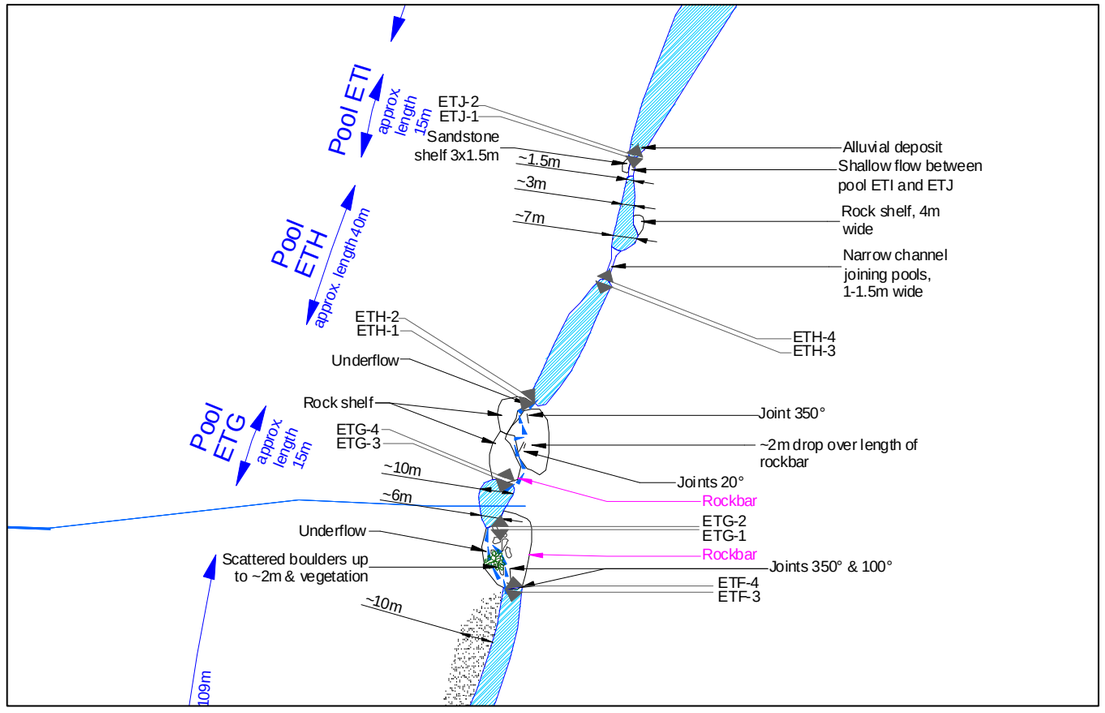
ETH-1 Upstream end of Pool ETH looking Upstream



ETH-2 Upstream end of Pool ETH looking Downstream

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.





ETH-3 Downstream end of Pool ETH looking Upstream



ETH-4 Downstream end of Pool ETH looking Downstream

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

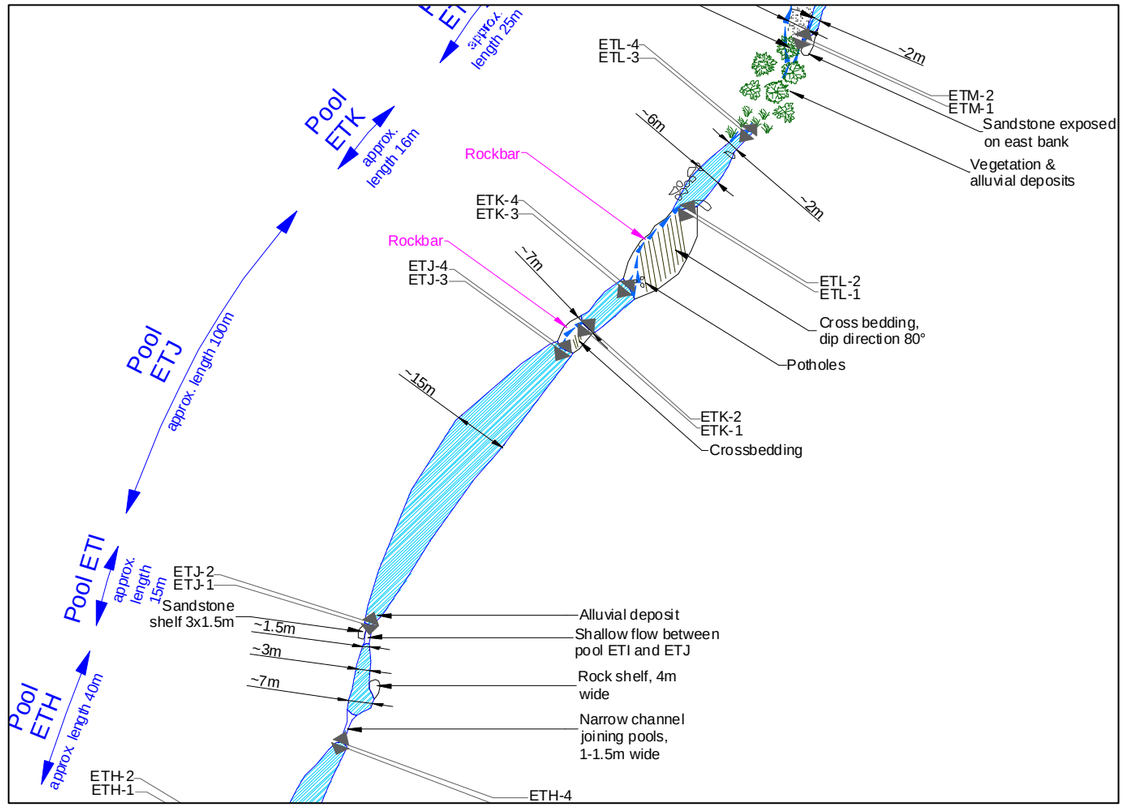


Photo Details

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.

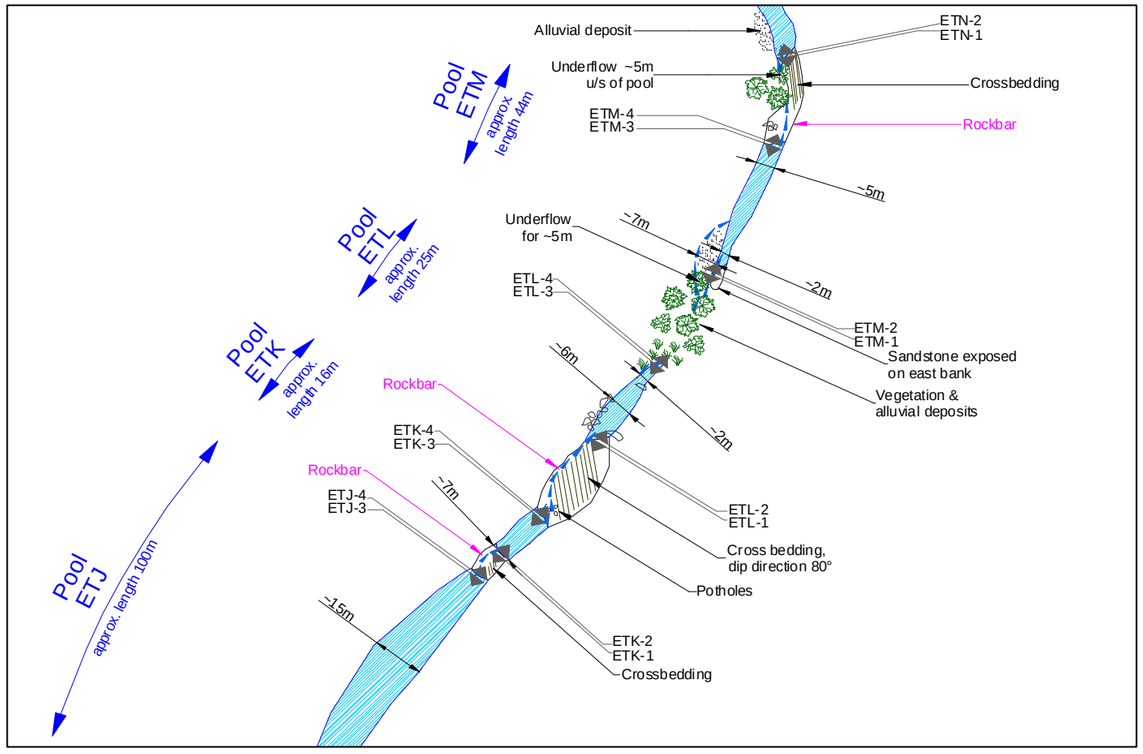


Photo Details

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.

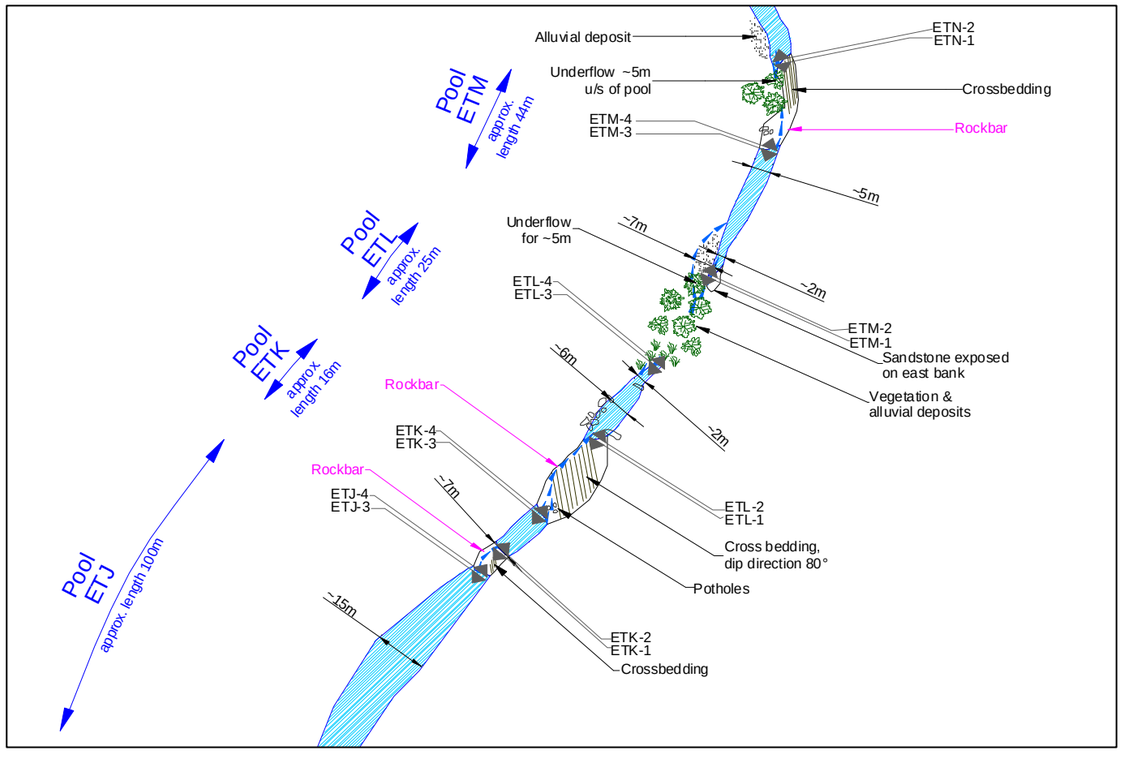


Photo Details

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

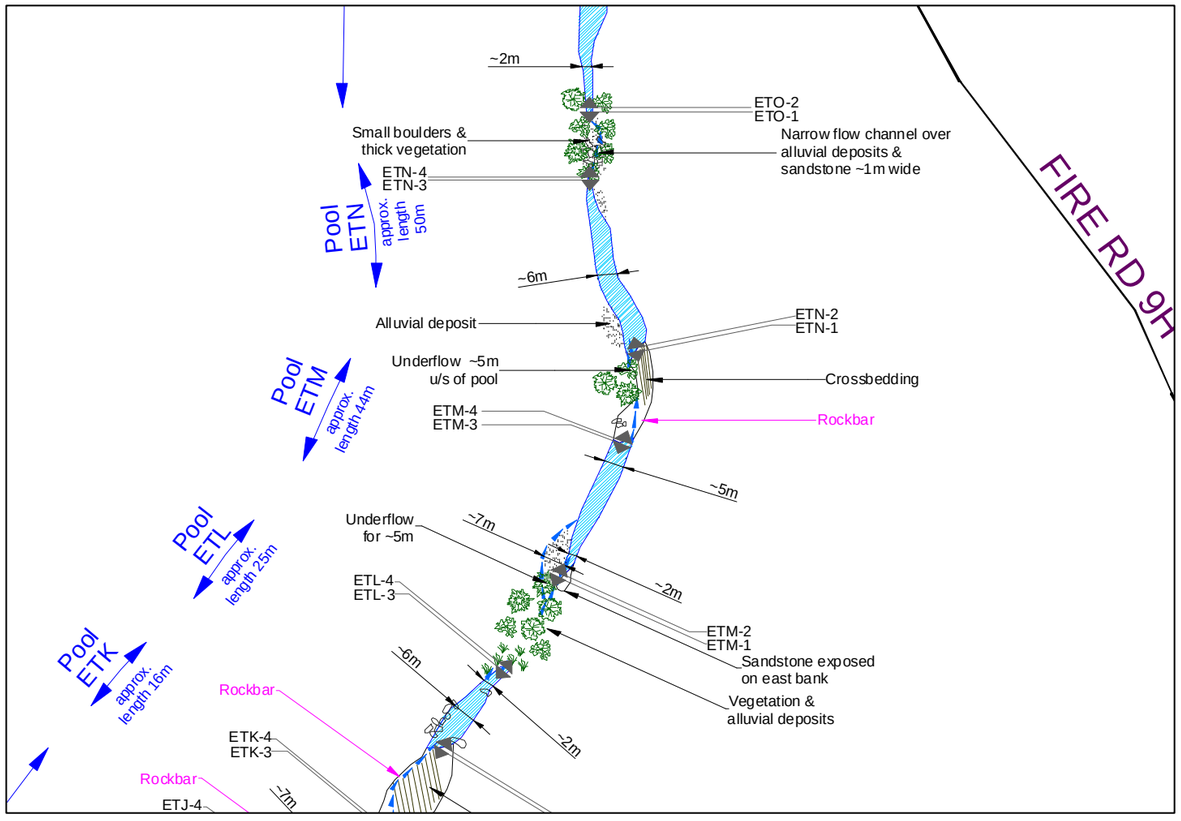


Photo Details

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

Pool ETN notes (as at 29 Dec 2008)

- 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.

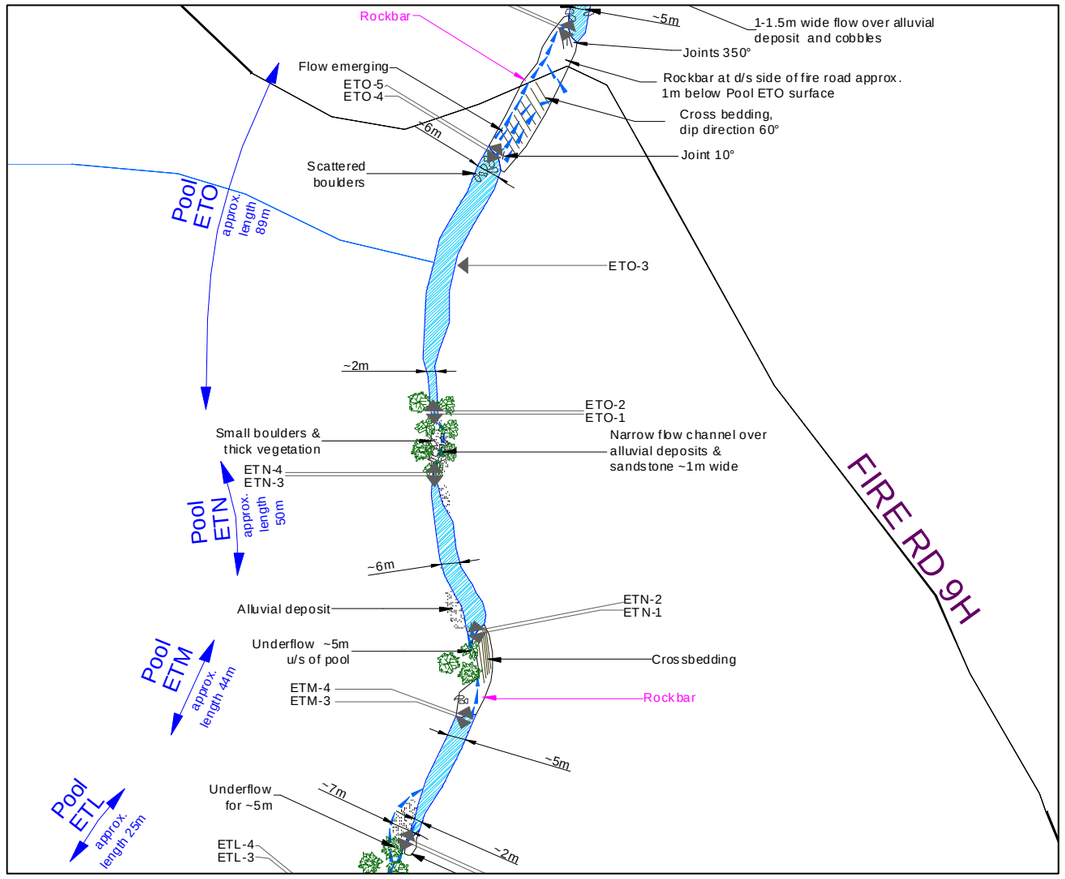


Photo Details

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

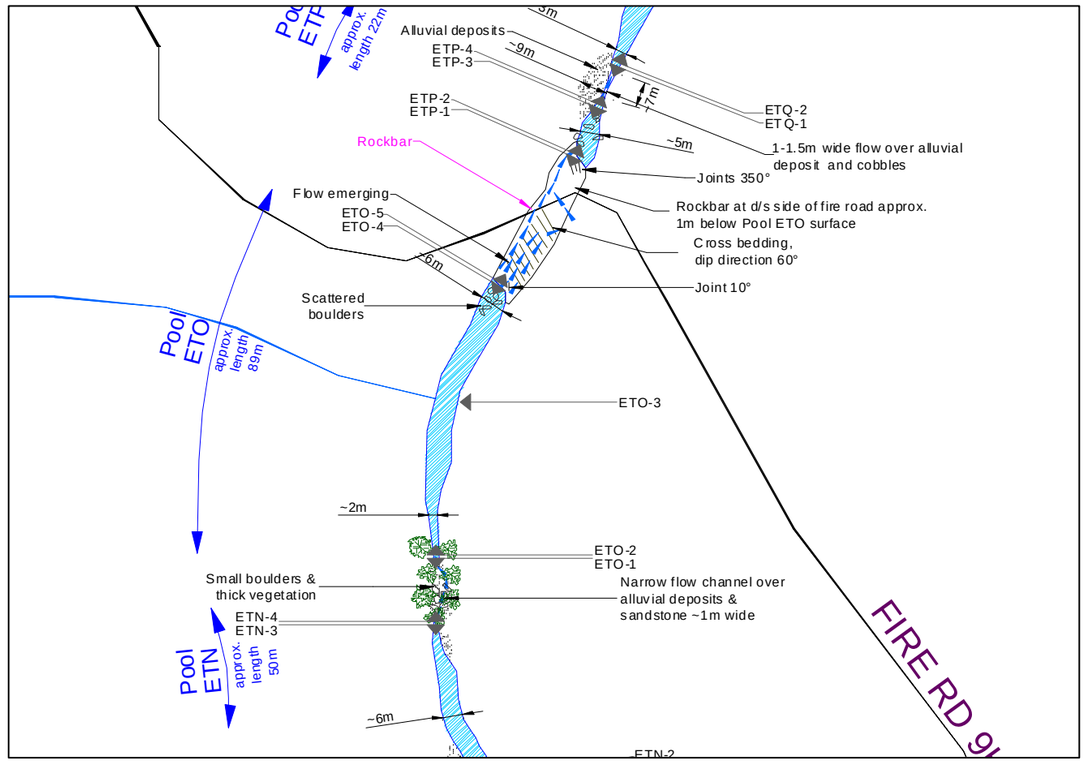


Photo Details

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.

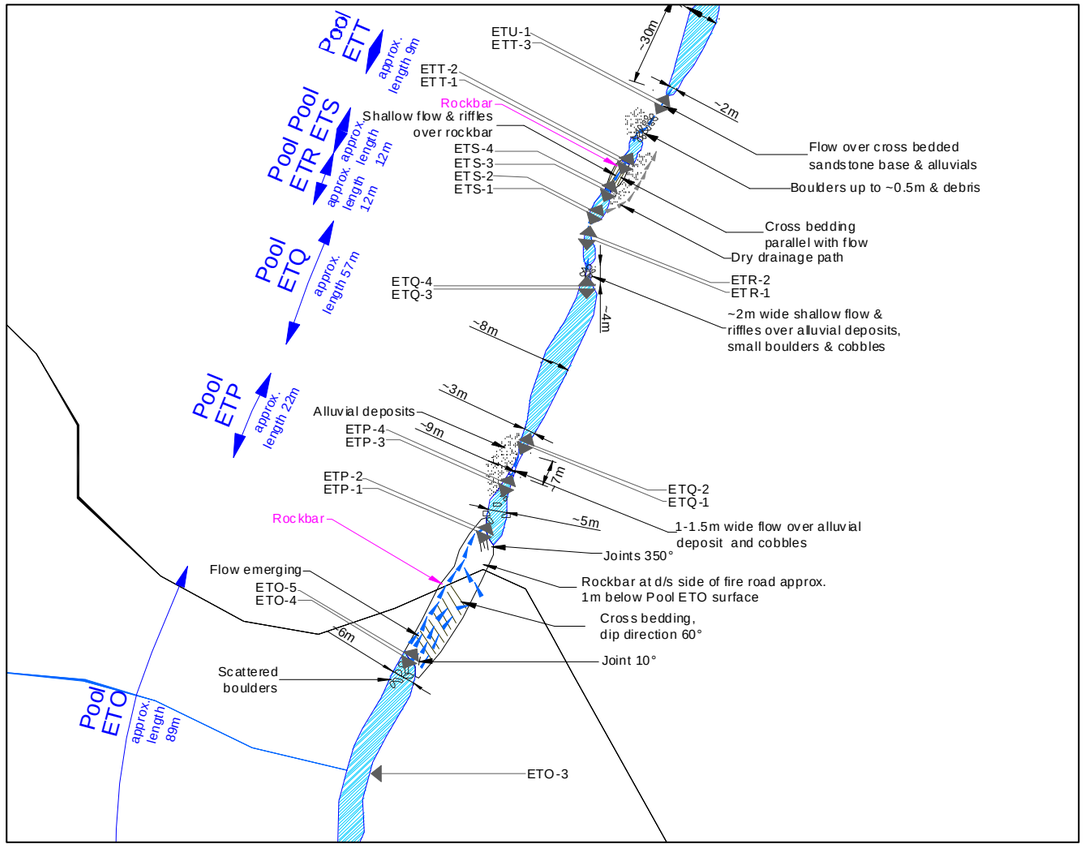


Photo Details

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

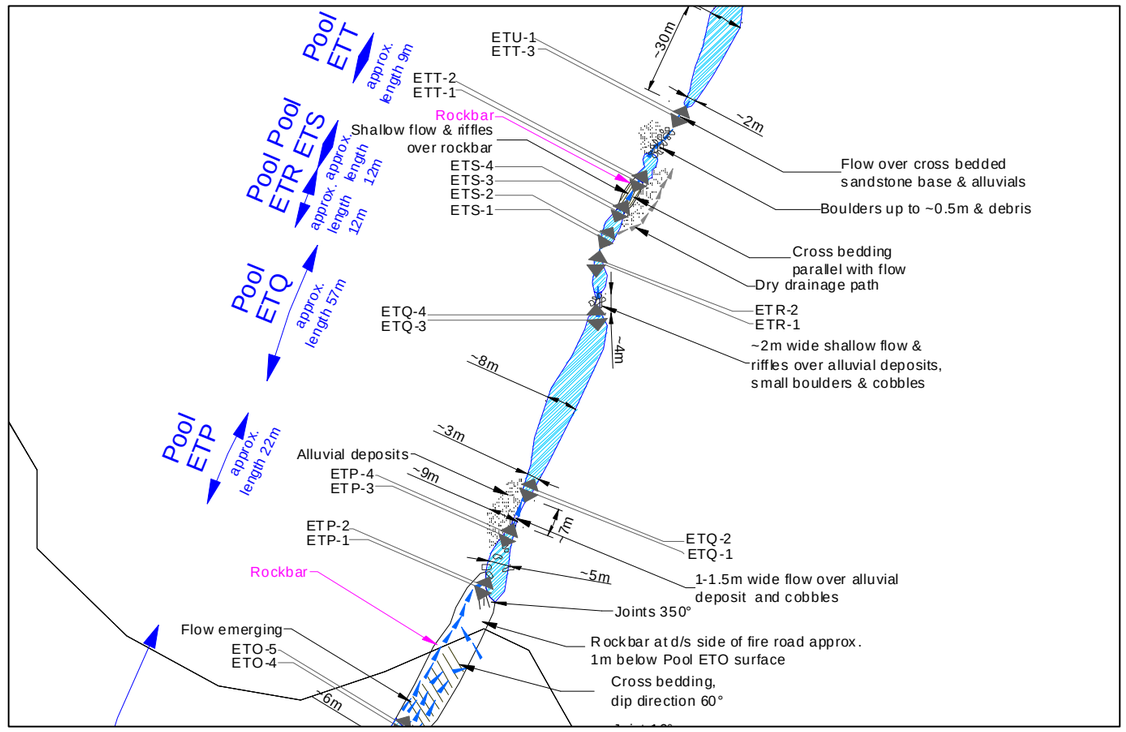


Photo Details

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

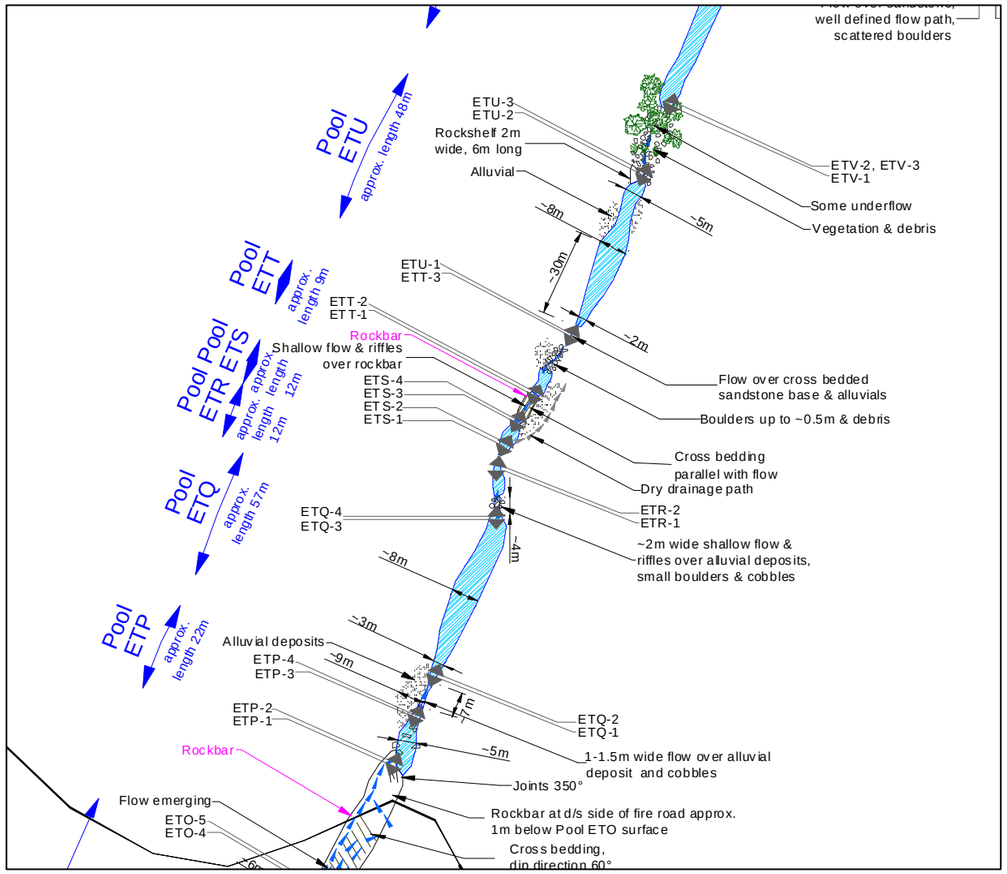
POOL ETR STREAM MAPPING SUMMARY



ETR-1 Downstream end of Pool ETR looking Upstream

Pool ETR notes (as at 29 Dec 2008)

- 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.





ETR-2 Downstream end of Pool ETR looking Downstream

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



ETS-3 Downstream end of Pool ETS looking Upstream



ETS-4 Downstream 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.

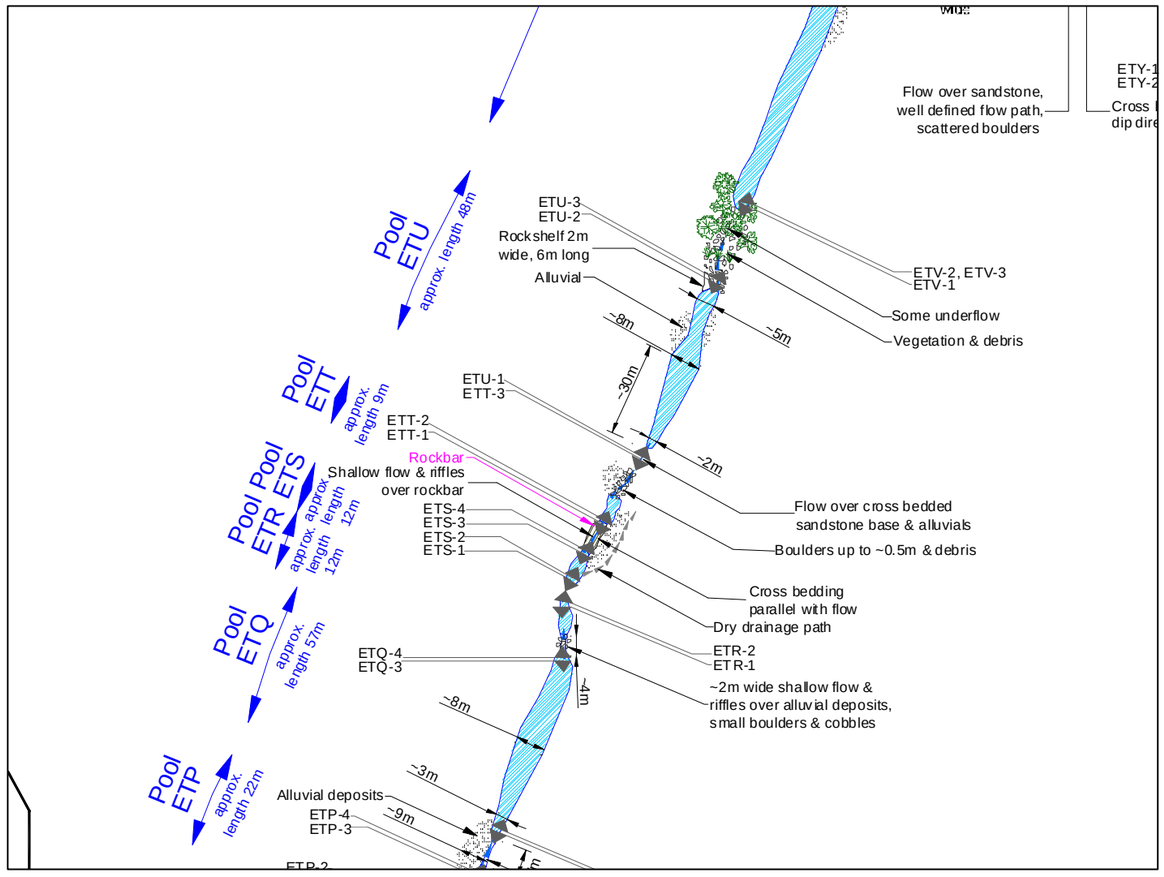


Photo Details

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

Pool ETT notes (as at 29 Dec 2008)

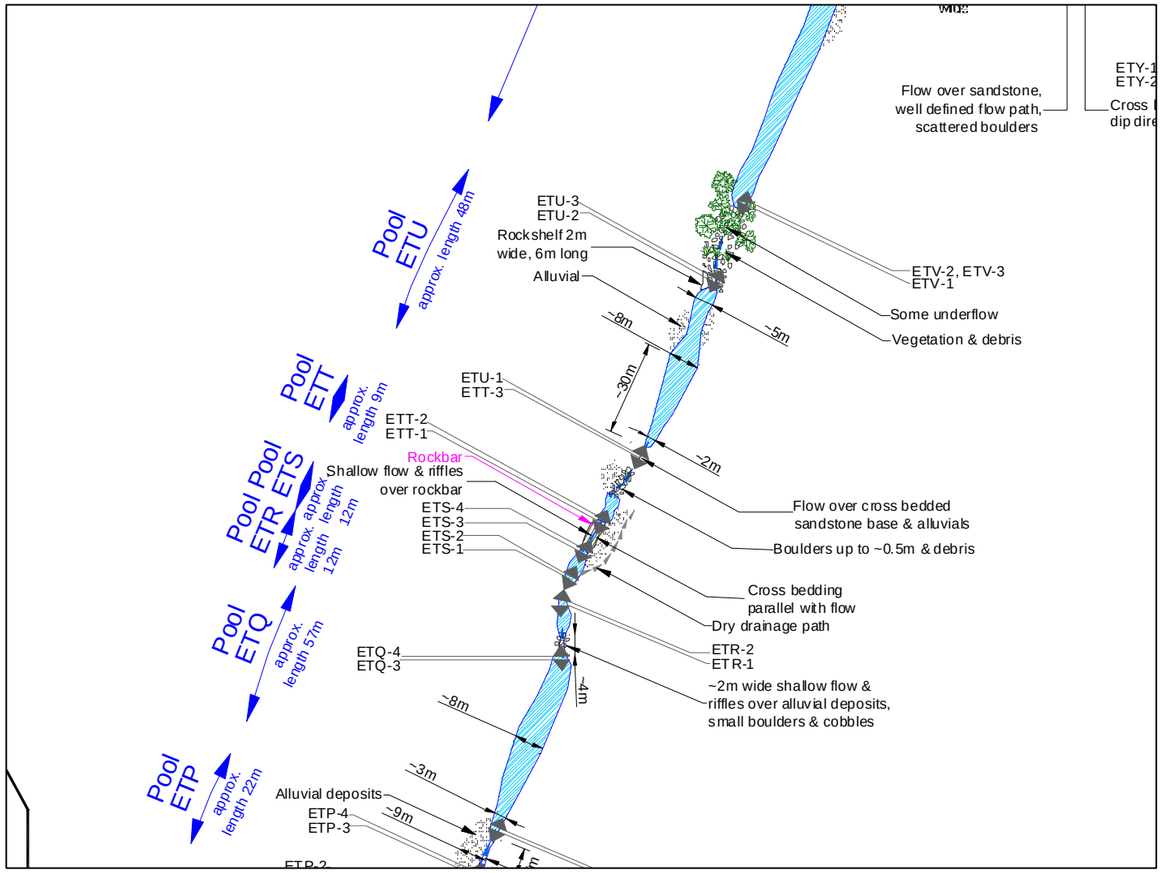
- Width varies from approximately 2m to 4m
- Water depth varies from approximately 0.2m to 0.6m with an average of approximately 0.3m.
- Base of the pool is sandstone with allluvial deposits, boulders and cobbles.
- Large alluvial deposit on eastern side of the pool. A dry drainage path is present through 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

Pool ETU notes (as at 29 Dec 2008)

- 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.

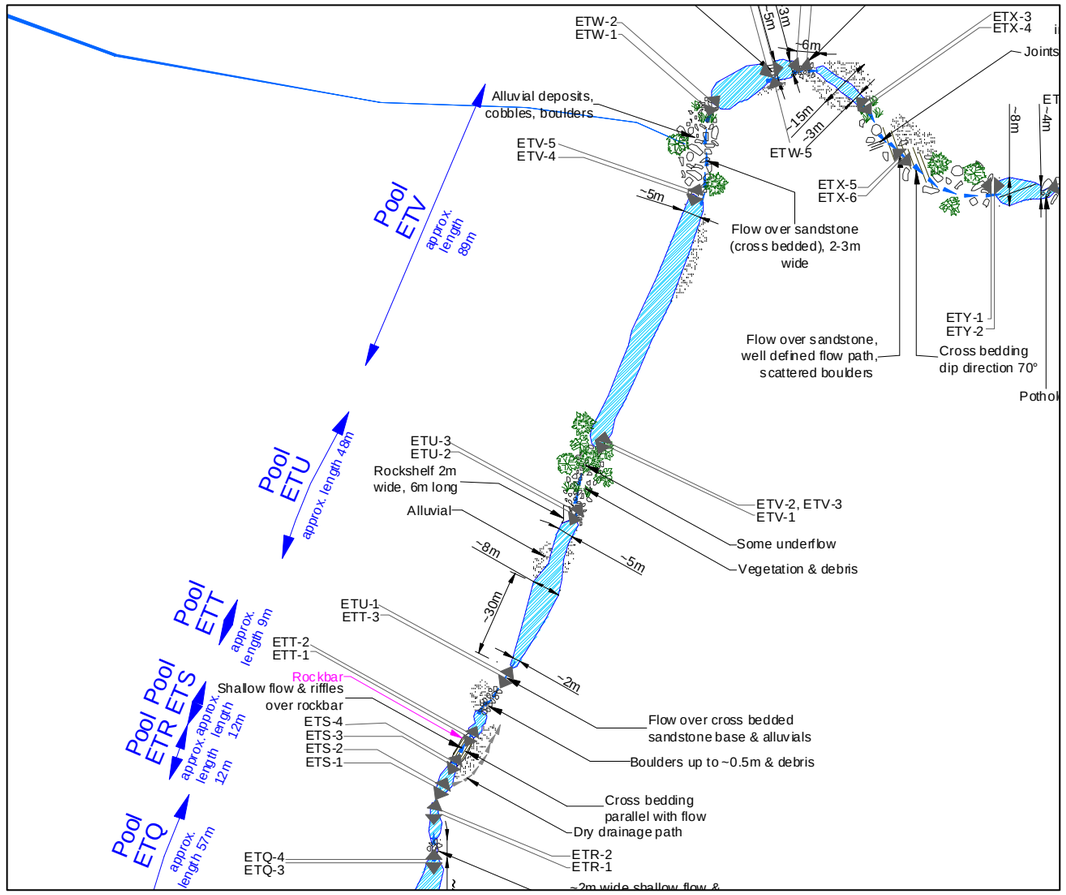


Photo Details

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





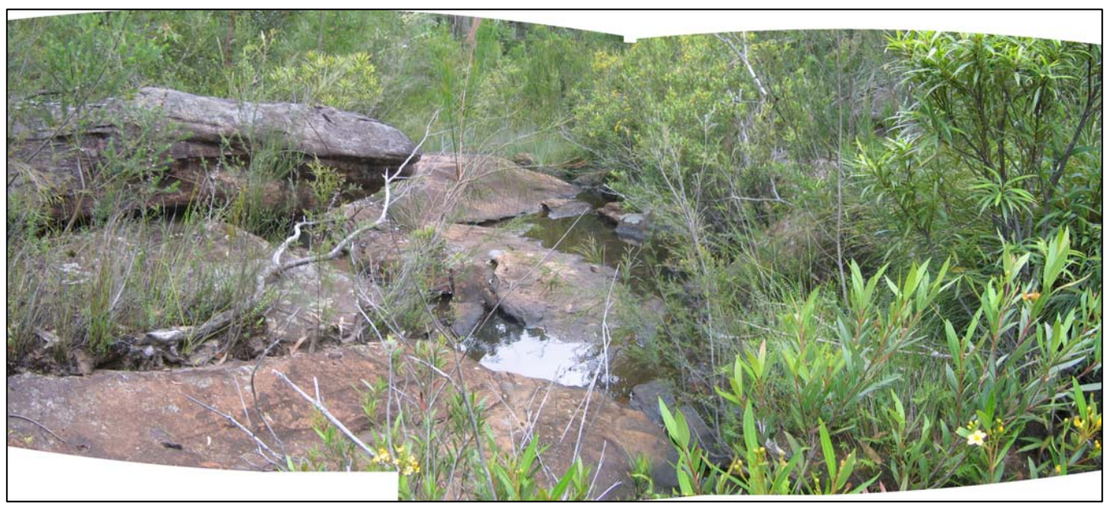
ETV-2 and ETV-3 Upstream end of Pool ETV looking Downstream

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

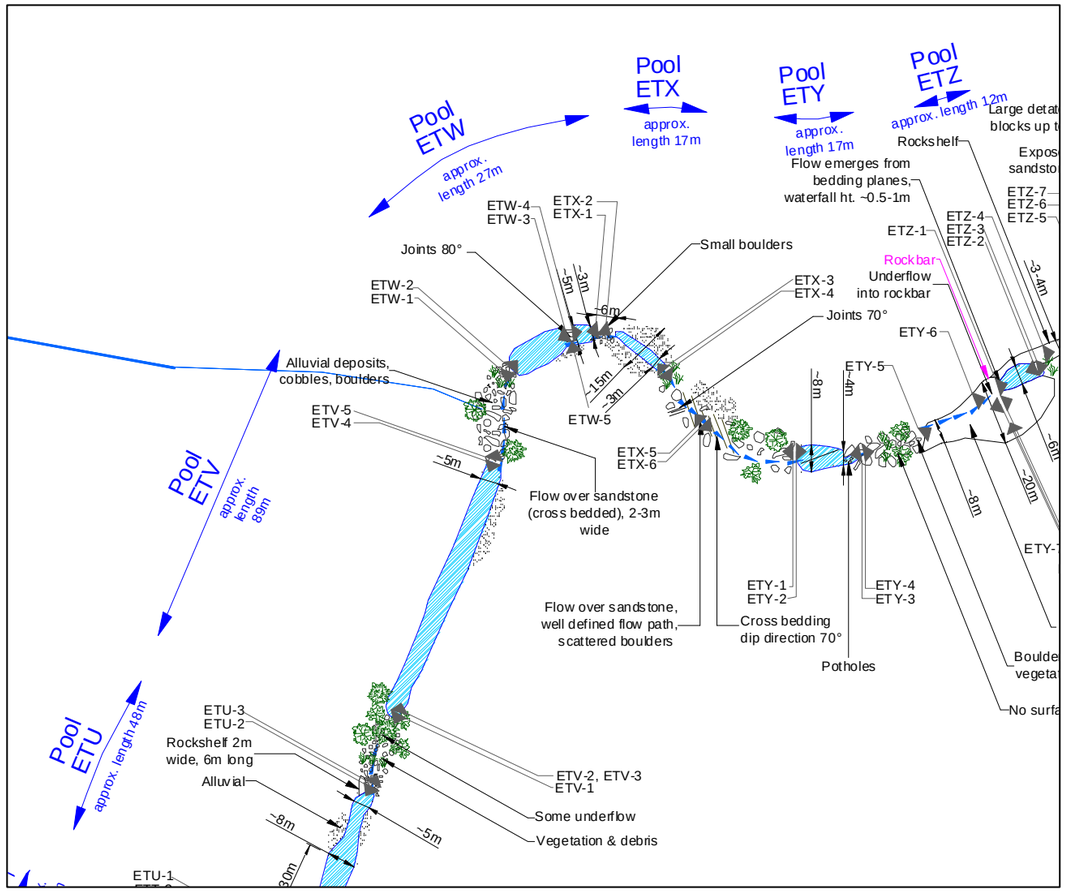


Photo Details

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)

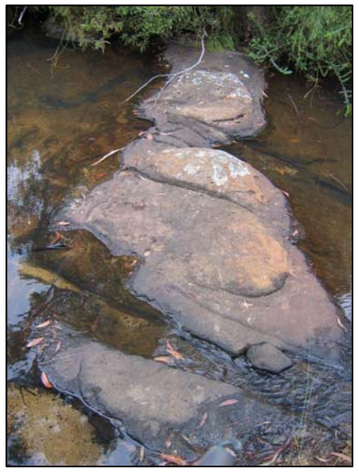
- Width varies from approximately 3m to 5m.
- Water depth varies up to a maximum of approximately 1.5m to 2m.
- Base of the pool is sandstone with alluvial deposits and several boulders up to approximately 1m size.
- A small rockbar almost separates a smaller section of the pool downstream. The rockbar 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

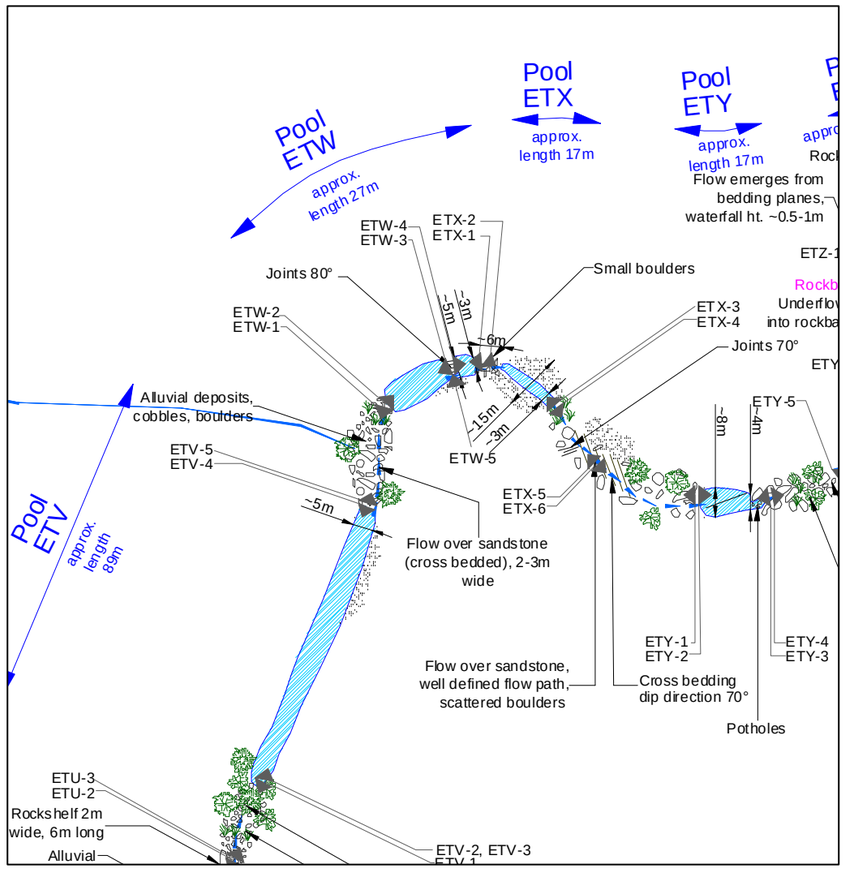


Photo Details

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



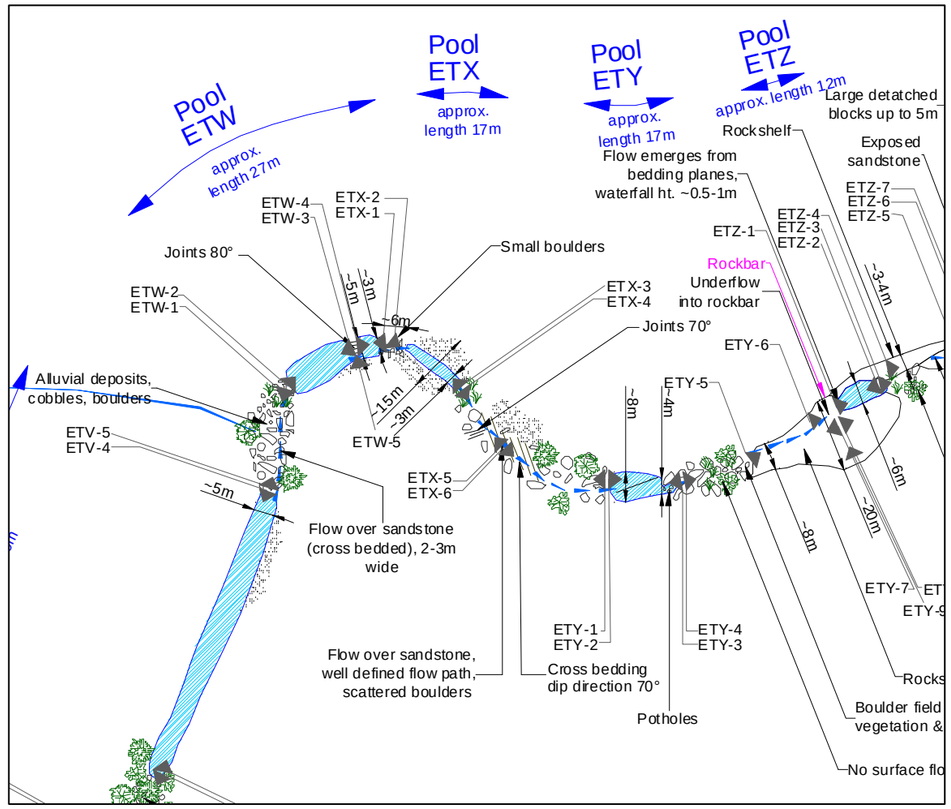
ETX-3 Downstream end of Pool ETX looking Upstream



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

Pool ETY notes (as at 29 Dec 2008)

- 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.

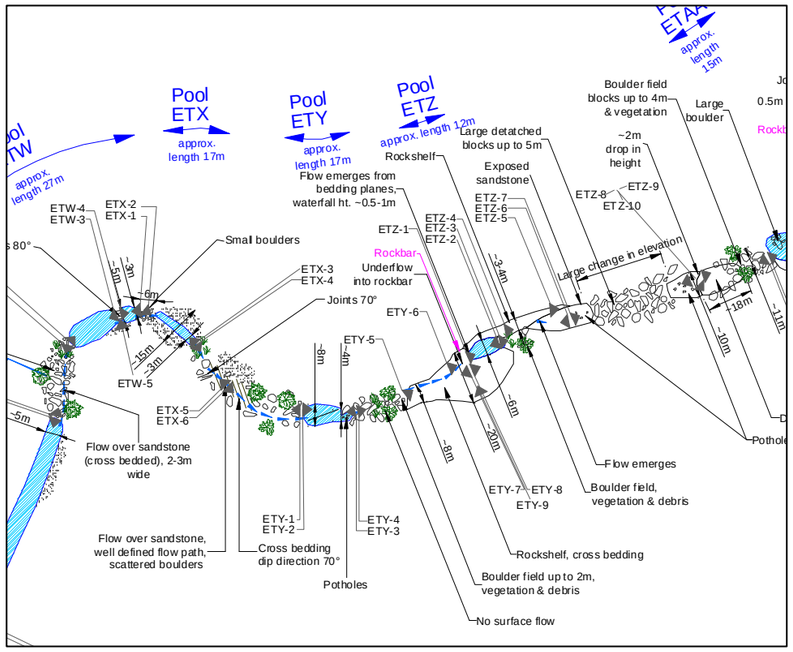
(notes for downstream section continued on following sheet)



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

Pool ETY Downstream notes (as at 29 Dec 2008)

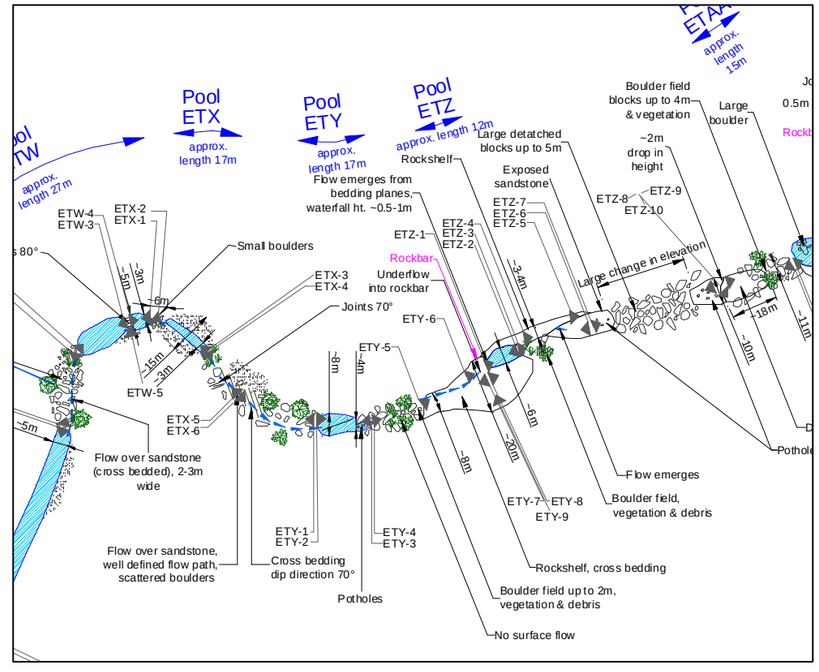
- Water from Pool ETY enters a boulder field with boulders up to approximately 2m size, vegetation and debris.
- No surface flow was observed in the boulder field.
- Flow emerges onto a rock shelf approximately 8m to 20m wide. Cross bedding present.
- Flow emerges from bedding planes and enters Pool 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

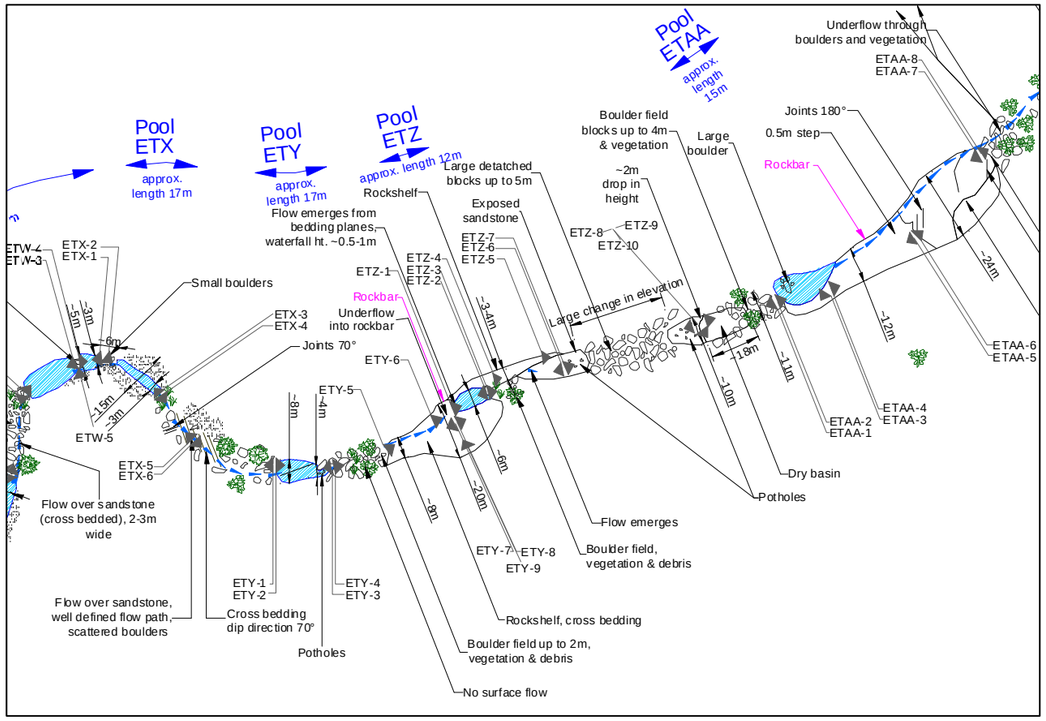


ETZ-2 Downstream end of Pool ETZ looking Upstream

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



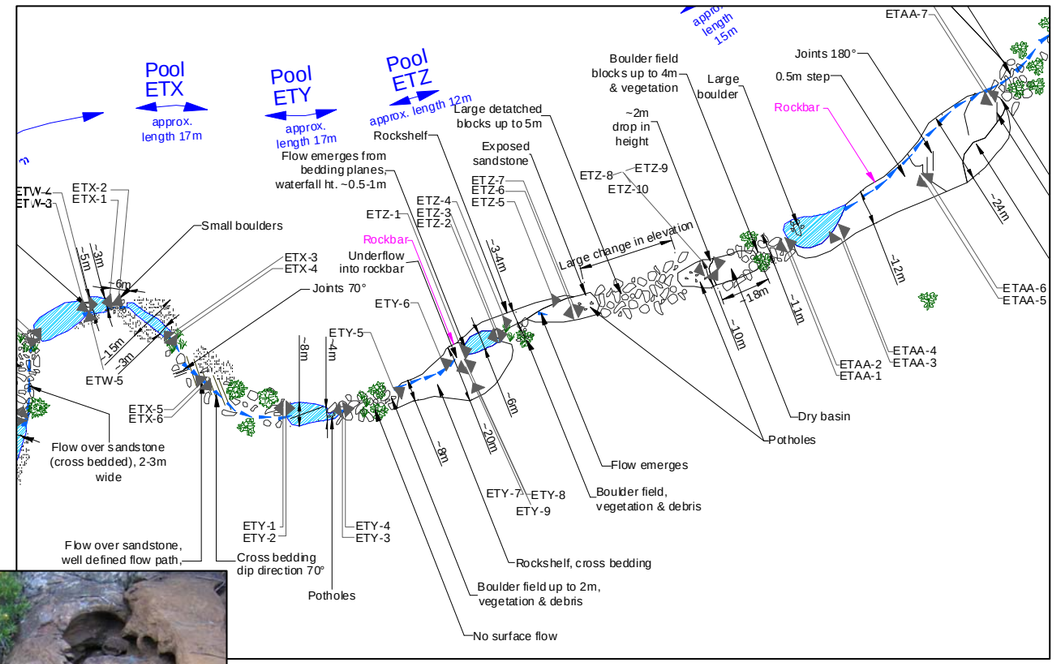
ETZ-7 Exposed sandstone Downstream end of Pool ETZ looking Downstream

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

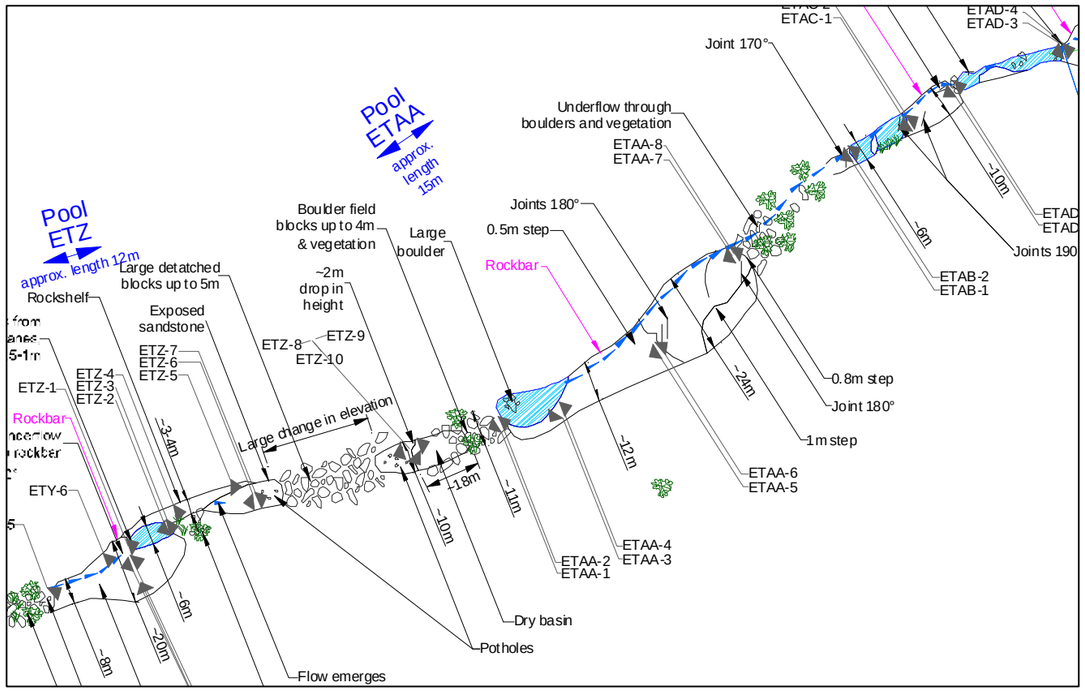


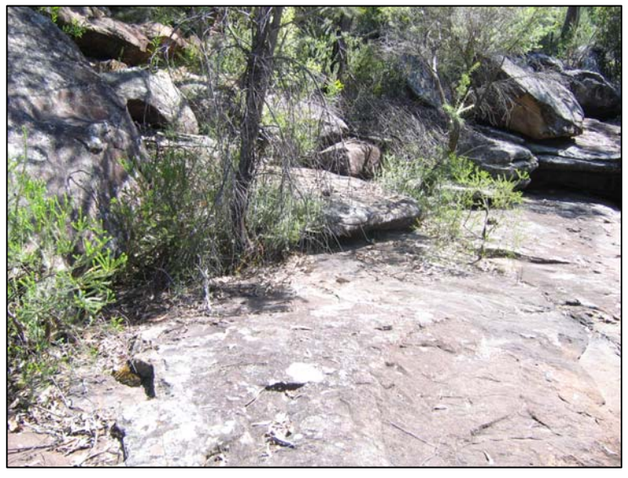
ETAA-2 Upstream end of Pool ETAA looking Downstream

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

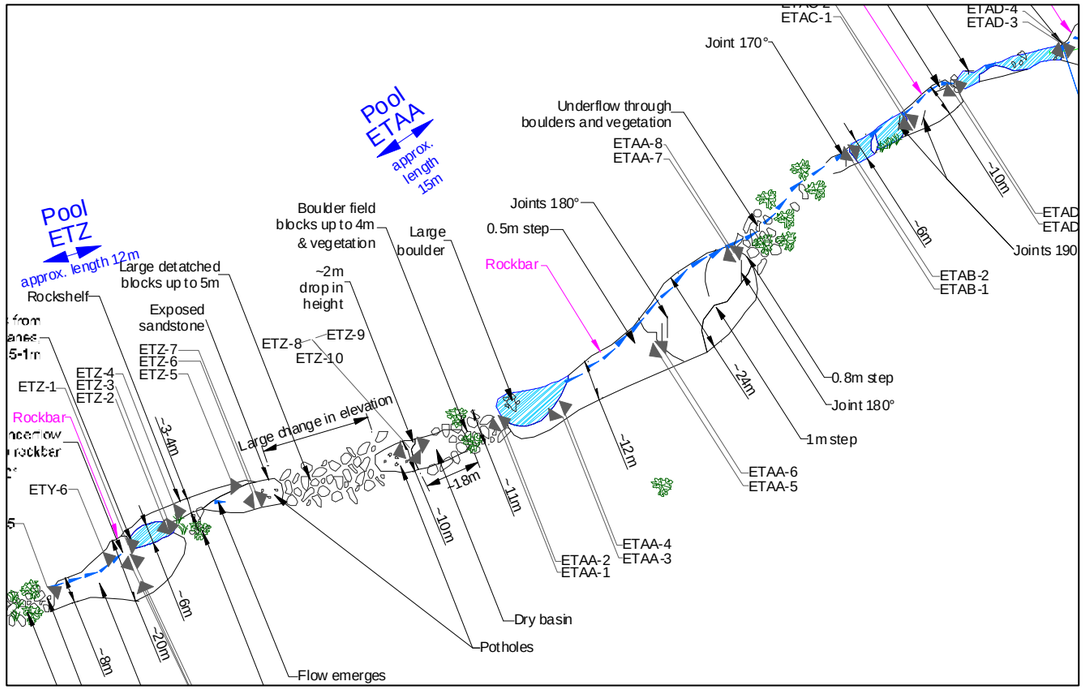
POOL ETAA DOWNSTREAM MAPPING SUMMARY



ETAA-5 On rockbar Downstream of Pool ETAA looking Upstream

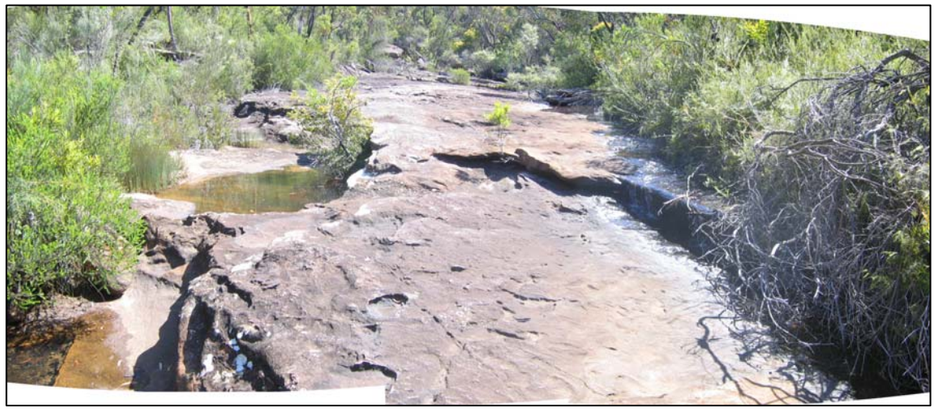
Pool ETAA Downstream notes (as at 19 Dec 2008)

- 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

Pools ETAB and ETAC notes (as at 19 Dec 2008)

- 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

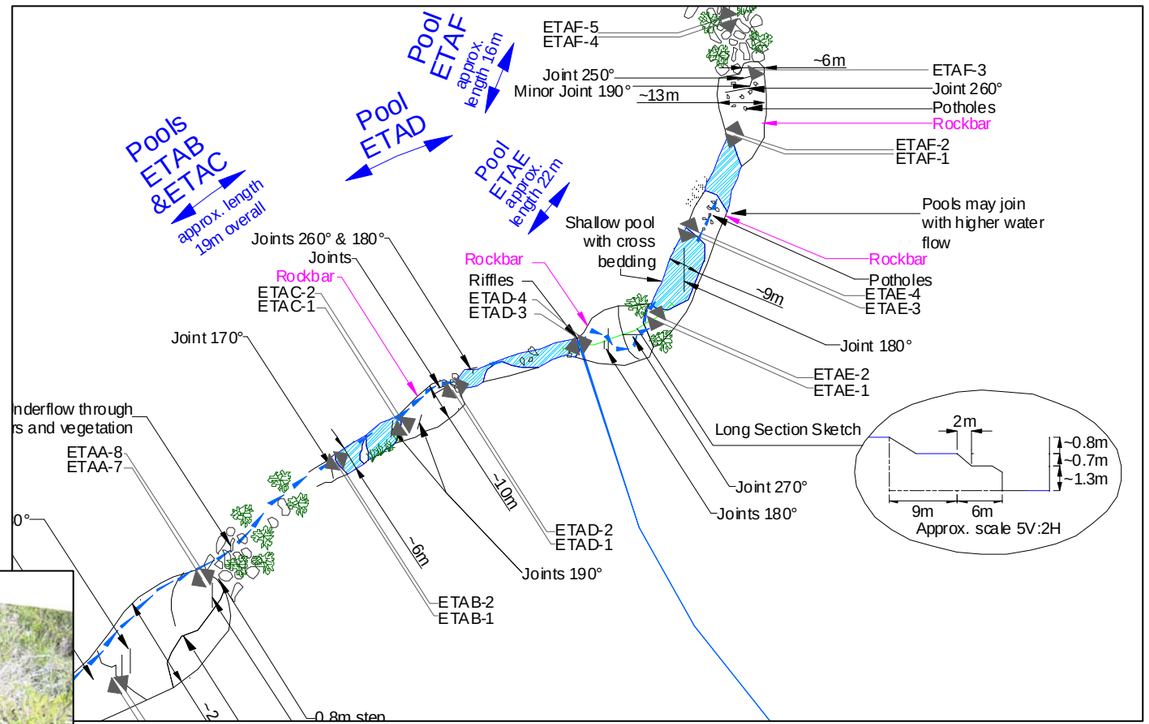


Photo Details

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

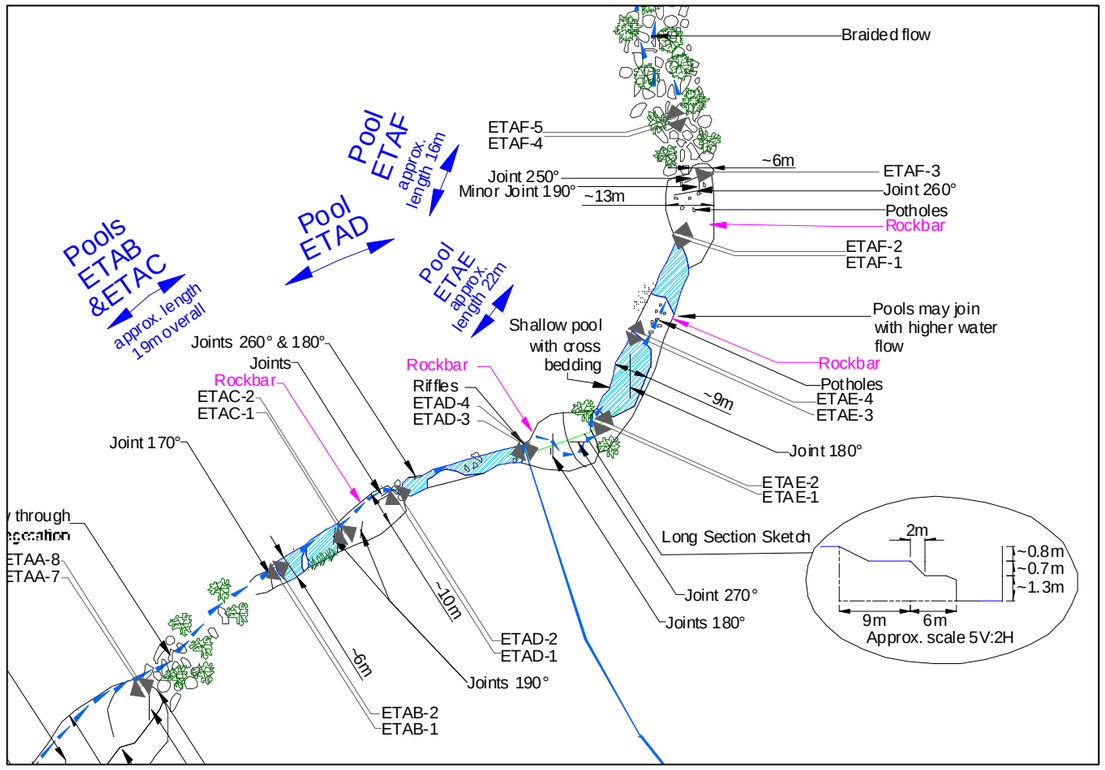


Photo Details

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



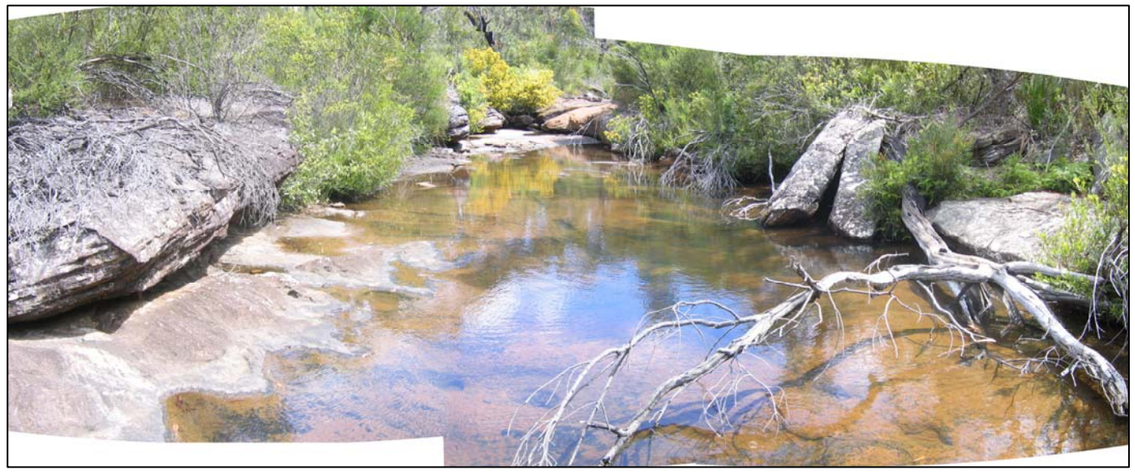
ETAE-1 Upstream end of Pool ETAE looking Upstream



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

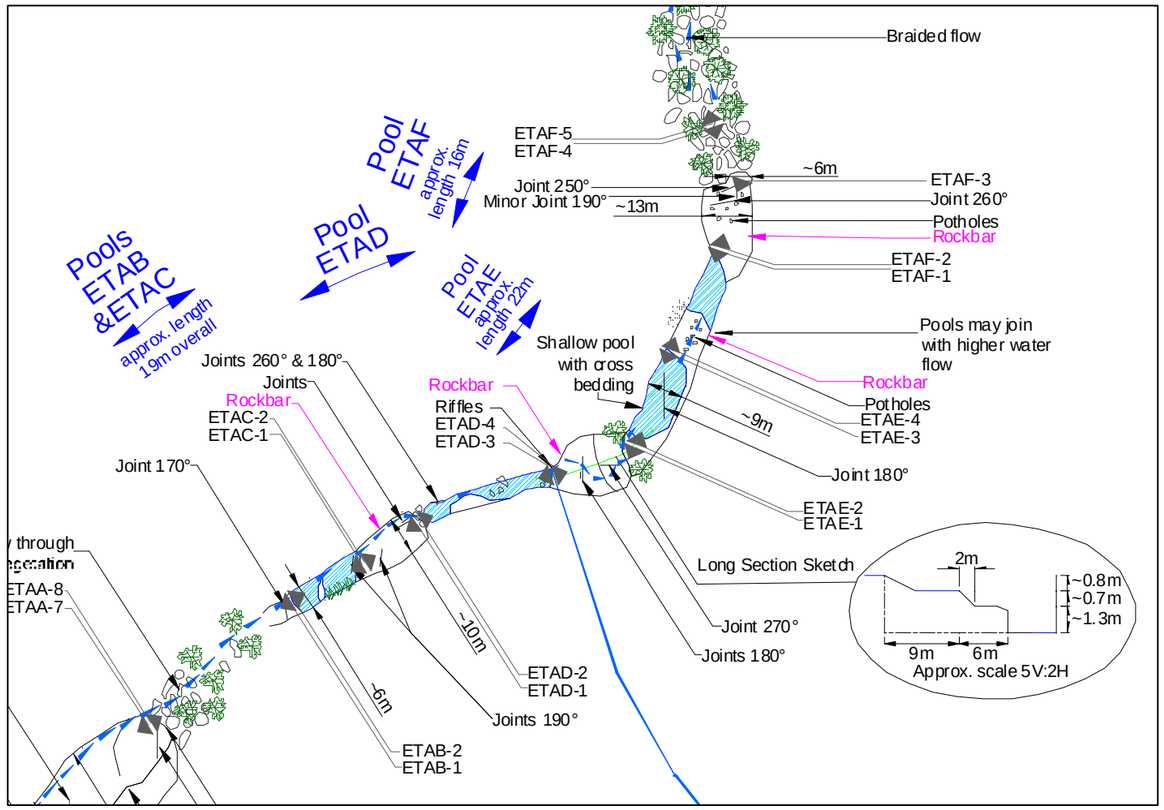


Photo Details

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)

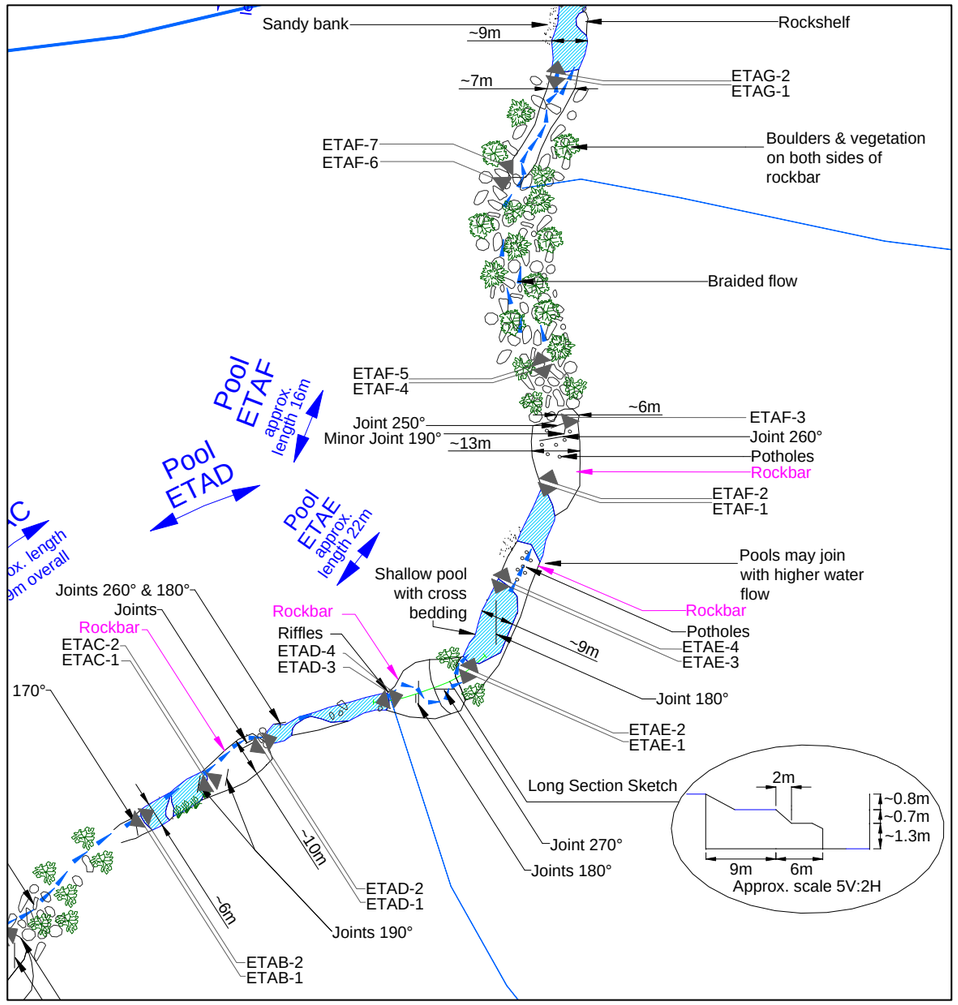


Photo Details

Photo ID	Easting	Northing	Bearing
ETAF-1	312216	6214663	204
ETAF-2	312216	6214663	24
ETAF-3	312211	6214680	203