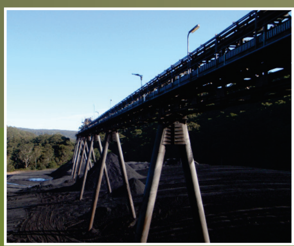
METROPOLITAN COAL LONGWALLS 305-307

BIODIVERSITY MANAGEMENT PLAN

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LONGWALLS 305-307

BIODIVERSITY MANAGEMENT PLAN

ME-TSE-MNP-0080

Revision Status Register

Section/Page/ Annexure	Revision Number	Amendment/Addition	Distribution	DPIE Approval Date
All	BMP-R01-A	Original	DPIE, BCD, DPI - Fisheries	16 March 2020

October 2019

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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). Longwalls 305-307 are situated to the west of Longwalls 301-304, and define the next mining sub-domain within the Project underground mining area (Figures 1 and 2). Longwalls 308 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 Biodiversity Management Plan (BMP) has been prepared as a component of the Metropolitan Coal Longwalls 305-307 Extraction Plan to manage the potential environmental consequences of the Extraction Plan on aquatic and terrestrial flora and fauna, with a specific focus on swamps.

The relationship of this BMP to the Metropolitan Coal Environmental Management Structure and to the Metropolitan Coal Longwalls 305-307 Extraction Plan is shown on Figure 3.

This BMP includes post-mining monitoring and management of aquatic and terrestrial flora and fauna for Longwalls 20-22, 23-27, 301-303 and 304, subject to the previously approved Metropolitan Coal Longwall 304 BMP. 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of Resources and Energy (DRE) (2015) *Guidelines for the Preparation of Extraction Plans*, the Longwall 304 BMP will be superseded by this document following the completion of Longwall 304.

In accordance with Condition 6, Schedule 3 of the Project Approval, this BMP has been prepared by Metropolitan Coal, with assistance from Ecoplanning, Cenwest Environmental Services, SLR Consulting and Mine Subsidence Engineering Consultants (MSEC).

1.2 STRUCTURE OF THE BIODIVERSITY MANAGEMENT PLAN

The remainder of the BMP is structured as follows:

Section 2: Describes the review and update of the BMP.

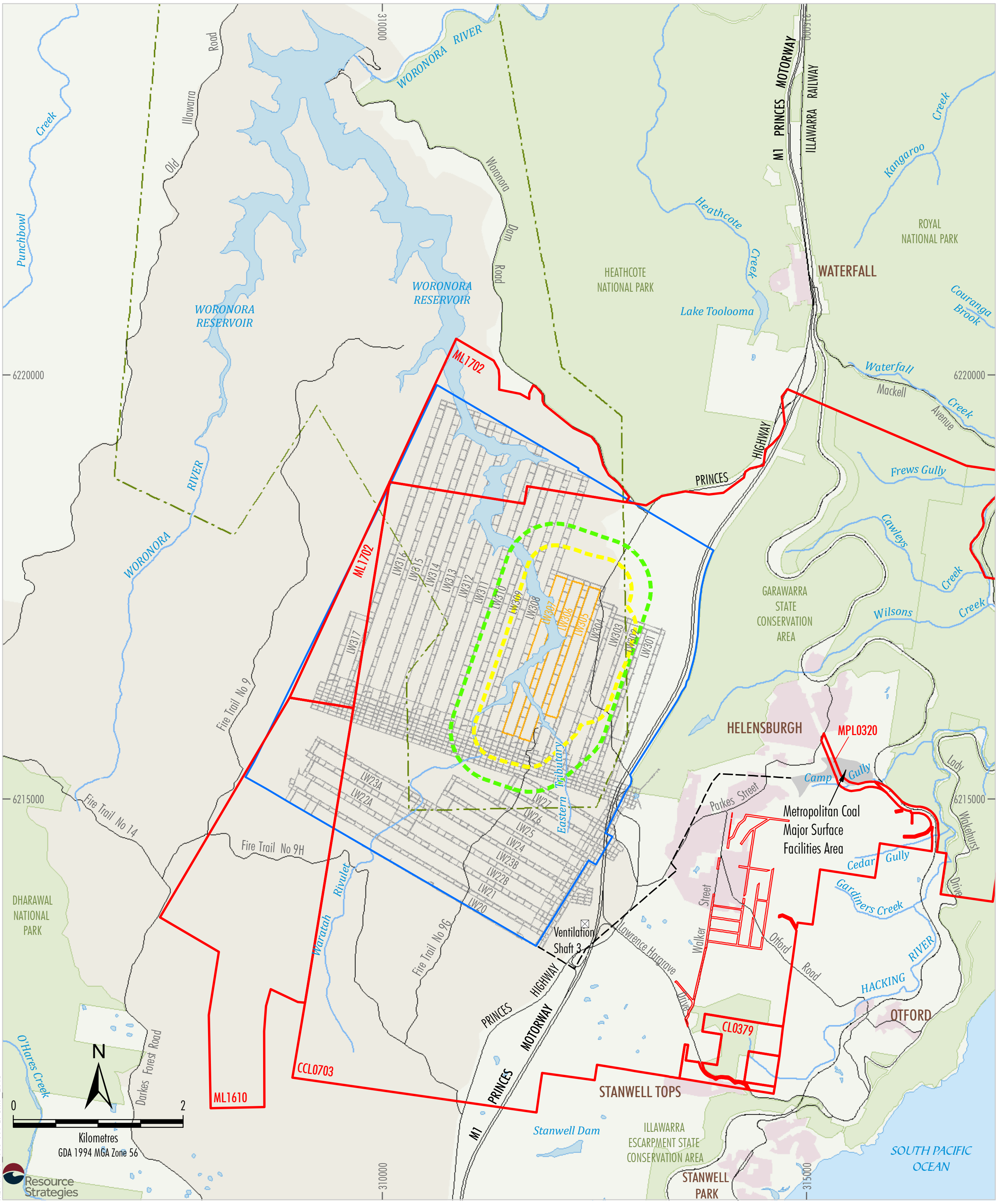
Section 3: Outlines the statutory requirements applicable to the BMP.

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

Section 5: Provides a revised assessment of the potential subsidence impacts and environmental consequences for Longwalls 305-307.

Section 6: Details the performance measures and indicators that will be used to assess the Project.

Section 7: Details the available baseline data.



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 305-307 Secondary Extraction
- Longwalls 305-307 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 305-307 Secondary Extraction
- 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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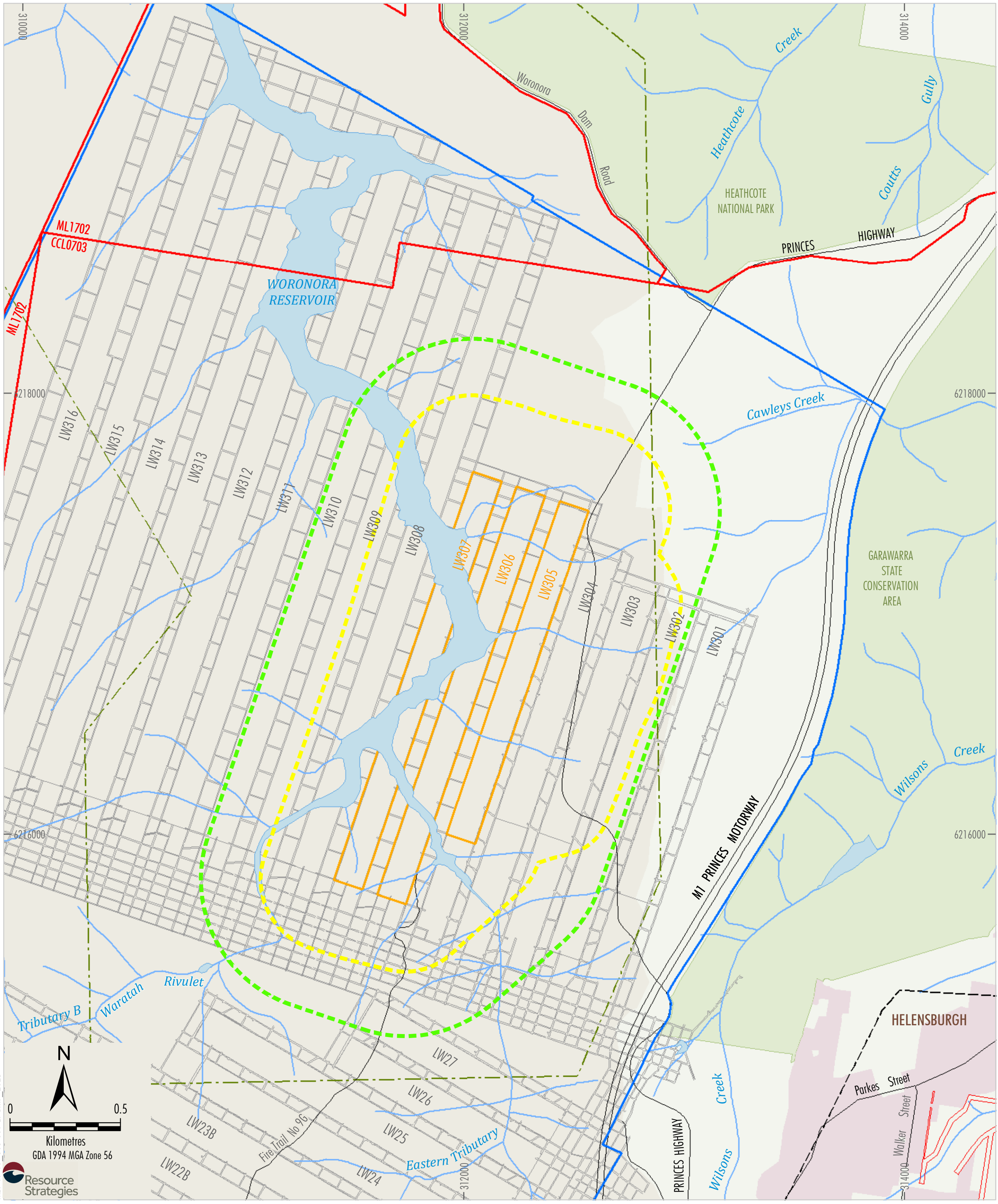
Longwalls 305-307 and Project Underground Mining Area

Figure 1



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

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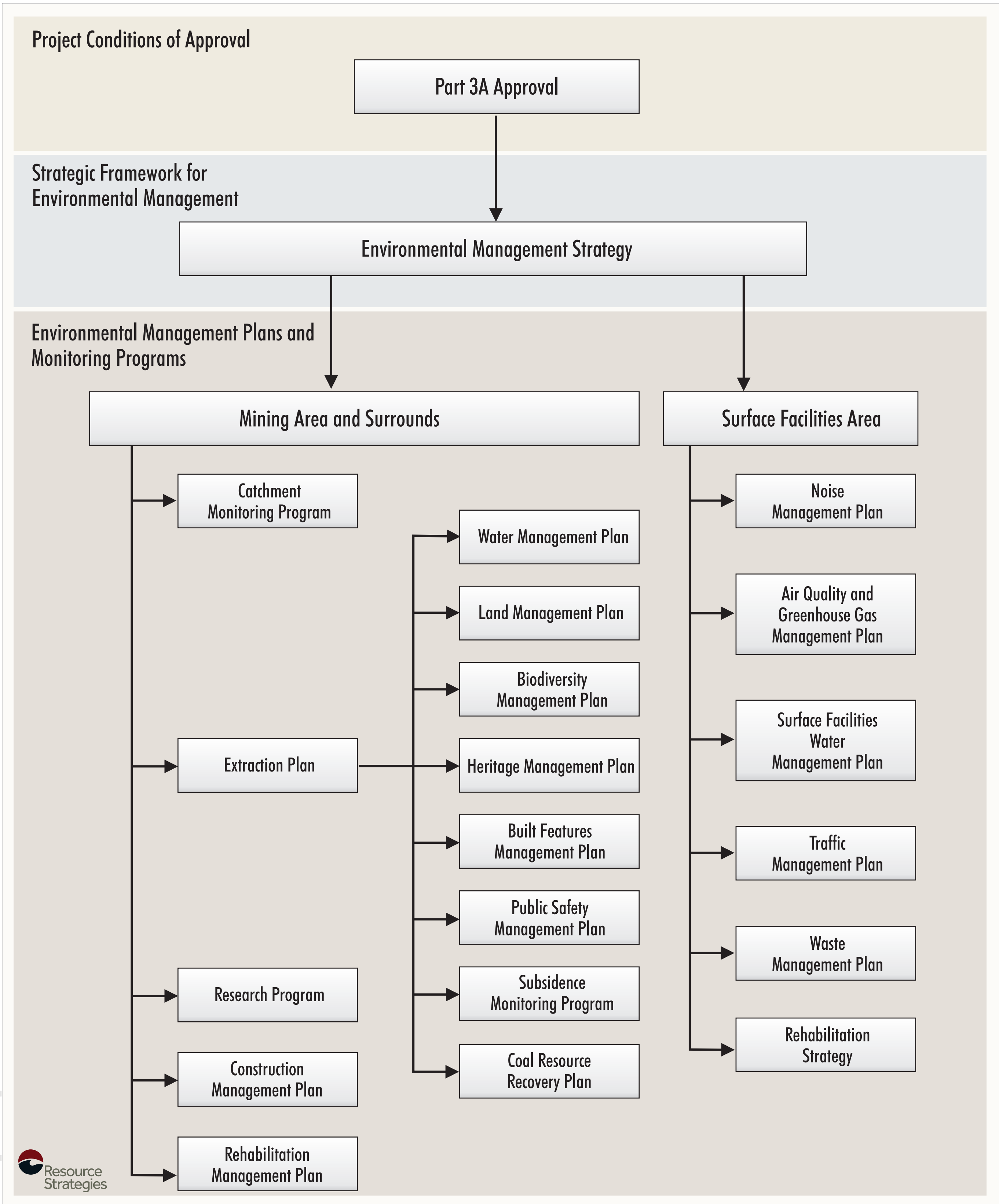
Longwalls 305-307 Layout

Figure 2



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Environmental Management Structure

Figure 3

Section 8: Describes the monitoring programs and provides the detailed Trigger Action Response Plans (TARPs).

Section 9: Describes the management measures that will be implemented.

Section 10: Provides a Contingency Plan to manage any unpredicted impacts and their consequences.

Section 11: Describes the program to collect baseline data for future Extraction Plans.

Section 12: Describes the annual review and improvement of environmental performance.

Section 13: Outlines the management and reporting of incidents.

Section 14: Outlines the management and reporting of complaints.

Section 15: Outlines the management and reporting of non-compliances with statutory requirements.

Section 16: Lists the references cited in this BMP.

2 BIODIVERSITY MANAGEMENT PLAN REVIEW AND UPDATE

In accordance with Condition 4, Schedule 7 of the Project Approval, this BMP 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 Department of Planning, Industry and Environment (DPIE) to ensure the BMP is updated on a regular basis and to incorporate any recommended measures to improve environmental performance.

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

The revision status of this BMP is indicated on the title page of each copy. The distribution register for controlled copies of the BMP 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 BMP publicly available on the Peabody website. A hard copy of the BMP 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 BMP, 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 BMP 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 BMP 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:*
>
> *…*
>
> - *Biodiversity Management Plan, which has been prepared in consultation with OEH[1] and DRE (Fisheries)[2], to manage the potential environmental consequences of the Extraction Plan on aquatic and terrestrial flora and fauna, with a specific focus on swamps;*

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 BMP. Table 1 indicates where each component of the conditions is addressed within this BMP.

---

[1] The NSW Office of Environment and Heritage (OEH) is now the Department of Planning, Industry and Environment – Biodiversity and Conservation Division (BCD).

[2] The Division of Resources and Energy (DRE) - Fisheries is now the Department of Primary Industries (DPI) - Fisheries.

Table 1
Management Plan Requirements

Project Approval Condition	BMP 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 Industry – Water (now DPIE – 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;*
- *Mining Act, 1992;*

[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).

- *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 INFORMATION OBTAINED SINCE PROJECT APPROVAL

Sections 4.1 to 4.3 summarise the water, land and biodiversity management information obtained since Project Approval, respectively.

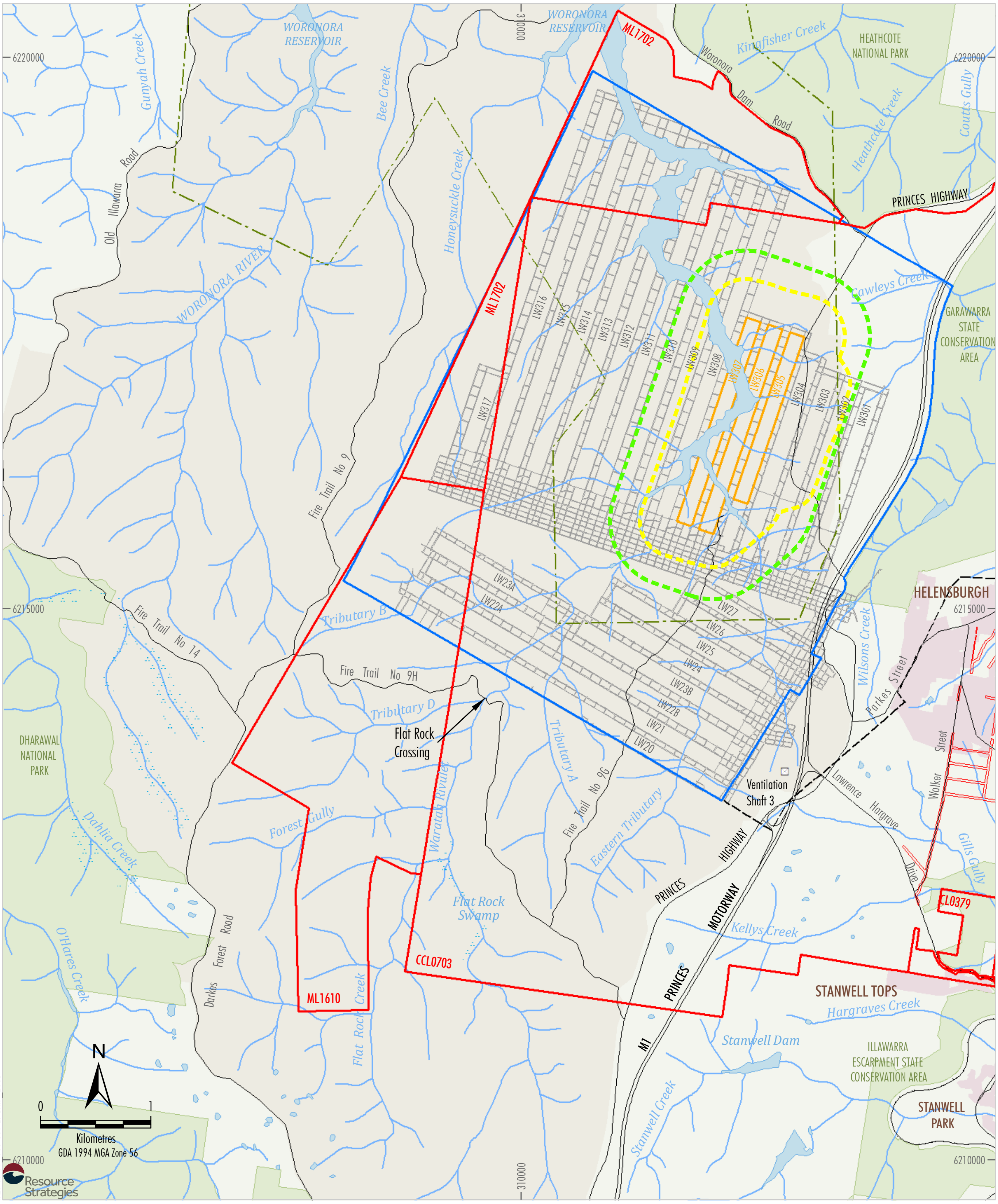
4.1 RELEVANT WATER MANAGEMENT INFORMATION OBTAINED SINCE PROJECT APPROVAL

The Metropolitan Coal Water Management Plans were prepared to manage the potential environmental consequences of the Metropolitan Coal Extraction Plans on water resources and watercourses in accordance with Condition 6, Schedule 3 of the Project Approval.

4.1.1 Surface Water

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

The Waratah Rivulet and Eastern Tributary are the subject of Project performance measures, as described in Section 6. The locations of pools on the Waratah Rivulet and the Eastern Tributary are shown on Figure 5. The Preferred Project Report (HCPL, 2009) indicated that valley closure values of greater than 200 millimetres (mm) were predicted for a number of pools/rock bars on the Waratah Rivulet, Eastern Tributary and other streams. 'Negligible consequence' for a watercourse was considered by the Project Approval to mean, *'no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases'*, and was assumed to be achieved in circumstances where predicted valley closure was less than 200 mm. Subsidence impacts to a number of pools on the Eastern Tributary occurred during the mining of Longwalls 26 and 27 at predicted valley closure values of less than 200 mm.



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- 600 m from Longwalls 305-307 Secondary Extraction
- 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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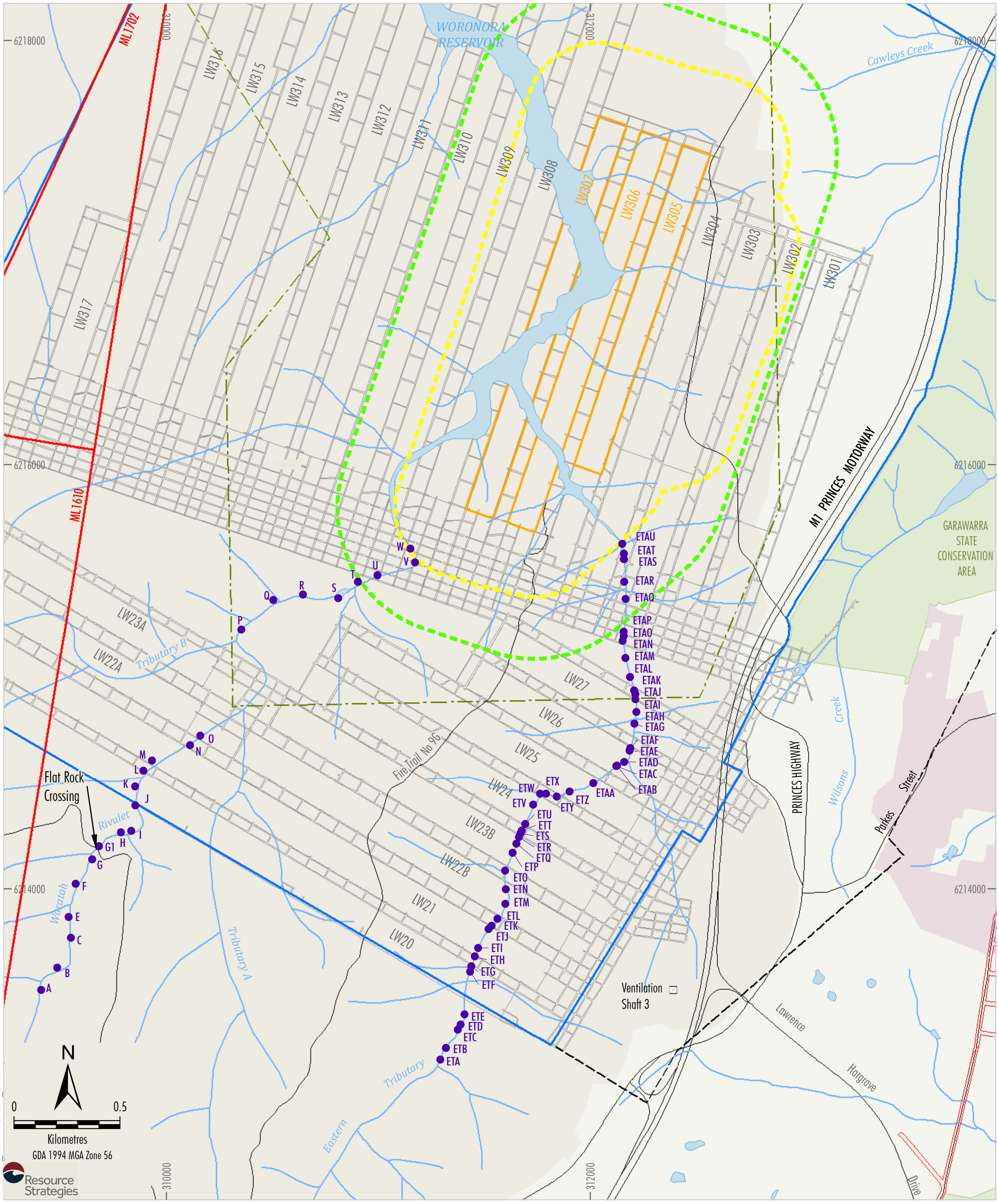
Streams within the Project Underground Mining Area and Surrounds

Figure 4



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- Existing Underground Access Drive (Main Drift)
- Pool

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

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

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Waratah Rivulet and Eastern Tributary Pools

Figure 5

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 agreed that the 200 mm valley closure concept required revision in relation to the Eastern Tributary, noting that the unexpected impacts are particular to the Eastern Tributary and not the Waratah Rivulet. Restricting total predicted valley closure to 200 mm has been a successful design tool for mining in the vicinity of the Waratah Rivulet.

The negligible environmental consequences performance measure for watercourses as described above applied specifically for the Waratah Rivulet along the portion of the '*Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P)'.* This section of the Waratah Rivulet includes Pool P to rock bar W, located to the south of Longwalls 305-307.

To date, the restriction of predicted valley closure to 200 mm has been a successful design tool on the Waratah Rivulet, with no impacts to pools and rock bars along the Waratah Rivulet at predicted total valley closure of less than 200 mm. Pool P to rock bar W have not exceeded the negligible environmental consequence performance measure for the Waratah Rivulet. Predicted total valley closure for Pool P to rock bar W was less than 200 mm for the extraction of Longwalls 20-27 and Longwalls 301-303 and did not increase after Longwall 27 for any of the 300 series longwalls.

Pool A to Pool O4 (a total of 16 pools) are located upstream of Pool P, and are therefore not subject to the Waratah Rivulet negligible environmental impact performance measure. It is noted that the majority of these pools were predicted to experience maximum predicted total closure of greater than 200 mm. However, of these pools, only two (Pools G1 and N) have experienced subsidence impacts that would have resulted in an exceedance of the negligible environmental impact performance measure. Impacts that have occurred at these pools have been the result of mining directly beneath the Waratah Rivulet or in close proximity (< 100 m) to the rock bars, at predicted total valley closure greater than 200 mm.

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

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

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

[4] The IEPMC was established in November 2017 by the NSW Government to provide expert advice to the DPIE 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.

Based on the results of the assessment, the geological features identified along the Eastern Tributary are considered to be unique, compared to the Waratah Rivulet. The Eastern Tributary is therefore more likely to be susceptible to subsidence movements. Restricting valley closure to 200 mm therefore continues to be an appropriate design tool for the Waratah Rivulet. Further discussion on the subsidence predictions and 200 mm valley closure design tool for Longwalls 305-307 is provided in the Longwalls 305-307 Water Management Plan.

Metropolitan Coal developed a monitoring and adaptive management approach to the mining of Longwall 303 towards the Eastern Tributary. As Longwall 303 mined towards the Eastern Tributary, Metropolitan Coal used a TARP designed to detect the development of subsidence effects on the Eastern Tributary. The monitoring and adaptive management approach will also be implemented for Longwall 304 as it mines closer to the Eastern Tributary. The Eastern Tributary TARP for Longwalls 305 and 306 is provided in the Longwalls 305-307 Water Management Plan. 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 Water Management Plans.

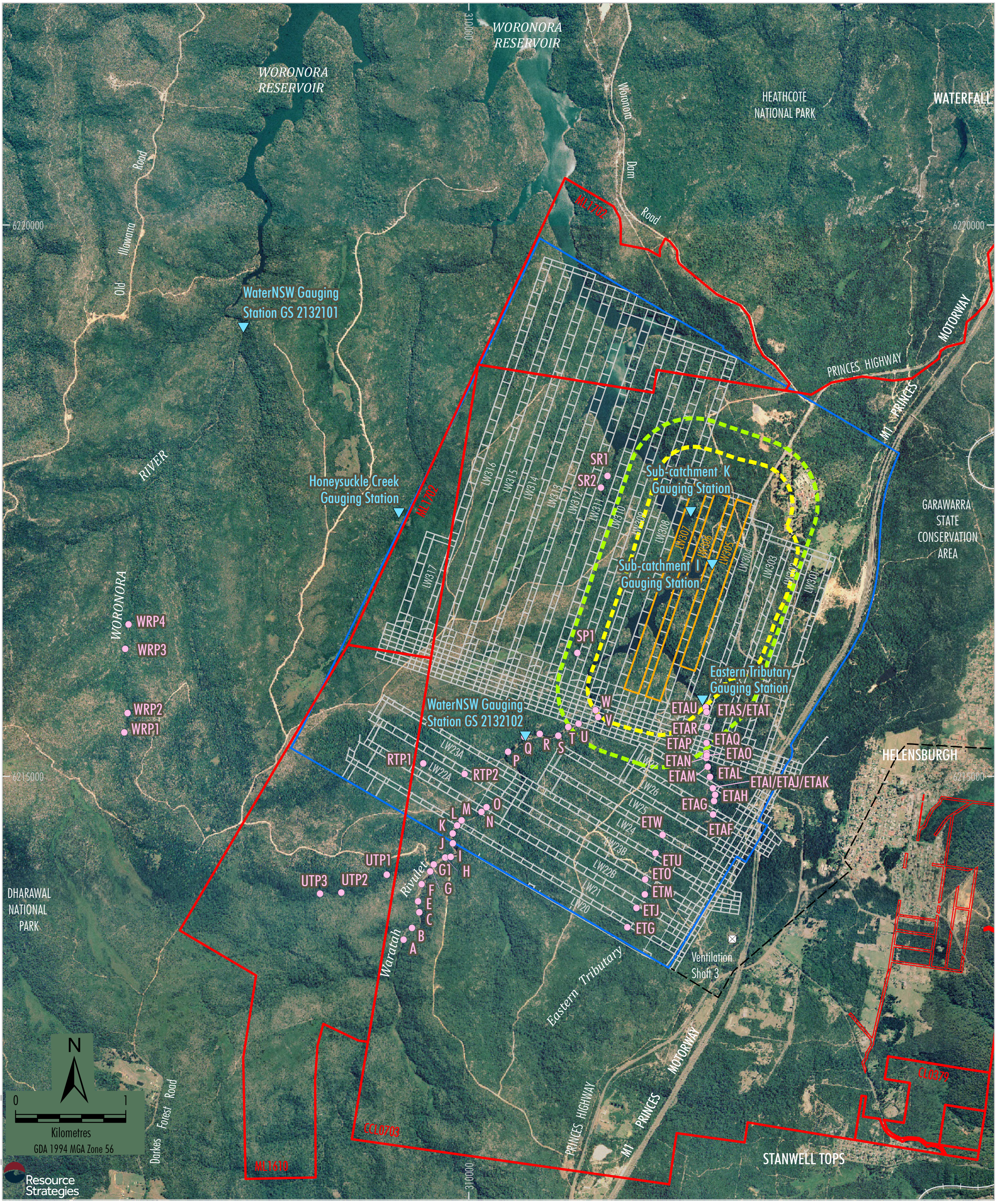
Water levels in pools on the Waratah Rivulet (Pools A, B, C, E, F, G, G1, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V and W) have either been manually monitored on a daily basis or monitored using a continuous water level sensor and logger (Figure 6). A number of pools on the Eastern Tributary (Pools ETG, ETJ, ETM, ETO, ETU, ETW, ETAF, ETAG, ETAH, ETAI/ETAJ/ETAK[5], ETAL, ETAM, ETAN, ETAO, ETAP, ETAQ ETAR, ETAS/ETAT[6] and ETAU), Tributary B (Pools RTP1 and RTP2) and Woronora River (Pools WRP1, WRP2, WRP3 and WRP4) have also been monitored using a continuous water level sensor and logger (Figure 6).

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 Water Management Plans. 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.

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. The water level meter situated in Pool ETAT is considered to be representative of the water level in Pool ETAS.



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- 600 m from Longwalls 305-307 Secondary Extraction
- Existing Underground Access Drive (Main Drift)
- Gauging Station
- Pool Water Level Site

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

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Surface Water Quantity Sites

Figure 6

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

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

Prior to the commencement of Longwall 20, the water levels in pools upstream of Flat Rock Crossing (i.e. Pools A to G, Figure 5) on the Waratah Rivulet had been impacted by mine subsidence. Since the commencement of Longwall 20, two additional pools on the Waratah Rivulet have been impacted by mine subsidence (i.e. fallen below their cease to flow levels and not as a result of climatic conditions, namely, Pool G1 in March 2011 and Pool N in September 2012[7]) (Figure 5). Stream remediation activities on the Waratah Rivulet to date have been conducted at Pools A, F and G. Mining has not resulted in the diversion of flows or change to the natural drainage behaviour of pools downstream of the maingate of Longwall 23 (i.e. Pools P to W) (Figure 5).

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 percent [%]) of impact rather than certainty. In the Longwalls 23-27 Extraction Plan Subsidence Assessment, additional case studies were added to the pool impact model, including cases where loss of pool water levels had occurred at 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). Mining has not resulted in the diversion of flows or change to the natural drainage behaviour of Pools ETAS, ETAT and ETAU (Figure 5).

7 To date (December 2018), Pool N has overflowed its rock bar since December 2014, with the exception of relatively short periods. Pools on the Woronora River also stopped flowing within the same periods. Monitoring of Pool N will continue to be conducted.

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

Woronora Reservoir Inflows

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

Surface water flow monitoring has been conducted at the Waratah Rivulet, Woronora River (Figure 6) and O'Hares Creek gauging stations since the commencement of Longwall 20 in 2010. As documented in the original model in the Project Environmental Assessment, the Waratah Rivulet catchment model is capable of reliably identifying a loss of 1 megalitre per day (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 continuous and that it has been generally consistent with, or above, model predictions. This indicates that flows reaching the Woronora Reservoir have not been reduced by mining.

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

The gauging stations installed in sub-catchments I and K as a component of the Woronora Reservoir Impact Strategy are discussed in Section 4.1.3.

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.

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 DPIE and other relevant agencies in accordance with Condition 6, Schedule 7 of the Project Approval and the Metropolitan Coal Longwalls 23-27 Water Management Plan 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, 2019). The iron staining/flocculent is associated with Eastern Tributary water quality impacts, which have occurred in association with the exceedance of the Eastern Tributary watercourse performance measure. Reducing conditions (through water saturation excluding oxygen) has solubilised iron in the groundwater, which has been transferred to surface water through mine-induced cracking. The soluble iron (iron (II) ion, Fe^{2+}), rapidly oxidises to iron (III) Fe^{3+}, and forms insoluble hydrated ferric hydroxide in colloidal (<0.45 micrometres [µm]) and particulate (>0.45 µm) forms (The University of Queensland, 2018a). Iron oxidising bacteria can also create oxidised iron precipitate (National Health and Medical Research Council, 2011). The iron floc is a mixture of precipitated iron oxyhydroxide material >0.45 µm size and colloidal material which is <0.45 µm size. The colloidal material coagulates to give the larger size precipitated material and coats the creek bed rock surfaces (The University of Queensland, 2018a). The iron oxyhydroxide gradually converts to goethite (Yee et al., 2006) which has a darker colour 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 Water Management Plan recognised there was the potential for gas releases to occur.

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

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 Water Management Plans 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

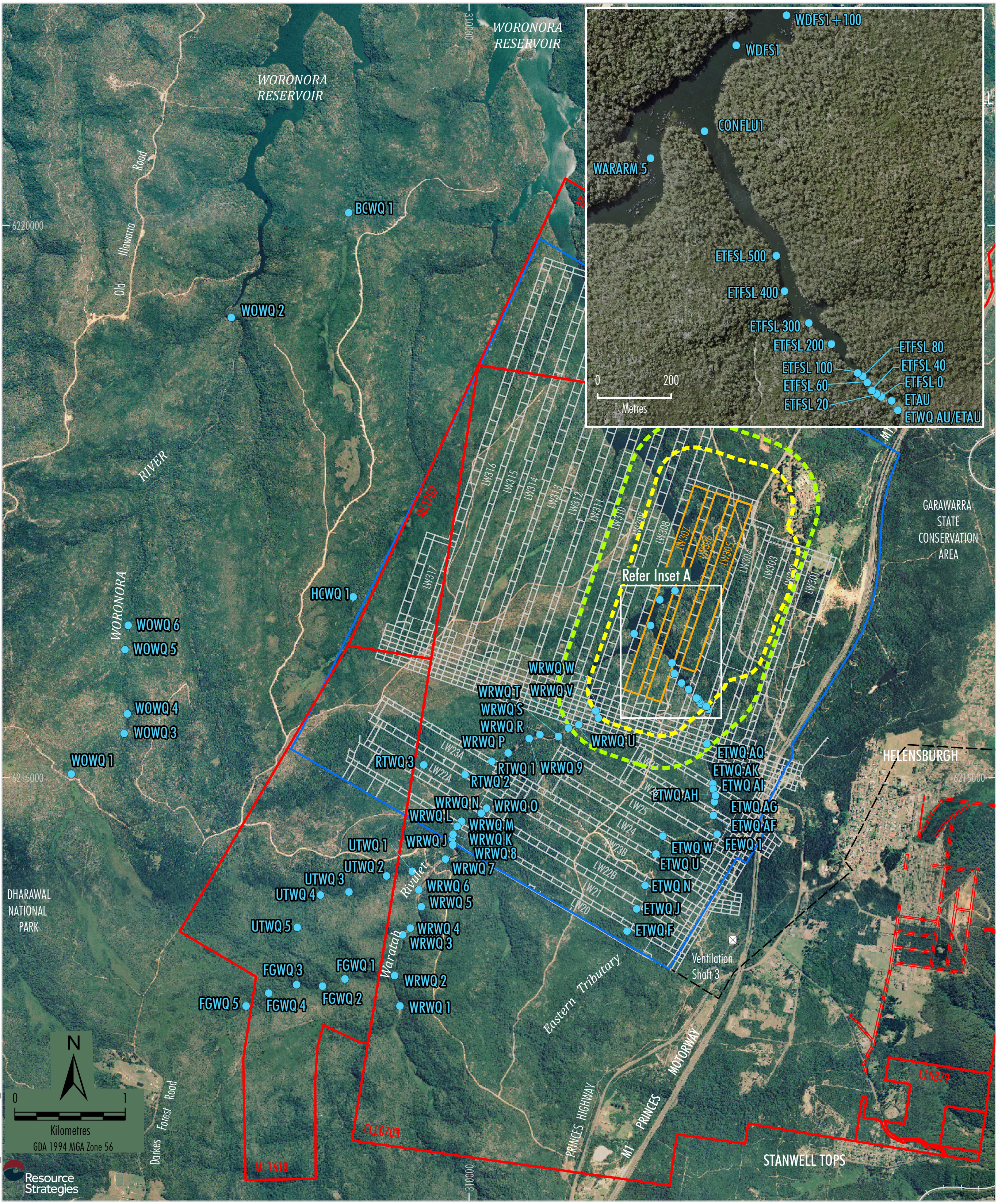
Subsidence impacts on water quality were predicted by the Project EA, Preferred Project Report, and Metropolitan Coal Water Management Plans to be similar to that previously observed at Metropolitan Coal, specifically, transient pulses of iron, manganese and to a lesser extent aluminium, which would 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 (2019a). The water quality sites are shown on Figure 7.

Table 2
Stream Water Quality Monitoring Results

Stream	Monitoring Results to Date
Waratah Rivulet (sites WRWQ 2, WRWQ 6, WRWQ 8, WRWQ 9, WRWQ M, WRWQ N, WRWQ P, WRWQ R, WRWQ T and WRWQ W)	• Water quality 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 low. Higher than previously recorded values were recorded at upper to middle reach sites from January to December 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[1] and WOWQ 2)	• Sites on Woronora River typically show slight acidity and high variability in pH. • Electrical conductivity values have been similar to values recorded on Waratah Rivulet. • Dissolved iron has been generally low and similar to values recorded in Waratah Rivulet. • Dissolved manganese has been typically low with evidence of more elevated concentrations occurring in the summer months. • Dissolved aluminium concentrations have been typically low and typically higher upstream.
Eastern Tributary (sites ETWQ F, ETWQ J, ETWQ N, ETWQ U, ETWQ W, ETWQ AF, ETWQ AH, ETWQ AQ and ETWQ AU)	• Recent variable results are considered to be associated with low water levels and sampling of non-flowing or stagnant pools. • Sampling sites on Eastern Tributary show variable but typically near neutral pH values, with some historically low pH levels recorded in 2018. • Electrical conductivity values have historically been low, however have been more variable since mid 2016, with higher than historical values 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. • Dissolved aluminium concentrations are typically low, with some elevated levels recorded in 2018 following periods of no flow in these sections of the Eastern Tributary.
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). Some elevated values recorded on Bee Creek and Honeysuckle Creek from mid to late 2018.

Source: after Hydro Engineering & Consulting (2019a)



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 305-307 Secondary Extraction
- Longwalls 305-307 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 305-307 Secondary Extraction
- 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

The cracking and dilation of bedrock and associated diversion of surface flow and leakage of water through rock bars at pools which has occurred on the Eastern Tributary (including the reach associated with the exceedance of the Eastern Tributary watercourse performance measure) has resulted in impacts on water quality, in particular increases in dissolved manganese and at times iron. Reducing conditions (through water saturation excluding oxygen) has solubilised iron (and manganese) in the groundwater. The soluble iron and manganese has been transferred to surface water through mine-induced cracking, resulting in increases in iron and manganese concentrations in the Eastern Tributary. The soluble iron (iron (II) ion, Fe^{2+}), rapidly oxidises to iron (III) Fe^{3+}, and forms insoluble hydrated ferric hydroxide in colloidal (<0.45 μm) and particulate (>0.45 μm) forms (The University of Queensland, 2018a). Manganese remains dissolved in the water column as oxidation at near-neutral pH is slow (Raveendran *et al.,* 2001) and soluble manganese (II ion, Mn^{2+}) is the most stable species (Rayner-Canham, 1996) (The University of Queensland, 2018a). Low levels of manganese, e.g. <0.1 milligrams per litre (mg/L) exist in the natural creek water. Dissolved manganese is however 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 – 2018l; 2019a – 2019c) 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.

Woronora Reservoir Water Quality

The Project EA, Preferred Project Report, and Metropolitan Coal Water Management Plans 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.

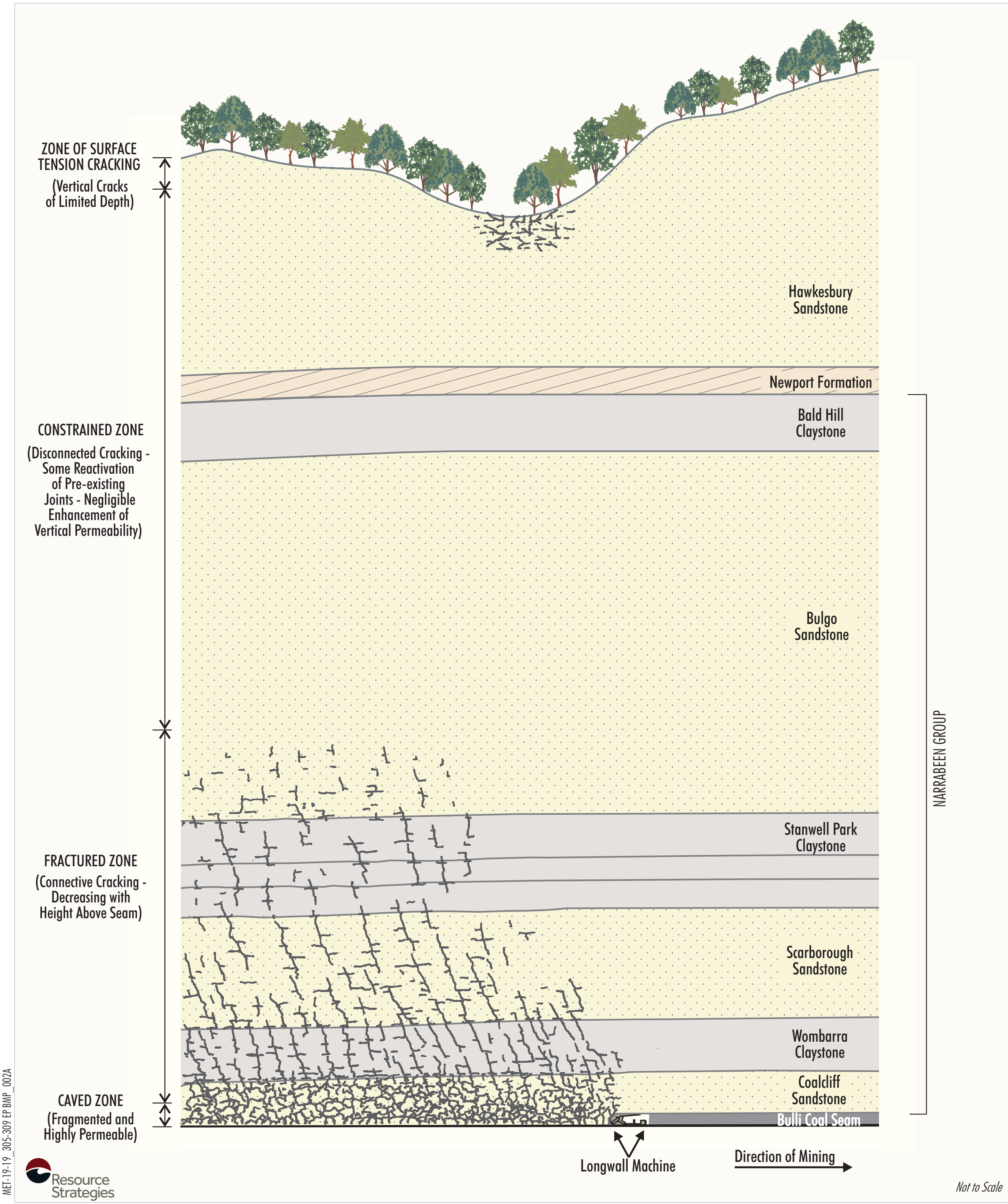
Metropolitan Coal sources water quality data for the Woronora Reservoir from WaterNSW in accordance with a data exchange agreement and analyses data for total iron, total aluminium and total manganese from 0 m to 9 m below the reservoir surface.

The 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.

4.1.2 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.



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

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Schematic - Longwall Mining and Subsidence Profile

Figure 8

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 (July 2019) indicates no privately owned registered bores, other than those registered by Metropolitan Coal, are located in the vicinity of the 300 series longwalls.

Groundwater Model

A tabulated list of groundwater models developed and used for the Project by 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 and Longwalls 305-307.

SLR Consulting (previously HydroSimulations) is in the process of updating the groundwater model. Updates include converting to MODFLOW-USG code, using the stacked drain approach for the fractured zone and recalibrating the model parameters. The calibrated model will be subject to peer review and will be used to confirm the predictions of the current (2018) model for Longwalls 305-307.

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 Water Management Plans and BMPs, included:

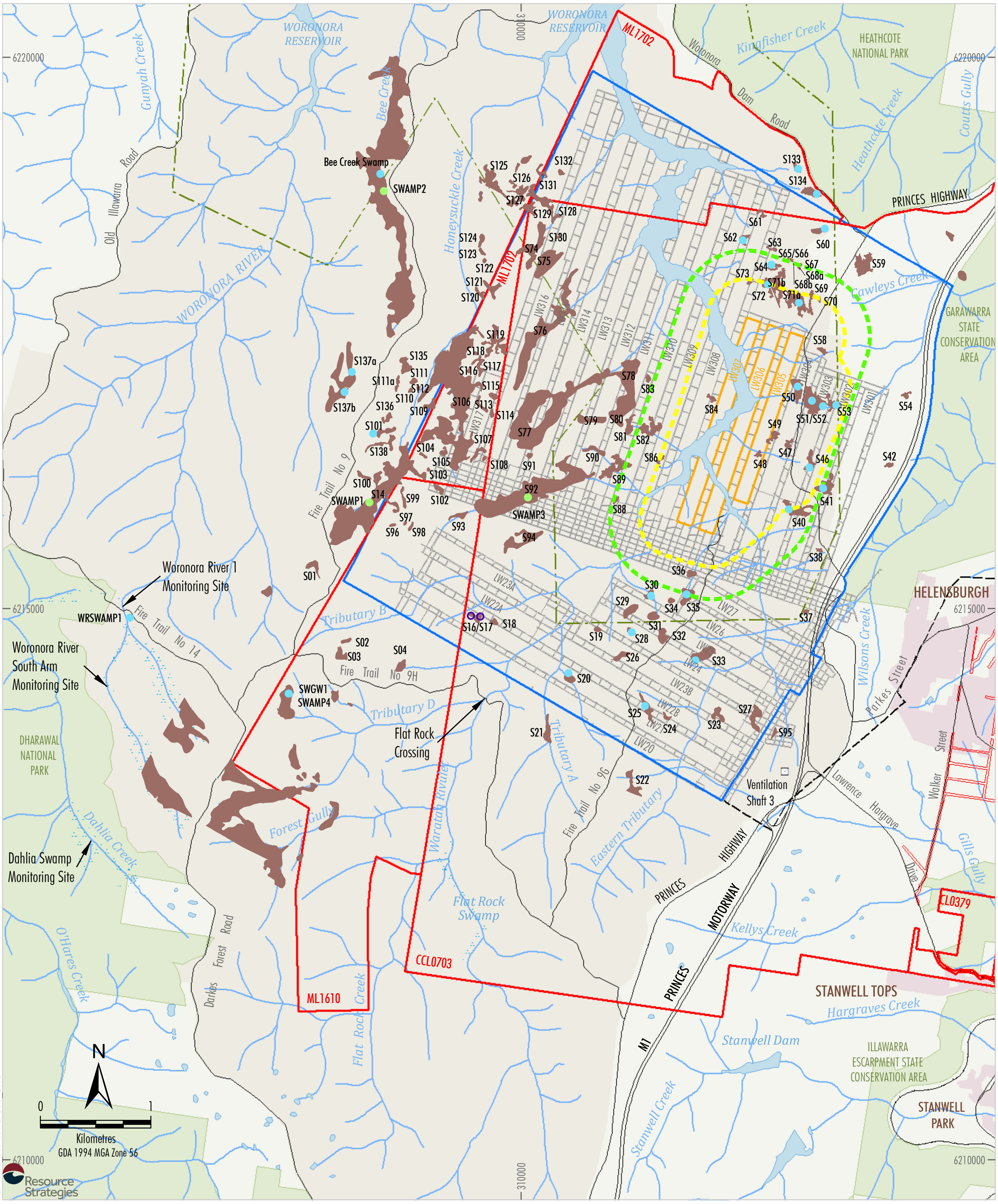
- Any cracking of the bedrock within upland swamps was expected to be isolated and of a minor nature, due to the relatively low magnitudes of the predicted strains and the relatively high depths of cover.
- Surface cracking resulting from mine subsidence within the upland swamps was not expected to result in an increase in the vertical movement of water from the perched water table into the regional aquifer as the sandstone bedrock is massive in structure and permeability decreases with depth.
- It was expected that any surface cracking that may occur would be superficial in nature (i.e. would be relatively shallow) and would terminate within the unsaturated part of the low permeability sandstone. Any changes in swamp water levels as a result of cracking were expected to be unmeasurable when compared to the scale of seasonal and even individual rainfall event-based changes in swamp groundwater levels.
- Whilst swamp grades vary naturally, the predicted maximum mining-induced tilts were generally orders of magnitude lower than the existing natural grades within the swamps. The predicted tilts would not have any significant effect on the localised or overall gradient of the swamps or the flow of water. Any minor mining-induced tilting of the scale and nature predicted was not expected to significantly increase lateral surface water movements which are small in relation to the other components in the swamp water balance.

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

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

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

Groundwater monitoring of upland swamps has involved the use, where practicable, of paired piezometers, one swamp substrate piezometer (at approximately 1 m depth) and one sandstone piezometer (at a depth of approximately 10 m) (Figure 9). Specifically, paired piezometers have been monitored in 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). Longwall 304 had recently commenced at the time of BMP development. Assessment of the paired piezometers in Swamp 50 will be conducted during the extraction of Longwall 304. 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).



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 305-307 Secondary Extraction
- Longwalls 305-307 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 305-307 Secondary Extraction
- 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); Eco Logical Australia (2015; 2016; 2018)

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Upland Swamps Mapped Over Longwalls 20-27, Longwalls 301-317 and Surrrounds

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).

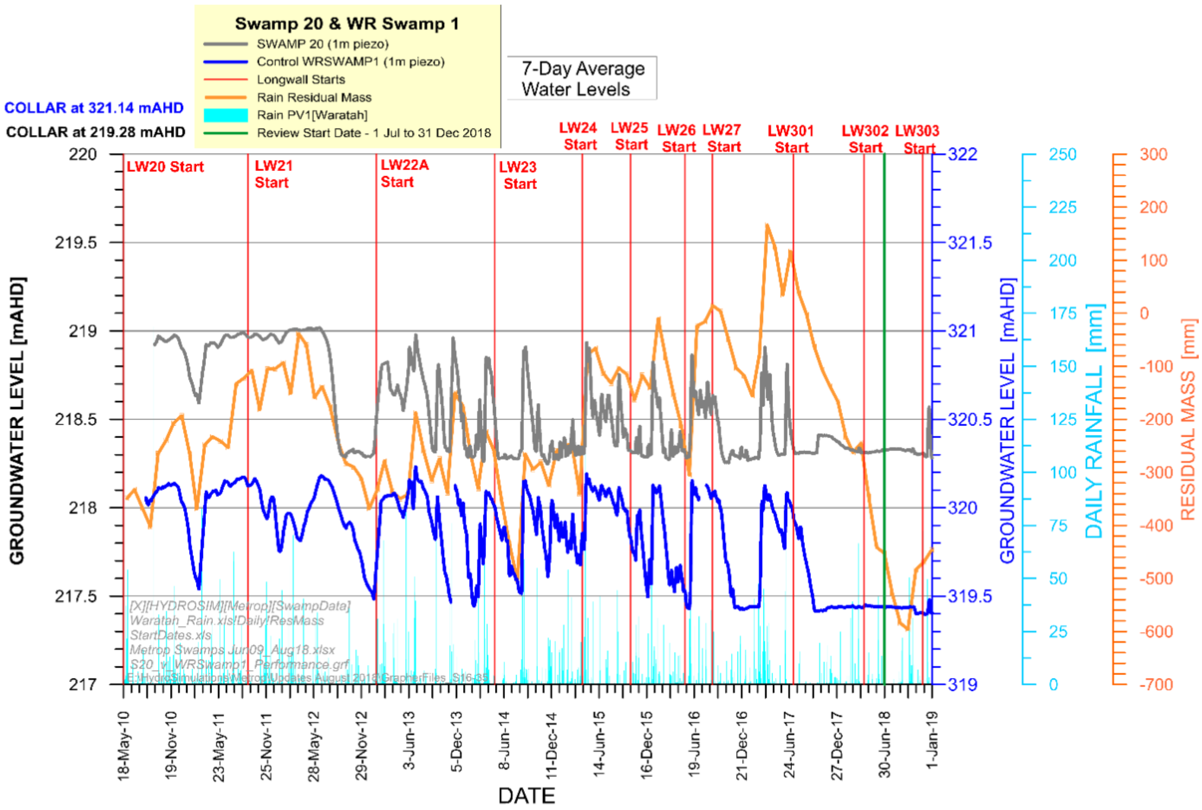

Chart 1 **Comparison of Piezometer Responses at Swamp 20 and Woronora River 1 Control Swamp**

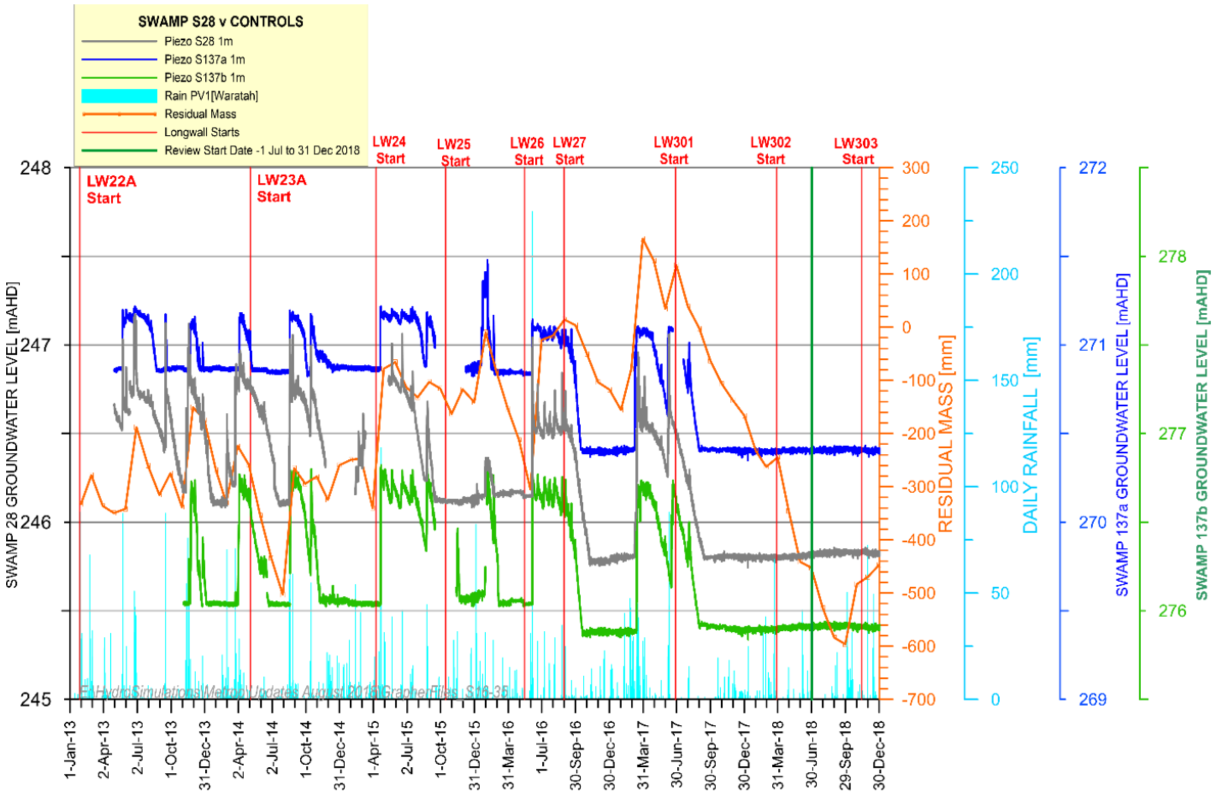

Chart 2 Groundwater Hydrographs at Swamp 28 and Two Control Swamps (137a and 137b)

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).

Analysis of the swamp substrate water levels of Swamps 25, 30, 33, 35, 40, 41, 46, 51, 52 and 53 including comparisons with control swamps and rainfall records have indicated the dry conditions recorded in the swamps to date are a natural response to reduced rainfall (HydroSimulations, 2019).

While the water lost from Swamp 20 and Swamp 28 was retained in the unsaturated sandstone above the regional water table, the changes in swamp water levels as a result of cracking are measurable when compared to seasonal individual rainfall event-based changes in swamp groundwater levels. There is currently no sign that the vegetation in Swamp 20 is being impacted by the changed hydrological conditions. The vegetation monitoring results since autumn 2017 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 Water Management Plans 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 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 Water Management Plans.

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 Water Management Plans, 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 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[8]. The revised groundwater model (that was used for Longwall 304) predicted that inflow for Longwalls 301-303 would be in the order of 0.003 to 0.10 ML/day. The revised groundwater model predicts that inflow for Longwalls 301-304 is expected to lie in the range 0.003-0.14 ML/day [9]
- 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.

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. Given the large fluctuations in daily water usage and the cycle period for water entering the mine and for assessment of environmental performance of the mine, a 20 day average is used by Metropolitan Coal to provide a more reliable estimate of water make. The 20 day average daily mine water make has been below 0.5 ML/day (Charts 3a and 3b). The increased water make during the period April 2011 to July 2011 (Chart 3a) was a result of dewatering of old workings in advance of the 200 Mains Panel (Metropolitan Coal, 2011). From January 2009 to July 2019, the mine water make has averaged 0.01 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.

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[8] 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.

[9] Modelling and assessments conducted for Longwall 304 were documented in the Metropolitan Coal Longwall 304 Extraction Plan.

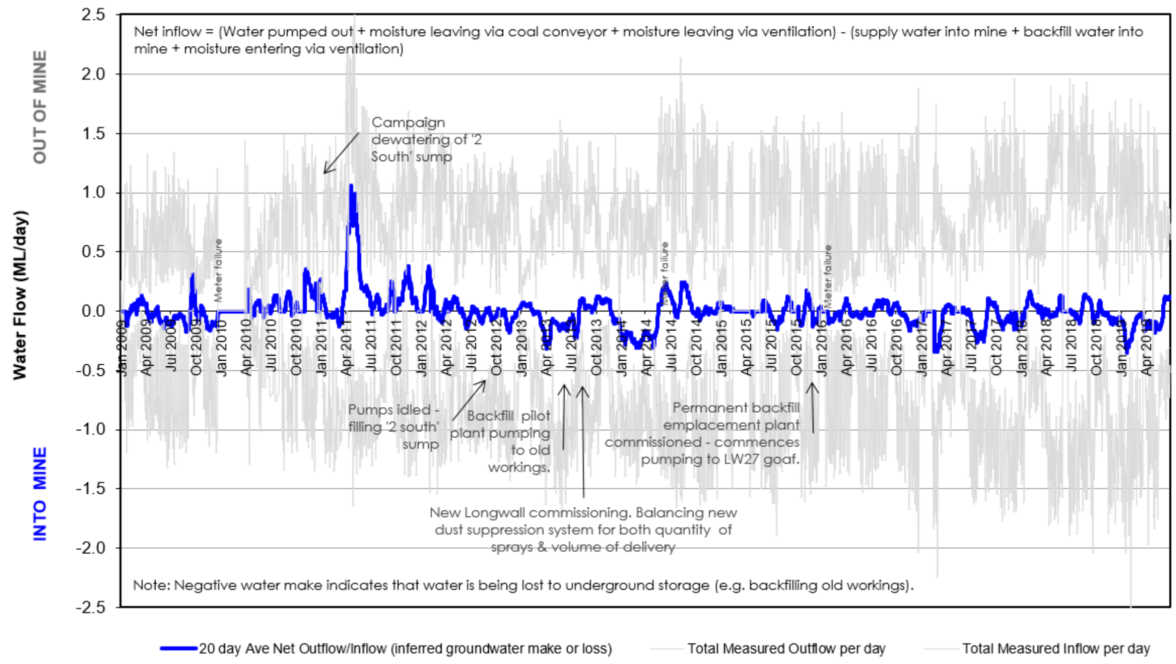


Chart 3a Estimated Daily Mine Water Make, 2009 to July 2019

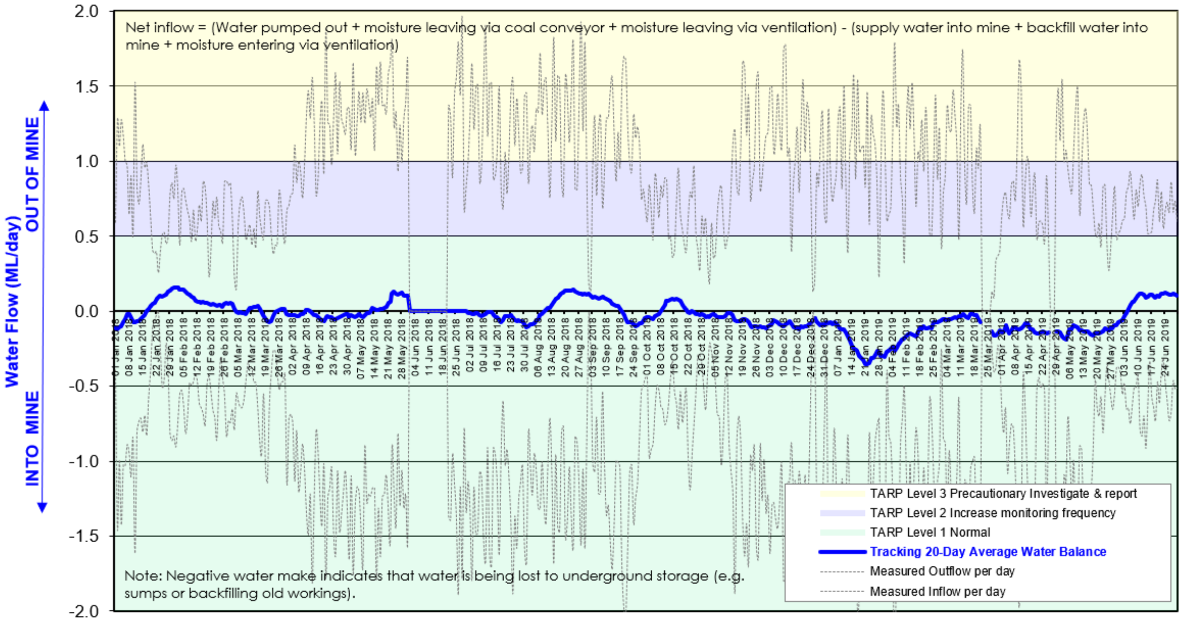


Chart 3b Estimated Daily Mine Water Make, January 2018 to July 2019

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.

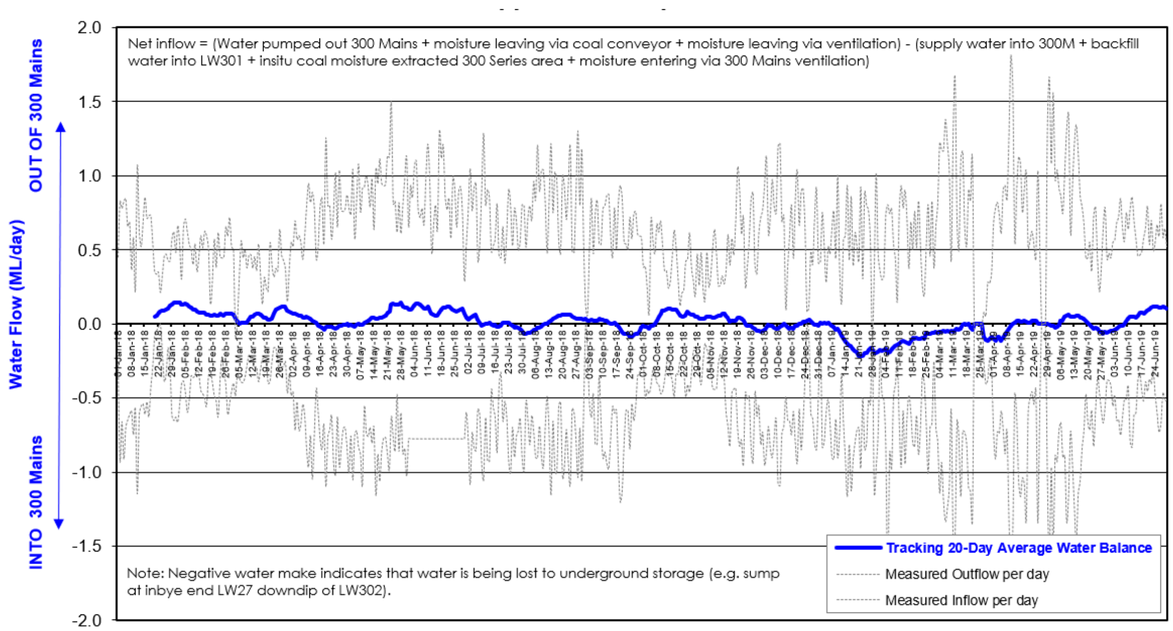


Chart 3c 300 Mains Water Balance, January 2018 to July 2019

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[10], 9EGW2-4, PM03, PHGW1B, PHGW2A, F6GW3A and F6GW4A in accordance with the Metropolitan Coal Water Management Plans. 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 4.1.3.

In accordance with the Dams Safety Committee Approvals 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 data analysis (to June 2019) shows through statistics, trend diagrams (Piper), time-series plots and ratio plots 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 Water Management Plans.

[10] 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.

4.1.3 Woronora Reservoir Impact Strategy

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

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

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

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

The surface water and groundwater monitoring locations that have been installed as a component of the Woronora Reservoir Impact Strategy are described in the Longwalls 305-307 Water Management Plan.

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

Data collected from the flumes on sub-catchments I and K commenced on 31 May 2018 and 3 June 2018, respectively (the flumes were installed on 17 May 2018 and 16 May 2018, respectively). Secondary extraction from Longwall 302 was occurring at the commencement of monitoring and continued through to 6 October 2018. Secondary extraction of Longwall 303 commenced on 13 November 2018 and was completed in May 2019. Longwall 304 had not commenced within the period of the assessed flow record (to 2 July 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 (to 2 July 2019) 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 primary purpose of the water balance analysis was to establish whether the inputs to and outputs from the Woronora Reservoir could be measured sufficiently accurately to estimate a loss through the bed of the reservoir because of longwall mining being undertaken in the catchment and/or from other activities that may affect the water balance. The issues identified in the water balance suggest that the magnitude of bias and uncertainty in the data used in the analysis is such that it is of doubtful that the water balance values provide a satisfactory baseline for assessing the potential loss of reservoir water through the bed and it was recommended that a Stage 2 water balance study be not undertaken.

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

The Stage 2 report recommended groundwater model derived cross sections be generated to display the pressure head profiles before and after mining specific panels with the zero pressure heads clearly displayed. The cross sections will be prepared for Longwalls 305-307 using the re-calibrated model and stacked drains.

4.2 RELEVANT LAND MANAGEMENT INFORMATION OBTAINED SINCE PROJECT APPROVAL

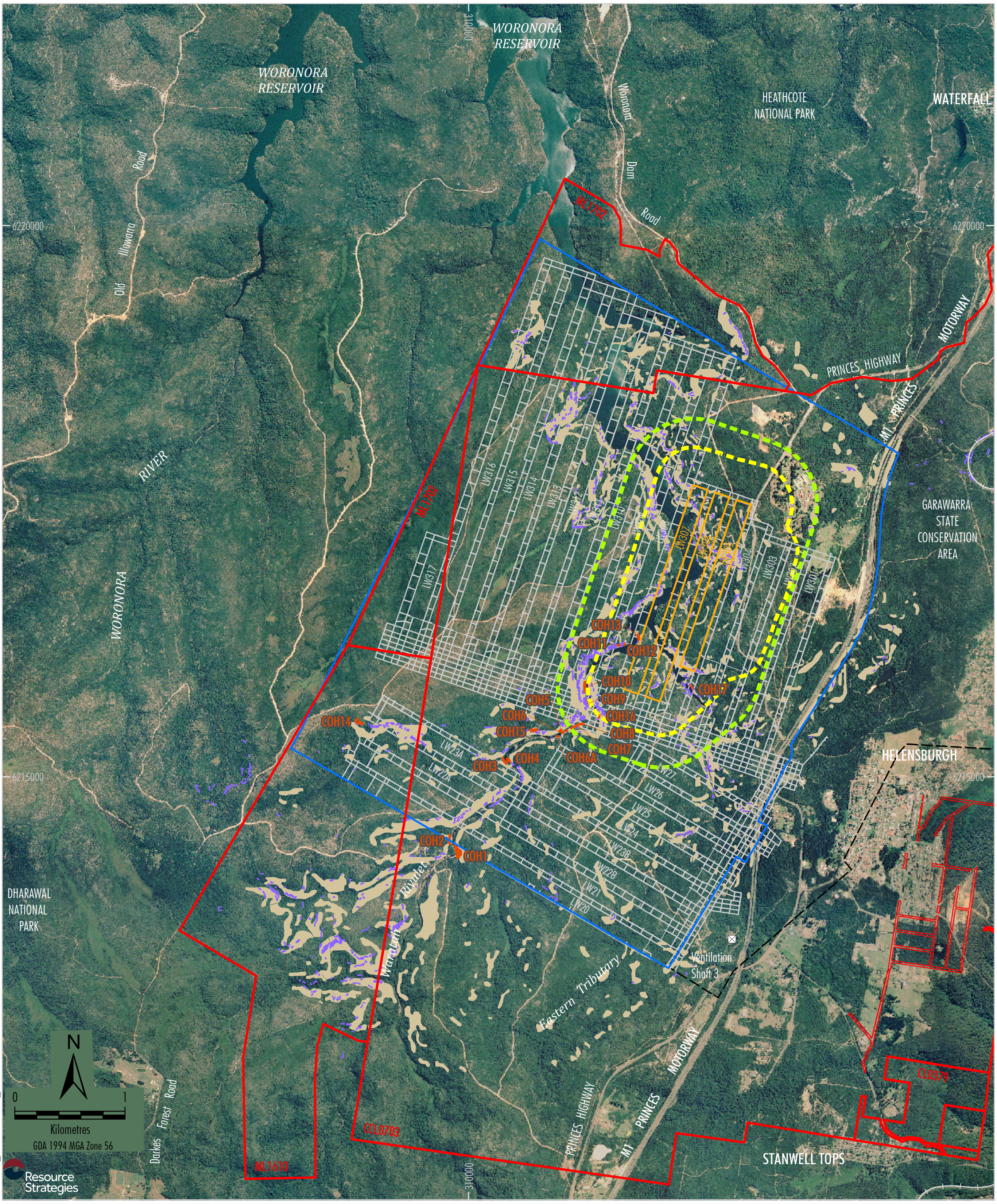
Visual inspections of cliffs and overhangs were conducted monthly when mining of Longwalls 20-22 and/or Longwalls 23-27 was within 400 m of sites COH1, COH2, COH3, COH4, COH5, COH6, COH6A, COH7, COH8, COH9, COH10, COH14, COH15 and COH16 (Figure 10) and following the completion of each longwall to record evidence of subsidence impacts. A vertical tension crack (approximately 50 mm wide and 15 m long) on the cliff face and a small rock fall (approximately 1.5 m long, 0.5 m wide and 0.5 m^3) were recorded at site COH2 (Figure 10) in December 2013 during the mining of Longwall 22 (Metropolitan Coal, 2014). No additional subsidence impacts at the abovementioned cliff or overhang sites were recorded following the completion of Longwall 27 (Metropolitan Coal, 2017).

An additional cliff and overhang site (COH17) was identified below the full supply level on the Eastern Tributary arm of the Woronora Reservoir in August 2018. A visual inspection of site COH17 was conducted following the completion of Longwall 303 to record evidence of subsidence impacts. No subsidence impacts were recorded.

Visual inspections for subsidence impacts on COH17 will also be conducted for Longwall 304. Longwall 304 had only recently commenced at the time of LMP development.

Observations of steep slopes and land in general have been conducted by Metropolitan Coal and its contractors as part of routine works conducted in the catchment. In February 2012 during the mining of Longwall 21, a surface tension crack was recorded on Fire Trail 9C adjacent to Longwall 20, approximately 10 m long with a maximum width of 20 mm (Metropolitan Coal, 2011). In February 2017 a surface tension crack was recorded on a rock platform located over Longwall 25 in the vicinity of Aboriginal heritage site FRC 301 approximately 10 mm wide and 25 m long (Metropolitan Coal, 2017).

In September 2011 during the mining of Longwall 21, a rock ledge was recorded to have collapsed on the Unnamed Tributary/Tributary D, located to the south of Longwalls 20-22 (Metropolitan Coal, 2012). In July 2015 during the mining of Longwall 24, a rock ledge collapse was recorded on Tributary B (Metropolitan Coal, 2016). In February 2017 rock fall from the underside of a sandstone boulder overhang, approximately 60 cm wide and 80 cm in length, was recorded in the vicinity of Aboriginal heritage site FRC 285 located over Longwall 22B (Metropolitan Coal, 2017).



Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2019); MSEC (2008; 2018; 2019)

LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 305-307 Secondary Extraction
- Longwalls 305-307 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 305-307 Secondary Extraction
- Existing Underground Access Drive (Main Drift)
- Cliffs and Overhangs
- Steep Slopes (Project Approval)
- Steep Slopes (Project Environmental Assessment)

Peabody

METROPOLITAN COAL

Cliffs and Overhangs, Steep Slopes and Land in General within the Project Underground Mining Area and Surrounds

Figure 10

The potential for impacts on public safety, as well as the potential environmental consequences of the observed subsidence impacts were assessed. None of the recorded subsidence impacts were considered to represent a safety or environmental hazard and no management measures were considered necessary.

The recorded subsidence impacts are consistent with the potential subsidence impacts described in the Project EA and Preferred Project Report.

4.3 RELEVANT BIODIVERSITY MANAGEMENT INFORMATION OBTAINED SINCE PROJECT APPROVAL

The Metropolitan Coal Longwall 304 BMP was prepared to manage the potential environmental consequences of the Metropolitan Coal Longwalls 20-22, 23-27, 301-303 and 304 Extraction Plans on aquatic and terrestrial flora and fauna, with a specific focus on swamps, in accordance with Condition 6, Schedule 3 of the Project Approval.

4.3.1 Upland Swamps

4.3.1.1 Swamp Types

Several types of upland swamps have been defined in the Metropolitan Coal Project underground mining area and surrounds according to the geomorphological settings in which they occur by the Metropolitan Coal BMPs, as follows:

1. <u>Headwater swamps</u>. These are the largest swamp type. They occupy broad, shallow, trough-shaped valleys, usually on first order watercourses at the head of valleys on broad plateaux. They sit on a relatively impermeable, low gradient sandstone base with dispersed seepage flows that encourage the growth of hygrophilic vegetation that in turn traps sediment, thereby increasing the water holding capacity. These swamps usually terminate at points where the watercourse suddenly steepens or drops away at a 'terminal step'. Terminal steps often occur at constrictions in the landscape where two ridges converge, causing a narrowing of the swamp and a concentration of water flows into a central channel.
2. <u>Valley side swamps</u>. Valley side swamps occur on steeper terrain than headwater swamps and are sustained by small horizontal aquifers that seep from the sandstone strata and flow over unbroken outcropping rock masses. These 'swamps' have shallow soils because the gradient usually limits sediment accumulation. They tend to terminate either on a horizontal step in the bedrock, or where broken rock, scree or deeper soil occurs at the base of the outcropping rock.
3. <u>In-valley swamps</u>. In-valley swamps are uncommon and occur on relatively flat sections of more deeply incised second and third order watercourses. Some are thought to develop behind obstructions in the watercourse, such as fallen rocks or log jams that result in a slowing of the water flow and deposition of sediments. Flat Rock Swamp is considered to represent a 'classic' in-valley swamp. Because of their relatively large catchment areas these swamps tend to be wetter than many headwater and valley side swamps.

Although these swamp types may occur discretely in the landscape, they can also occur in the same connected swamp system. For example, large headwater swamps may transition into in-valley swamps at the downstream end. Similarly, valley side swamps may occur around the steeper margins of some headwater swamps.

The terrain over Longwalls 20-27 and Longwalls 301-304 is highly dissected with narrow ridges. All the swamps mapped in the Longwalls 20-22, Longwalls 23-27 and Longwalls 301-304 mining areas are valley side swamps, with the exception of Swamp 20 which is a small in-valley swamp on a second order stream over Longwall 21 (Figure 9). Swamp 20 (situated in a gently inclined valley over solid bedrock) appears to have developed behind a terminal step, at a geological constriction in a valley, in much the same way as headwater swamps develop.

4.3.1.2 Swamp Characterisation

Swamp characterisation studies were conducted by Cenwest Environmental Services (2010) for the Longwalls 20-22 BMP and Cenwest Environmental Services (2011, 2013a) for the Longwalls 23-27 BMP. These studies have contributed to Metropolitan Coal's understanding of the ecological, hydrological and geomorphic processes of the upland swamps over Longwalls 20-27.

4.3.1.3 Swamp Vegetation Mapping

Bangalay Botanical Surveys (2008) conducted a baseline flora survey and mapped vegetation communities within the Project underground mining area for Longwalls 20-27 and Longwalls 301-317 for the Project EA (HCPL, 2008). Swamps were mapped by Bangalay Botanical Surveys (2008) consistent with vegetation mapping by the NSW National Parks and Wildlife Service (NPWS) (2003) as either vegetation community 3a (Banksia Thicket), 3b (Tea Tree Thicket), 3c (Sedgeland-heath Complex), 3d (Fringing Eucalypt Woodland), or a combination of these communities.

Longwalls 20-27

Swamps mapped by Bangalay Botanical Surveys (2008) located above or immediately adjacent to Longwalls 20-27 include Swamps 16, 17, 18, 19, 20, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35 and 36 (Figure 9).

While Swamp 29 is illustrated on Figure 9 (for consistency with the previous BMPs), field inspections by Eco Logical for the Longwalls 23-27 vegetation monitoring program indicated that it is not a swamp. The vegetation was found to be similar to sandstone heath woodland, being dominated by *Angophora costata, Corymbia gummifera* and *Eucalyptus oblonga,* with an understorey of *Banksia ericifolia, Acacia ulicifolia, Leptospermum trinervium, Kunzea ambigua, Dillwynia retorta* and *Schoenus ericetorum*. Accordingly, Swamp 29 was not considered further in the Metropolitan Coal BMPs.

The vegetation in the remaining swamps (with the exception of Swamp 33) was classified by Bangalay Botanical Surveys (2008) as 'Sedgeland-heath Complex' consistent with vegetation mapping by NPWS (2003). Sedgeland-heath Complex is a mapping unit that amalgamates the Sedgeland, Restioid Heath and Cyperoid Heath vegetation associations identified by Keith and Myerscough (1993). The three communities were condensed by NPWS (2003) because they could not be reliably distinguished by Air Photo Interpretation for community mapping. Swamp 33 was mapped by Bangalay Botanical Surveys as 'Banksia Thicket' consistent with vegetation mapping by NPWS (2003).

Field inspections for the Longwalls 20-22 and Longwalls 23-27 BMPs by Eco Logical Australia (Eco Logical) indicated that all the swamps over Longwalls 20-27 comprised either Banksia Thicket or Restioid Heath (or a combination of the two), with the exception of Swamp 20 and Swamp 28. Swamp 20 supports Tea Tree Thicket, while Swamp 28 is a Banksia Thicket swamp with the lower portion supporting Tea Tree Thicket.

Three of the vegetation patches mapped as swamps (Swamps 16, 17 and 23), although showing seepage, do not appear to be upland swamps, being more akin to Sandstone Heath Woodland with low tree densities. The vegetation on these patches have species found in upland swamps, mixed with a range of non-swamp species, including *Banksia serrata, Eucalyptus sieberi* and *E. racemosa* in Swamps 16 and 17, and *Angophora hispida* and *Allocasuarina distyla* in the case of Swamp 23. However, Swamp 23 also has a number of characteristic swamp species, including *Sprengelia incarnata, Epacris obtusifolia* and *Pultenaea aristata,* indicating at least some parts of it are quite moist. However, despite this, Swamp 23 is considered to be transitional between swamp and wet heath and somewhat atypical.

Similarly, Swamp 32 and Swamp 34 included elements of the Sandstone-Heath Woodland consistent with descriptions of this community by NPWS (2003).

During the conduct of Longwalls 20-27 upland swamp vegetation monitoring, the swamp boundary of control swamps 101, 111a, 135, 136, 137a, 137b, 138 and Bee Creek Swamp were updated by Eco Logical (as shown on Figure 9).

Longwalls 301-303

Field inspections of upland swamp vegetation mapped by Bangalay Botanical Surveys (2008) in the vicinity of Longwalls 301-303 was conducted by Eco Logical in 2015. The field inspections indicated that the upland swamps were comprised of Banksia Thicket, with the exception of Swamps 58 and 59 which were mapped as a combination of Banksia Thicket and Sedgeland-heath Complex (Eco Logical, 2016). The revised upland swamp mapping was detailed in Eco Logical (2016), which was included as Appendix 2 of the Longwalls 301-303 BMP.

The revised mapping of Swamps 37, 38, 40, 41, 42, 46, 47, 48, 49, 50, 51/52, 53, 54, 58, 59, 69, 70, 71a and 71b by Eco Logical (2016) is shown on Figure 9.

Subsequent to the vegetation mapping, Swamps 46, 51/52, 69, 70, 71a and 71b were subject to WaterNSW hazard reduction burns in 2016 and/or 2017. It is recognised that while these swamps were all mapped as containing Banksia Thicket vegetation, the hazard reduction burns are likely to have affected the vegetation that is now present.

Longwalls 304-310

All of the upland swamps within the 35 degree (°) angle of draw and/or predicted 20 mm subsidence contour for Longwall 304 were included in Eco Logical’s field inspections for the Longwalls 301-303 BMP described above.

Field inspections of upland swamp vegetation mapped by Bangalay Botanical Surveys (2008) overlying or proximal to Longwalls 304-310 was conducted by Eco Logical in 2016 and 2017 to confirm the upland swamp vegetation communities present and swamp boundaries. Similar to the revised upland swamp vegetation mapping conducted for Longwalls 301-303, for each upland swamp a description of the vegetation was recorded including the different strata present, the dominant species and an estimation of percent foliage cover for each stratum to assign vegetation communities described by the NPWS (2003) and Bangalay Botanical Surveys (2008). Final delineation of vegetation community boundaries was undertaken by interpretation of recent aerial photographs. Patterns identified on aerial photographs were related to the field observations and used to delineate the boundaries of vegetation communities. The revised mapping of upland swamp vegetation overlying or proximal to Longwalls 304-310 secondary extraction is detailed in Eco Logical (2018), which is provided in Appendix 2 of this BMP.

The *NSW Native Vegetation Interim Type Standard* (Sivertsen 2009) requires patches of vegetation to be mapped if the dimensions of the representative polygon on a map sheet are 2 mm x 2 mm or greater (i.e. at a map scale of 1:25,000, patches of vegetation equal to or greater than 0.25 ha). However, the revised swamp vegetation mapping boundaries (including those swamps less than 0.25 hectares [ha] in area) are shown on Figures 9 and 15 to document the changes to the previous Bangalay Botanical Surveys (2008) vegetation mapping. It is noted that many of the revised swamp boundaries comprising vegetation characteristic of the upland swamp vegetation communities are very small in size and doubtfully represent an upland swamp (Appendix 2). For example, Swamp 65/66 (0.112 ha in area), Swamp 67 (0.030 ha in area), Swamp 68a (0.043 ha in area), Swamp 68b (0.034 ha in area) (Figure 15). In addition to those listed above, Swamps 61, 63, 73, 83, 86 and 88 are all less than 0.25 ha in area.

In addition to the swamps described above as being subject to hazard reduction burns, Swamps 63, 64, 65/66, 67, 68a and 68b overlying or proximal to Longwalls 305-307 were also subject to hazard reduction burns in October 2016 and August 2017. It is recognised that while these swamps were all re-mapped as containing Banksia Thicket vegetation (Appendix 2), the hazard reduction burns are likely to have affected the vegetation that is now present.

Further to the above, Swamp 84 and Swamp 86 are considered to be marginal upland swamps in that they contain non-swamp vegetation more consistent with sandstone woodland (Figure 15 and Appendix 2).

The revised upland swamp mapping and associated vegetation community mapping by Eco Logical (2018) of Swamps 60, 61, 62, 63, 64, 65/66, 67, 68a, 68b, 72, 81, 82, 83, 84, 86, 88, 89, 133 and 134 is shown on Figures 9 and 15.

4.3.1.4 Upland Swamp Vegetation Monitoring

Upland swamp vegetation monitoring for Longwalls 20-22, Longwalls 23-27, Longwalls 301-303 and Longwall 304 has included visual, quadrat/transect and/or indicator species monitoring, as described below.

The upland swamp vegetation monitoring programs were designed to comprehensively assess potential vegetation changes at three scales; overall gross changes across the whole swamp, changes at the community level and changes at the level of individual plants. Visual inspections aim to appraise the overall condition of the swamp and to detect any localised changes, described below, that may not be detected by detailed transect, quadrat and individual plant monitoring. The visual inspections provide qualitative information that may lead to further investigation and/or actions.

The fixed vegetation transects and associated quadrats aim to precisely measure changes in vegetation community composition over time in undermined and control swamps, including a two year pre-mining baseline data period. This sampling design follows that of Keith and Myerscough (1993) which is specifically tailored for upland swamp monitoring. The original design of the vegetation monitoring programs included sufficient replication for robust statistical analysis[11,12].

Monitoring of individual plants provides species level data on the health and survival of individual plants in undermined and control swamps. Monitoring is targeted to swamp specialist species that may be prone to any mining-induced changes to swamp hydrology.

[11] It should be noted that Swamp 46 and Swamp 51/52 were subject to WaterNSW hazard reduction burns resulting in vegetation along transects in these swamps no longer being comparable to the control swamps, and unable to be subject to statistical analysis.

[12] The vegetation monitoring program for Longwall 304 was originally designed for Longwalls 304-306.

Visual Inspections

Visual inspections have been conducted in Swamps 16, 17, 18, 19, 20, 23, 24, 25, 26, 27, 28, 30, 31, 32, 33, 34, 35, 36, 38, 40, 41, 46, 47, 48, 49, 50, 51/52, 53, 58, 93, 94, 95, 96, 97 and 98 overlying or adjacent to Longwalls 20-27 and/or Longwalls 301-304 to record evidence of potential subsidence impacts and control swamps.

Traverses covering the majority of the extent of the swamp have been conducted to record:

- cracking of exposed bedrock areas and/or swamp sediments;
- areas of increased erosion, particularly along any existing drainage lines;
- any changes in water colour;
- changes in vegetation condition, including areas of stressed[13] vegetation (i.e. plants that demonstrate symptoms of stress) and dead/dying plants that appear unusual; and
- whether the amount of seepage (at the terminal step/over exposed surfaces of the swamp) at the time of inspection appears unusual (relative to recent rainfall).

As many of the Longwalls 301-304 swamps comprise dense Banksia Thicket, it was anticipated that such traverses would be difficult to impractical to monitor at some locations.

Transect and Quadrat Monitoring

Transect and quadrat monitoring is conducted of:

- Banksia Thicket/Restioid Heath vegetation – in Swamps 16, 17, 18, 24 and 25 overlying Longwalls 20-22, Swamps 28 (upper portion), 30, 33, 35 and 94 overlying or adjacent to Longwalls 23-27, Swamps 40, 41, 46, 51/52 and 53 overlying Longwalls 301-303, Swamps 48 and 50 overlying or adjacent to Longwall 304 and in control Swamps 101, 111a, 125, 135, 136, 137a, 137b, 138 and Bee Creek Swamp (Figure 9); and
- Tea Tree Thicket vegetation – in Swamp 20 overlying Longwalls 20-22, in the lower portion of Swamp 28 overlying Longwalls 23-27, and in control swamps Woronora River 1, Woronora River south arm and Dahlia Swamp (Figure 9).

Baseline upland swamp vegetation surveys were conducted for Longwalls 20-22 in spring 2009 and autumn 2010[14], for Longwalls 23-27 from spring 2010 to spring 2013[15], for Longwalls 301-303 from spring 2015 to autumn 2017[16], and for Longwall 304 from spring 2015 to autumn 2019[17].

[13] Vegetation that is 'stressed' and vegetation that is dying or has died (senescent). Senescence is the process of ageing including the period leading up to death. It is sometimes difficult to differentiate between the two under field conditions.

[14] Longwall Swamps 16 and 17 (Restioid Heath/Sandstone Heath Woodland) were added to the vegetation monitoring program in autumn 2010.

[15] Monitoring of transects/quadrats in control Swamps 101, 111a, 125, Woronora River 1, Woronora River south arm and Dahlia Swamp commenced in spring 2009 and in control Swamps 135, 136, 137a, 137b, 138 and Bee Creek Swamp in spring 2010.

[16] Baseline data for upland swamps has been obtained up to, and including, autumn 2017 prior to the commencement of mining and is reported in Eco Logical (2018).

[17] Longwall 304 commenced in late July 2019.

The Banksia Thicket/Restioid Heath swamps and Swamp 20 (Tea Tree Thicket) have been monitored with three transects, with the exception of Swamp 28. Swamp 28 is a small valley-side swamp which supports Banksia Thicket in the upper portion of the swamp and Tea Tree Thicket in the lower portion of the swamp. Vegetation within Swamp 28 has been monitored along two transects, one within the Banksia Thicket and one within Tea Tree Thicket vegetation. Tea Tree Thicket control swamps Woronora River 1, Woronora River south arm and Dahlia Swamp have been monitored with a single transect owing to the much larger size of these control swamps.

For the Banksia Thicket/Restioid Heath swamps, assessments have been made on 1 square metre (m^2) quadrats along a transect line every 5 m starting from 0 m. For the Tea Tree Thicket swamps, assessments have been made on 1 m^2 quadrats located upslope of the transect line with one quadrat edge located on the line as a means of avoiding the impacts of vegetation trampling as a result of access into these thickly vegetated swamps. As for Banksia Thicket/Restioid Heath swamps, assessments are made every 5 m starting from 0 m.

The data collected for each quadrat includes:

- vegetation structure;
- dominant species;
- estimated cover and height for each stratum;
- full floristics;
- estimated cover abundance for each species using seven point Braun-Blanquet scale; and

  Modified Braun-Blanquet Scale
  1 = cover less than 5% of site and rare
  2 = cover less than 5% of site and uncommon
  3 = cover of less than 5% and common
  4 = cover of 5-20% of site
  5 = cover of 21-50% of site
  6 = cover of 51-75% of site
  7 = cover of greater than 75%

- condition/health rating for each species in the quadrat:

  Condition Scale
  1 severe damage/dieback
  2 many dead stems
  3 some dead branches
  4 minor damage
  5 healthy

Permanent photo points were established along each transect.

Existing control Swamps 101, 135, 136, 137a and 137b were selected for comparison with the swamps over Longwalls 301-303. It is noted that some of these control swamps have previously been identified as supporting Sedgeland-heath Complex (Bangalay Botanical Surveys, 2008; Metropolitan Coal, 2014), however, the height and density of the shrub layer of these swamps (in particular *Banksia ericifolia* subsp*. ericifolia*) has increased with time since fire, and these control swamps now support vegetation comparable to Banksia Thicket as described in NPWS (2003) and Bangalay Botanical Surveys (2008) and similar to that observed in swamps overlying Longwalls 301-303.

The existing control swamps were considered to be suitable for comparison with Swamp 48 and Swamp 50 vegetation.

Portions of Swamp 46 and Swamp 51/52 were subject to WaterNSW hazard reduction burns in 2017. Specifically, Swamp 46 (Transect 1) and Swamp 51/52 (Transects 1 and 3) have been affected by the hazard reduction burns. This has resulted in vegetation along some transects in these swamps no longer being comparable to the control swamps.

Indicator Species Monitoring

Indicator species monitoring has been conducted in Banksia Thicket/Restioid Heath swamps, as follows:

- *Epacris obtusifolia* in Swamps 18, 24 and 25 overlying Longwalls 20-22, in Swamps 19, 30, 33, 35 and 94 overlying or adjacent to Longwalls 23-27, Swamps 40, 51/52[18] and 53 overlying Longwalls 301-303 and in control Swamps 101, 111a, 125, 135, 136, 137a, 137b and 138[19].
- *Sprengelia incarnata* in Swamp 24 overlying Longwalls 20-22, in Swamps 19, 33, 35 and 94 overlying or adjacent to Longwalls 23-27, Swamps 40, 51/52[18] and 53 overlying Longwalls 301-303 and in control Swamps 101, 125, 135, 136, 137a and 138[19].
- *Pultenaea aristata*[20] in Swamps 18, 24 and 25 overlying Longwalls 20-22, in Swamps 19, 30, 33, 35 and 94 overlying or adjacent to Longwalls 23-27 and in control Swamps 101, 111a, 135, 136, 137a and 138.

Indicator species monitoring of *Banksia robur, Callistemon citrinus* and *Leptospermum juniperinum* has been conducted in the Tea Tree Thicket vegetation of Swamp 20 overlying Longwalls 20-22, of *Banksia robur* and *Callistemon citrinus* in the Tea Tree Thicket vegetation of Swamp 28 overlying Longwalls 23-27, and at the associated control sites (Woronora River 1, Woronora River south arm and Dahlia Swamp).

Baseline indicator species monitoring was conducted in spring 2009 and autumn 2010 for Longwalls 20-22[21], from spring 2010 to spring 2013 for Longwalls 23-27[22] and from spring 2015 to autumn 2017 for Longwalls 301-303[23].

Twenty tagged individuals of each species have been monitored in the swamps indicated above. Population monitoring data collected includes a condition/health rating (1 - severe damage/dieback, 2 - many dead stems, 3 - some dead branches, 4 - minor damage, 5 - healthy) and a reproductive rating (1 – nil, 2 - sparse [occasional flowers only], 3 - low [under 25 percent of potential], 4 - moderate [25 to 75 percent], 5 - high [over 75 percent of potential flowering]) for each plant.

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[18] Subsequent to the autumn 2017 survey and prior to the spring 2017 survey, Swamp 51/52 was subject to WaterNSW hazard reduction burns, resulting in the death of indicator species in Swamp 51/52. As a result, monitoring in Swamp 51/52 was removed from the monitoring program.

[19] Individuals of indicator species being monitored within these control swamps for Longwalls 23-27 have not been used for Longwalls 301-303 as a proportion of these individuals within control swamps have already been recorded with severe dieback or are dead. Additional individuals have been tagged as a component of the monitoring program.

[20] Insufficient individuals of *Pultenaea aristata* were available in the swamps over Longwalls 301-303 for monitoring.

[21] Monitoring of *Pultenaea aristata* in Swamp 24 commenced in autumn 2010.

[22] Monitoring of indicator species in control Swamps 101, 111a, 125, Woronora River 1, Woronora River south arm and Dahlia Swamp commenced in spring 2009 and monitoring of indicator species in control Swamps 135, 136, 137a, 137b and 138 commenced in spring 2010.

[23] Subsequent to the autumn 2017 survey and prior to the spring 2017 survey, WaterNSW hazard reduction burns resulted in the death of indicator species in Swamp 51/52. As a result, monitoring in Swamp 51/52 was removed from the monitoring program.

Monitoring Results to Date

The results of the Longwalls 20-22 and Longwalls 23-27 upland swamp vegetation monitoring programs (up to and including the autumn 2018 survey) can be summarised as follows:

- No cracking of exposed bedrock areas or swamp sediments has been observed, other than those recorded during the baseline surveys. Areas in which active erosion was observed were all minor and limited to access tracks, drainage lines and areas of bare earth without vegetation cover.
- Iron-stained groundwater seepage has been observed since spring 2012 on the terminal rocky step and/or the small rocky step of Swamp 20. In autumn 2018, iron staining continued to be reduced in area compared to previous seasons.
- The vegetation structure, dominant species and estimated cover abundance for each stratum has been variable across all seasons with variations recorded between sites, seasons and strata. No notable changes in vegetation structure, dominant species or estimated cover and abundance which could be attributed to impacts associated with the mining of Longwalls 20-22 or Longwalls 23-27 have been recorded.
- Recent surveys have been undertaken during extremely dry conditions which have contributed to the limited seepage and water stress observed in the vegetation during recent surveys. For example, in autumn 2018, standing water and seepage was not recorded in any of the larger headwater control swamps or Swamp 28. Swamp 28 is very small, does not contain any internal drainage lines and free surface water has never been observed at this site since the inception of monitoring. Seepage was only recorded in Swamp 20 in autumn 2018 where it has been observed in previous seasons, however standing water was not observed.
- Fluctuations in species cover/abundance and condition have been recorded across all sites. Visual inspections of Restioid Heath/Banksia Thicket swamps since spring 2017 identified that vegetation at both longwall and control swamps has been in poorer condition than in previous years, with yellowing and senescence common and widespread. Dieback was most evident where soils are shallow, particularly over rocky areas and downslope. For the Tea Tree Thicket swamps, vegetation of both longwall and control swamps was found to be generally in good condition in autumn 2018. Some isolated dieback was recorded throughout most longwall and control swamps. Close monitoring of trends in vegetation will continue to assess the contribution of dry climatic conditions versus mine subsidence impacts.
- Analysis of species richness within Restioid Heath/Banksia Thicket sites using analysis of variance (ANOVA) did not detect significant differences between longwall and control sites in any season including autumn 2018.
- Species richness within individual Tea Tree Thicket sites in autumn 2018 was within the range of previous seasons at all longwall sites and all control sites, with the exception of one control site (Woronora River 1) which was below the previously recorded range for this site.
- Monitoring of indicator species indicates the observed mortality appears to be driven by natural factors including predation, competition with other vegetation and abiotic factors and not related to longwall mining. The increased mortality of *Banksia robur* at the single Tea Tree Thicket longwall site (Swamp 28) over Longwalls 23-27 has been observed since spring 2012 prior to the commencement of mining Longwalls 23-27 and mine subsidence impacts (as indicated by piezometer data).

- The upland swamp vegetation performance indicator, *The vegetation in upland swamps is not expected to experience changes significantly different to changes in control swamps*, has not been exceeded for any of the monitored Restioid Heath/Banksia Thicket Swamps or Swamp 20 (Tea Tree Thicket vegetation). However, for longwall Tea Tree Thicket Swamp 28, based on the autumn 2017 continual decline in condition of the understorey and species richness, and the high mortality rate of *Banksia robur* in comparison to the control sites, the upland swamp performance indicator was considered to have been exceeded at this site since autumn 2017. Threatened flora and fauna assessments against the biodiversity subsidence impact performance measure, *negligible impact on the species, populations or ecological communities* have been conducted and to date the performance measure has been met.
- A significant increase in plant stem density has been observed since the 2001 bushfire in both control and longwall swamps, significantly increasing the fuel load and potential evapotranspiration in swamps).

The spring 2017 survey was the first survey undertaken during the mining of Longwalls 301-303. The results of the Longwalls 301-303 upland swamp vegetation monitoring program (up to and including the autumn 2018 survey) can be summarised as follows:

- Visual inspections have not identified any cracking of exposed bedrock areas or swamp sediments in longwall swamps as a result of mine subsidence.
- Vegetation at both longwall and control sites has generally been in good condition with no unusual areas of vegetation senescence or death observed. Some isolated dieback and senescence of individuals has occurred throughout most longwall and control swamps.
- The vegetation structure commonly found within all longwalls swamps is slightly different to that of the controls, most likely attributable to fire history. The mid layer is taller and denser compared with the mid layer at control sites. Similar to control swamps the mid layer is dominated by *Banksia ericifolia* subsp. *ericifolia*, *Hakea teretifolia* and *Leptospermum squarrosum* but the cover is generally greater with a generally less diverse ground layer in some areas of these swamps. Floristically, the longwall and control swamps are similar.
- Fluctuations in species cover/abundance and condition were recorded across all sites throughout the baseline monitoring period. For swamps not subject to the WaterNSW hazard reduction burns, no patterns of increasing or decreasing cover/abundance, or declines in vegetation condition, were identified in spring 2017 or autumn 2018 in relation to individual species across sites or groups of species (i.e. swamp indicator species, generalist species, shrubs, ground covers) within sites. Vegetation in Swamps 46 and 51/52 following hazard reduction burns is distinctly different to all other monitoring swamps.
- Analysis of species richness using ANOVA has not detected significant differences between longwall and control swamps. Data for Swamp 46 and Swamp 51/52, which were subject to hazard reduction burns, are excluded from the analysis. All observed changes in species richness are considered to be within the range of natural fluctuations in response to weather, population dynamics, seasonality of survey and natural disturbances including grazing by fauna species.
- In spring 2017 and autumn 2018, the proportion of upland swamp indicator species plants which were dead was greater at longwall sites than control sites for both indicator species, *Epacris obtusifolia and Sprengelia incarnata.* This trend was observed within the baseline monitoring period. A relatively large increase in the mortality of *Epacris obtusifolia* was recorded in longwall swamps in autumn 2018. The autumn 2018 survey was undertaken following an extremely dry period and is considered to likely be responsible for the mortality. Monitoring of swamp substrate water levels in the longwall swamps indicates the dry swamp conditions are natural.
- The upland swamp performance indicator '*The vegetation in upland swamps is not expected to experience changes significantly different to changes in control swamps*' has not been exceeded.

4.3.1.5 Upland Swamp Groundwater Monitoring

Groundwater monitoring of upland swamps is described in Section 4.1.2 above.

4.3.1.6 Assessment of Monitoring Results against Predicted Subsidence Impacts and Environmental Consequences

The key potential subsidence impacts and environmental consequences on perched groundwater systems and upland swamp vegetation described in the Project EA, Preferred Project Report, Metropolitan Coal Water Management Plans and BMPs are described in Section 4.1.2.

In summary, no change to the fundamental surface hydrological processes and upland swamp vegetation were expected within upland swamps; however, Swamp 20 was identified as being most at risk of subsidence impacts as a result of Longwalls 20-27.

Swamp substrate water levels have been assessed against the following upland swamp groundwater performance indicator:

> *Surface cracking within upland swamps resulting from mine subsidence is not expected to result in measurable changes to swamp groundwater levels when compared to control swamps or seasonal variations in water levels experienced by upland swamps prior to mining*.

The upland swamp groundwater performance indicator has been exceeded at Swamp 20 since 2012. Swamp 20 substrate water levels changed from being permanently saturated to being periodically saturated as a result of the passing of Longwall 21. It is considered that Longwall 21 caused a mining effect at Swamp 20, but the effects were not exacerbated by Longwalls 22-27.

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. Swamp 28 is considered to have 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.

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.

Analysis of swamp substrate water levels of Swamps 25, 30, 33 and 35 overlying Longwalls 20-27 and Swamps 40, 41, 46, 51, 52 and 53 overlying Longwalls 301-303 compared with control swamps (Swamps 101, 137a and 137b) and rainfall records have not shown any mining effect. Both control and longwall swamps have responded similarly to reduced rainfall under drought conditions (HydroSimulations, 2019).

To date, the upland swamp vegetation monitoring results indicate that the vegetation in Swamp 20 has not experienced changes significantly different to changes in control swamps. However, it is not possible to predict the long term impacts on the vegetation of Swamp 20 owing to uncertainty about the altered hydrological regime, particularly the extent of cracking, and the potential for natural remediation. The effects on vegetation of reductions in water levels in Swamp 20, if any, may take some years to be expressed in the absence of a catastrophic event such as extreme drought and/or a wildfire. Continued biannual quantitative monitoring is required to reliably determine the impact of subsidence on Swamp 20 vegetation.

Based on the decline in condition of the understorey and species richness, and the high mortality rate of *Banksia robur*, compared to the control swamps, the Tea Tree Thicket component of Swamp 28 is considered to have experienced changes significantly different[24] to the control sites since the autumn 2017 survey.

Assessments against the biodiversity subsidence impact performance measure, *Negligible impact on threatened species and populations* conducted to date for Swamp 20 and Swamp 28 by FloraSearch (2012, 2013, 2014, 2015, 2016a), Cenwest Environmental Services (2012, 2013b, 2014a, 2015, 2016, 2017, 2019), Eco Logical (2017a) and Ecoplanning (2019a) have concluded the subsidence impact performance measure has been met.

4.3.2 Riparian Vegetation

Riparian vegetation within the Project underground mining area occurs along streams which flow to the Woronora Reservoir, including Waratah Rivulet and the Eastern Tributary, and some of their tributaries. Vegetation mapping within the Project underground mining area is shown on Figure 11. Riparian vegetation includes vegetation mapped as community 4a (Sandstone Riparian Scrub).

4.3.2.1 Riparian Vegetation Mapping

Field inspections of Sandstone Riparian Scrub vegetation mapped by Bangalay Botanical Surveys (2008) on a tributary of the Woronora Reservoir on the lower reaches of the stream that is located above the middle of Longwall 304 were conducted by Eco Logical in 2015. The area mapped by Bangalay Botanical Surveys (2008) as Sandstone Riparian Scrub was found to support Sandstone Gully Apple-Peppermint Forest in the eastern upper portion and Sandstone Riparian Scrub in the western lower portion. The revised vegetation community mapping of this riparian vegetation by Eco Logical is shown on Figure 16.

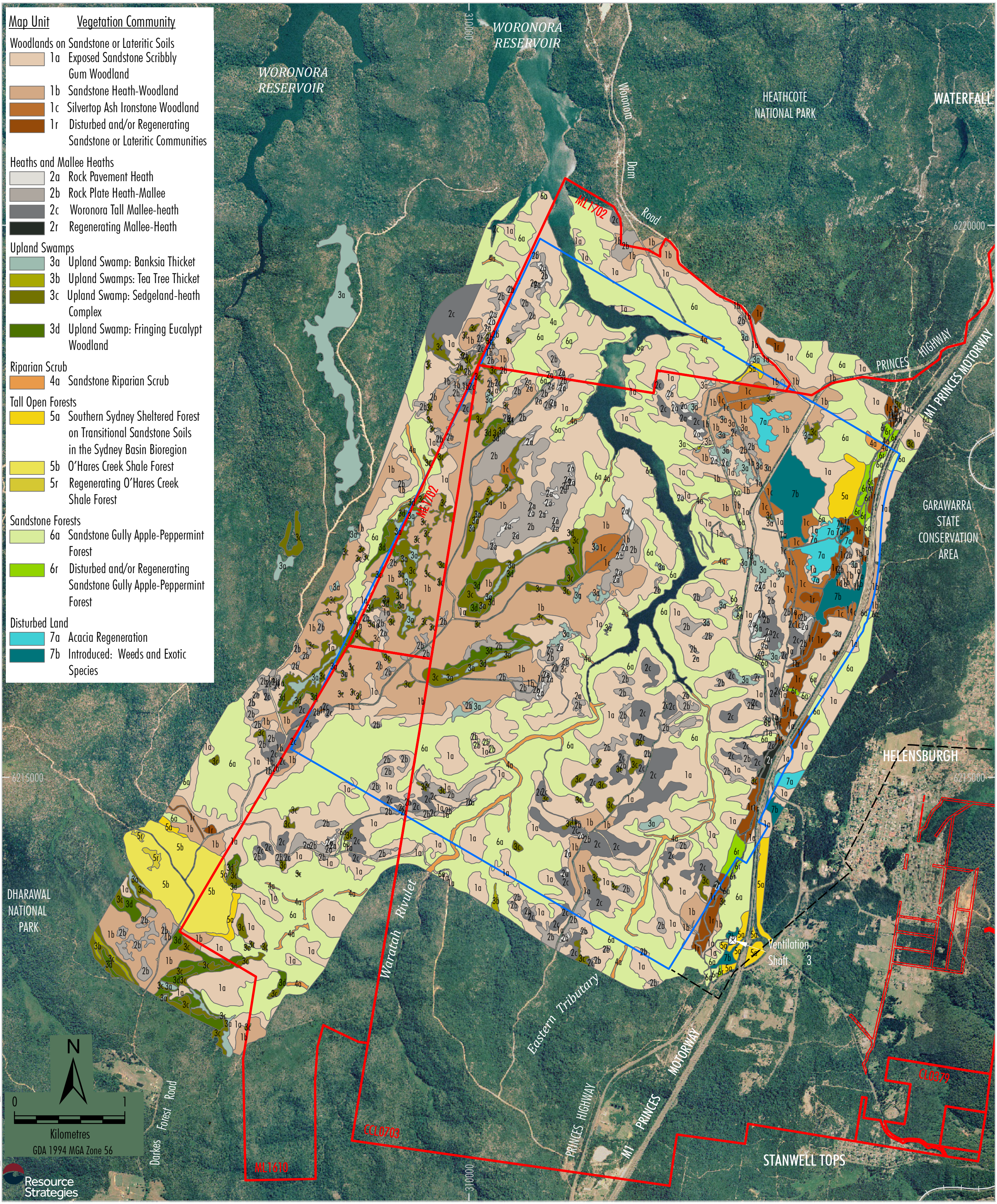
The area of Sandstone Riparian Scrub occurs along a steep and deeply incised drainage line with extensive stream boulders[25]. The vegetation of this area was consistent with the description of Sandstone Riparian Scrub by NPWS (2003) including the following features: a variable canopy commonly including overhanging *Angophora costata* and *Eucalyptus piperita;* a dense shrub layer commonly including *Ceratopetalum apetalum, Callicoma serratifolia, Lomatia myricoides* and *Tristania neriifolia;* and a ground layer dominated by mesic ferns such *as Sticherus flabellatus* var. *flabellatus* and *Gleichenia microphylla*. While the vegetation was closely aligned with the description of Sandstone Riparian Scrub by NPWS (2003), a number of abiotic features typical of the community (and observed along the Waratah Rivulet and Eastern Tributary) were absent including rock pools, rock platforms, sandy banks and sandy alluvial deposits.

4.3.2.2 Riparian Vegetation Monitoring

The riparian vegetation monitoring program includes visual, quadrat/transect and indicator species monitoring of riparian vegetation on the Waratah Rivulet and Eastern Tributary, as described below.

[24] As there is only one Tea Tree Thicket longwall site for Longwalls 23-27, data for the Tea Tree Thicket component of Swamp 28 is not able to be analysed using analysis of variance (ANOVA).

[25] At the time of inspection by Eco Logical, standing water was largely absent from the drainage line. Due to the steep slope it is expected that standing water would generally be absent and only be present for a short period after rainfall events.



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Existing Underground Access Drive (Main Drift)

Note: The NSW Native Vegetation Interim Type Standard 2009 requires patches of vegetation to be mapped if the dimensions of the representative polygon on a map sheet are 2 mm x 2 mm or greater (i.e. 0.25 hectares or greater at a scale of 1:25,000). Eco Logical Australia conducted field inspections of upland swamp vegetation previously mapped by Bangalay Botanical Surveys (2008) overlying or proximal to Longwalls 301-310 to confirm the upland swamp vegetation communities present and to confirm or update the swamp vegetation boundaries. It is noted that the revised boundaries of a number of upland swamps (Swamps 37, 38, 42, 48, 54, 58, 61, 63, 65/66, 67, 68a, 68b, 70, 73, 83, 86 and 88) are less than 0.25 hectares in area and consistent with NSW vegetation mapping guidelines are not required to be mapped. Notwithstanding, the revised swamp vegetation mapping boundaries (including those swamps less than 0.25 hectares in area) are shown on this figure to document the changes to previous vegetation mapping.

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2019); after NPWS (2003), Bangalay Botanical Surveys (2008) and Eco Logical Australia (2015; 2016; 2018)

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Mapped Vegetation Communities Within the Project Underground Mining Area and Surrounds

Figure 11

The riparian vegetation monitoring program was designed to comprehensively assess potential vegetation changes at three scales; overall gross changes across the observed streamside section, changes at the community level and changes at the level of individual plants. Visual inspections aim to appraise the overall condition of the riparian zone and to detect any localised changes, described below, that may not be detected by detailed transect, quadrat and individual plant monitoring. The visual inspections provide qualitative information that may lead to further investigation and/or actions.

The fixed vegetation transects and associated quadrats aimed to precisely measure changes in vegetation community composition over time, including a two-year pre-mining baseline data period.

Monitoring of individual plants provides species level data on the health and survival of individual within riparian zone species. Monitoring is targeted to specialist species that depend on the habitats of the riparian zone and may be prone to any mining-induced changes to stream geomorphology.

Visual Inspections

Visual inspections of riparian areas have been conducted biannually in locations adjacent to riparian vegetation monitoring sites (sites MRIP01 to MRIP12) (Figure 12), and areas traversed whilst accessing the monitoring sites, to record evidence of subsidence impacts including:

- areas of new water ponding;
- any cracking or rock displacement; and
- changes in vegetation condition, including areas of stressed vegetation that appear unusual.

Transect/Quadrat Monitoring

A permanent quadrat (20 m x 2 m) and permanent transect (50 m x 2 m, i.e. a 30 m extension of each quadrat) have been used to monitor riparian vegetation on the Waratah Rivulet and Eastern Tributary at (Figure 12)[26]:

- sites MRIP01, MRIP02, MRIP05 and MRIP06 overlying Longwalls 20-22;
- sites MRIP11 and MRIP12 overlying Longwalls 23-27; and
- sites MRIP03, MRIP04, MRIP07 and MRIP08 downstream of Longwalls 23-27[27].

The data collected for each quadrat includes:

- vegetation structure;
- dominant species;
- estimated cover and height for each stratum;
- full floristics;

[26] Note that no quadrat or transect monitoring is conducted at sites MRIP09 and MRIP10. These sites were established for the purpose of visual inspections and indicator species monitoring only.

[27] Prior to the autumn 2017 vegetation monitoring survey, mine subsidence impacts to pool drainage behaviour were recorded by Metropolitan Coal at sites MRIP07 and MRIP08.

- estimated cover abundance for each species using seven point Braun-Blanquet scale; and

  Modified Braun-Blanquet Scale

  1 = cover less than 5% of site and rare
  2 = cover less than 5% of site and uncommon
  3 = cover of less than 5% and common
  4 = cover of 5-20% of site
  5 = cover of 21-50% of site
  6 = cover of 51-75% of site
  7 = cover of greater than 75%

- condition/health rating for each species in the quadrat.

  Condition Scale

  1 severe damage/dieback
  2 many dead stems
  3 some dead branches
  4 minor damage
  5 healthy

Data was collected along each transect during the mining of Longwalls 20-27, including the occurrence of weed species (species and location) and a condition/health rating for each plant along the transect[28].

Permanent photo points were established for each quadrat and along each transect.

Baseline riparian transect/quadrat surveys were conducted biannually from spring 2008 to autumn 2010 at sites MRIP01 to MRIP08 and from spring 2010 to spring 2013 (i.e. prior to the commencement of Longwall 23) at sites MRIP11 and MRIP12.

Indicator Species

Three riparian vegetation indicator species have been monitored along Waratah Rivulet and the Eastern Tributary, namely, *Prostanthera linearis*, *Schoenus melanostachys* and *Lomatia myricoides*. Twenty tagged individuals of each species have been monitored at the following sites (Figure 12):

- sites MRIP01, MRIP02, MRIP05, MRIP06 and MRIP09 overlying Longwalls 20-22;
- sites MRIP11 and MRIP12 overlying Longwalls 23-27; and
- sites MRIP03, MRIP04, MRIP07, MRIP08[29] and MRIP10 downstream of Longwalls 23-27.

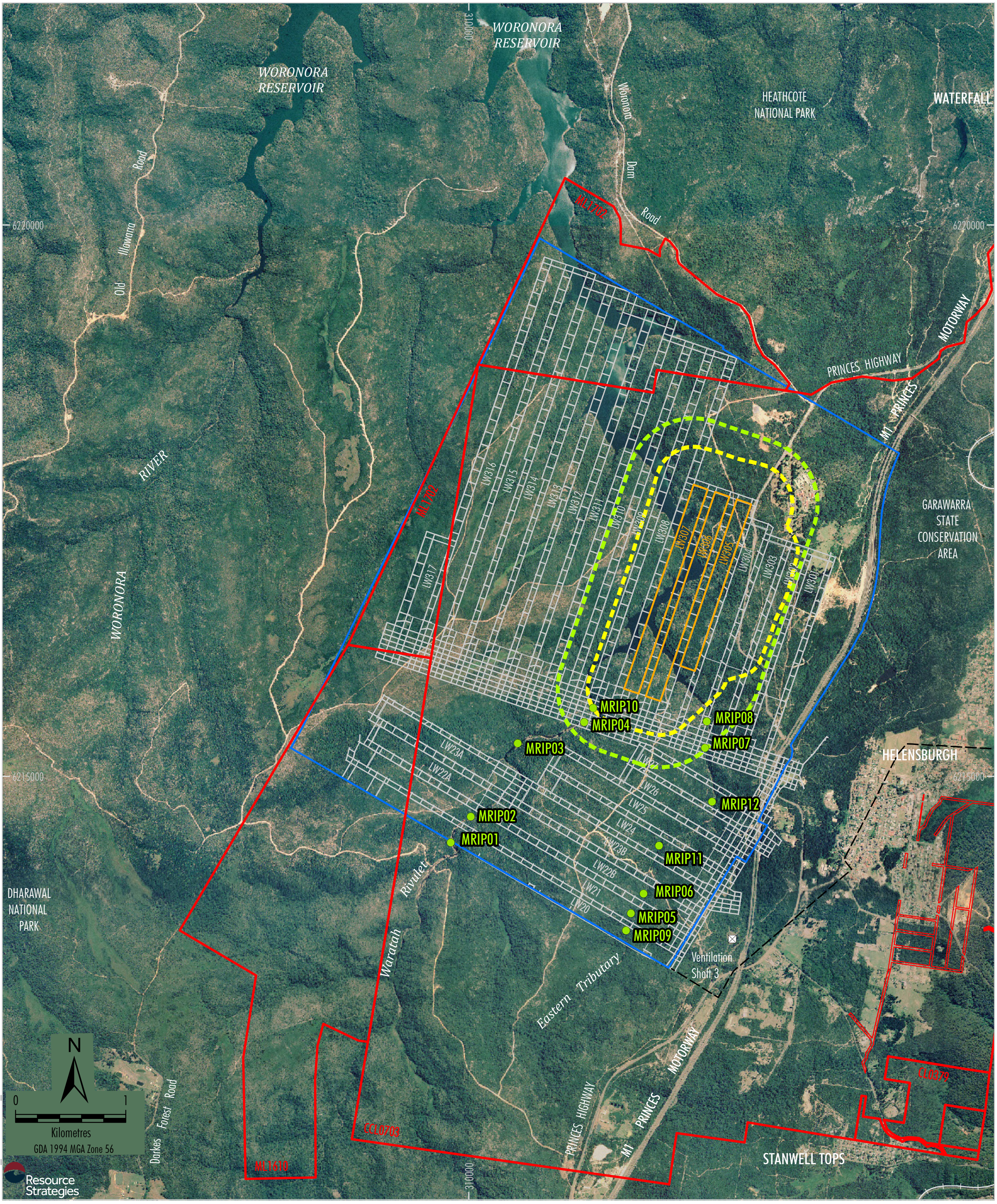
Population monitoring data collected includes a condition/health rating (1 - severe damage/dieback, 2 - many dead stems, 3 - some dead branches, 4 - minor damage, 5 – healthy) and a reproductive rating (1 – nil, 2 - sparse [occasional flowers only], 3 - low [under 25 percent of potential], 4 - moderate [25 to 75 percent], 5 - high [over 75 percent of potential flowering]) for each plant.

Surveys have been conducted bi-annually in autumn and spring.

Baseline indicator species monitoring was conducted in spring 2009 and autumn 2010 at sites MRIP01 to MRIP10 and from spring 2010 to spring 2013 (i.e. prior to the commencement of Longwall 23) at sites MRIP11 and MRIP12.

[28] Analysis of the transect data indicated the data was highly variable between seasons, which is attributed to the dynamic nature of riparian vegetation associated with variable flooding impacts. As described in the Longwalls 301-303 BMP, this variability was found to reduce the ability of this monitoring technique to detect changes to riparian vegetation associated with potential mining impacts and was discontinued for Longwalls 301-303.

[29] Note: Twenty individuals of *Prostanthera linearis* were not available for tagging at site MRIP08.



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 305-307 Secondary Extraction
- Longwalls 305-307 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 305-307 Secondary Extraction
- Existing Underground Access Drive (Main Drift)

Monitoring Site

- Riparian Vegetation Monitoring 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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Riparian Vegetation Monitoring Locations

Figure 12

Monitoring Results to Date

The results of the riparian vegetation monitoring programs (up to and including the autumn 2018 survey) are summarised below.

Vegetation has generally been observed in good condition, with the exception of observed flood impacts including prone vegetation and burial by flood debris. Increased depth and breadth of ponding from subsidence at site MRIP02 on the Waratah Rivulet and between sites MRIP05 and MRIP09 on the Eastern Tributary (Figure 12) has previously resulted in submersion of streamside vegetation causing vegetation dieback. Vegetation dieback was first observed at site MRIP02 in spring 2012 and between sites MRIP09 and MRIP05 in spring 2013.

Vegetation dieback greater than 50 cm from the Waratah Rivulet/Eastern Tributary at site MRIP02 on the Waratah Rivulet and between sites MRIP05 and MRIP09 on the Eastern Tributary has been recorded. It was considered that the most appropriate action was to continue monitoring to determine whether the vegetation recovers in these areas or whether management measures are required, consistent with management measures outlined in the BMPs.

Up until autumn 2017, the amount of dieback had not changed at these sites over time (i.e. the same dead vegetation has been re-recorded on each survey visit and there had been no recovery). It was anticipated that over time a new stream bank would be established that would be colonised in due course by native riparian vegetation adapted to the changed conditions.

In spring 2017, site MRIP02 on the Waratah Rivulet and between sites MRIP05 and MRIP09 on the Eastern Tributary were inspected and the vegetation was found to be in an improved condition at sites MRIP02 and MRIP09, where regeneration was observed and dieback was less than 50 cm from the stream. Vegetation dieback was noted to be greater than 50 cm from the stream at site MRIP05, extending beyond that recorded previously. In autumn 2018, site inspections of site MRIP05 indicated the dieback had increased compared to that recorded in spring 2017 and continued to be greater than 50 cm from the stream.

Assessments against the biodiversity subsidence impact performance measure, *Negligible impact on threatened species and populations* by FloraSearch (2012-2013, 2014, 2015, 2016b), Cenwest Environmental Services (2012-2013, 2014b, 2015, 2016, 2017, 2019), Eco Logical (2017b) and Ecoplanning (2019b) conducted to date for the riparian vegetation dieback at Site MRIP02, and between Sites MRIP05 and MRIP09 have concluded the subsidence impact performance measure has been met.

4.3.2.3 Assessment of Monitoring Results against Predicted Subsidence Impacts and Environmental Consequences

The key potential subsidence impacts and environmental consequences on streams described in the Project EA, Preferred Project Report and Metropolitan Coal Water Management Plans and BMPs are described in Section 4.1.1.

The Project EA, Preferred Project Report and Metropolitan Coal BMPs predicted potential impacts on riparian vegetation, primarily as a result of changes in stream water levels. As described above and in Section 4.1.1, increased ponding from changes in bed gradients has previously resulted in the prolonged inundation of the adjacent riparian vegetation which has resulted in vegetation dieback.

4.3.3 Aquatic Biota and their Habitats

4.3.3.1 Aquatic Ecology Monitoring

The richness and abundance of assemblages of fish recorded by the Project EA aquatic ecology surveys was low. Only two native species were recorded, *viz.* the Long-finned Eel (*Anguilla reinhardtii*) in the Waratah Rivulet and Woronora River, and Australian Smelt (*Retropinna semoni*) in the Woronora Reservoir. The introduced Mosquito Fish (*Gambusia holbrooki*) was recorded in the Woronora Reservoir, Waratah Rivulet and Woronora River.

No threatened fish have been recorded in the Woronora Reservoir, Waratah Rivulet or Woronora River and the dam wall of the Woronora Reservoir is likely to be a major barrier to migration of fish. Further to discussions with the Department of Primary Industries (DPI) – Fisheries during development of the Metropolitan Coal Longwalls 20-22 BMP, fish were not included in the aquatic ecology monitoring programs.

Metropolitan Coal has assessed subsidence impacts and environmental consequences on aquatic habitats in accordance with the Metropolitan Coal Water Management Plans (Section 4.1.1). Surface water monitoring includes monitoring of stream features, surface water flow, pool water levels, surface water quality, iron staining and gas releases. Observations of surface cracking, iron staining and gas releases are also made during the conduct of the aquatic ecology surveys.

The Longwalls 20-22 and Longwalls 23-27 aquatic ecology monitoring programs include the monitoring of aquatic habitat characteristics, water quality, macroinvertebrates and aquatic macrophytes. Consistent with the Project EA, the Longwalls 20-22 and Longwalls 23-27 aquatic ecology monitoring programs were designed to:

- monitor subsidence-induced impacts on aquatic ecology (stream monitoring); and
- monitor the response of aquatic ecosystems to the implementation of future potential stream remediation works (pool monitoring).

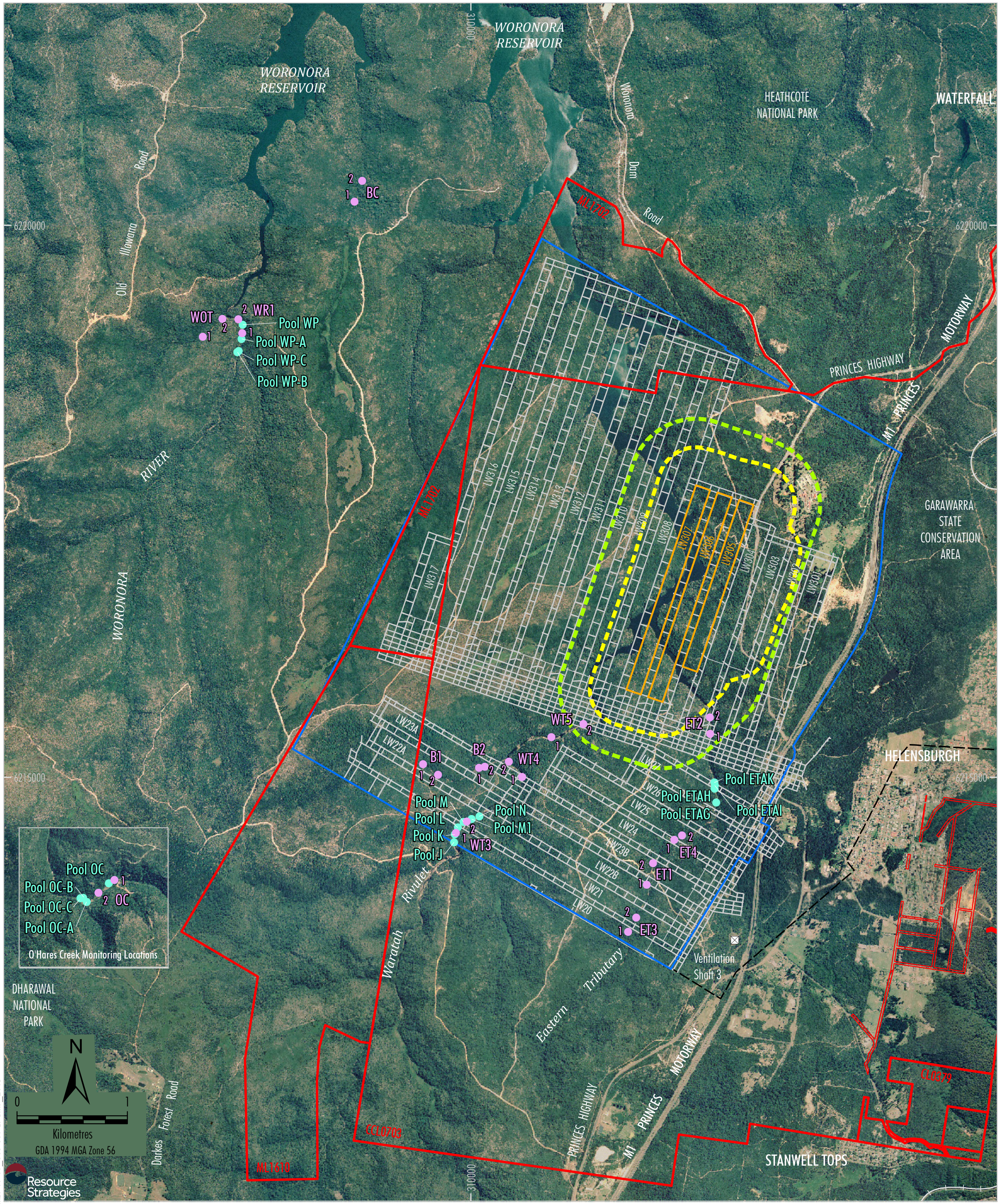
The design of the monitoring programs uses a “Beyond BACI” experimental design and focuses on representative sampling within streams and pools in mining areas and in suitable control streams and pools (i.e. not subject to mine subsidence).

Stream Monitoring

Monitoring of aquatic biota has been conducted at two sampling sites (approximately 100 m long) at the following stream sampling locations (Figure 13):

- Location WT3 on Waratah Rivulet, Locations ET1, ET3 and ET4 on the Eastern Tributary and Locations B1 and B2 on Tributary B overlying Longwalls 20-27.
- Location WT4 on Waratah Rivulet adjacent to Longwalls 20-27.
- Location WT5 on Waratah Rivulet and Location ET2 on the Eastern Tributary, downstream of Longwalls 20-27.
- Control Locations: WR1 on Woronora River; OC on O’Hares Creek; BC on Bee Creek; and WOT on Woronora Tributary.

The approximate locations of the sampling sites are shown on Figure 13.



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 305-307 Secondary Extraction
- Longwalls 305-307 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 305-307 Secondary Extraction
- Existing Underground Access Drive (Main Drift)

Monitoring

- Pool Aquatic Ecology Sampling Site
- Stream Aquatic Ecology Sampling 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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Aquatic Ecology Sampling Locations

Figure 13

Monitoring of the sampling sites has been conducted biannually in spring (15 September to 15 December) and autumn (15 March to 15 June), consistent with the timing required by the Australian River Assessment System (AUSRIVAS) protocol.

Baseline aquatic ecology surveys of macroinvertebrates and macrophytes were conducted biannually from spring 2008 or spring 2009[30] to autumn 2010 for Longwalls 20-22 stream monitoring at Locations WT3, WT4 and WT5 on Waratah Rivulet, Locations ET1, ET2 and ET3 on the Eastern Tributary, Location B1 on Tributary B, Location WR1 on Woronora River, Location OC on O'Hares Creek, Location BC on Bee Creek and Location WOT on Woronora Tributary (Figure 13). Baseline surveys of macroinvertebrates and macrophytes were conducted prior to the commencement of Longwall 23 (biannually from spring 2009 to spring 2013) for the additional Longwalls 23-27 stream monitoring sites at Location ET4 on the Eastern Tributary and Location B2 on Tributary B (Figure 13).

The monitoring parameters and methods are described in Table 4.

Pool Monitoring

A number of pools are monitored to assess the response of aquatic ecosystems to the implementation of potential future stream remediation works, namely (Figure 13):

- Larger pools (i.e. >40 m in length) J, M1 and N on Waratah Rivulet and ETAH on the Eastern Tributary, overlying Longwalls 20-27.
- Smaller pools (i.e. <40 m in length) K, L and M on Waratah Rivulet and ETAG, ETAI and ETAK on the Eastern Tributary, overlying Longwalls 20-27.
- One larger control pool on Woronora River (Pool WP) and one larger control pool on O'Hares Creek (Pool OC).
- Three smaller control pools on Woronora River (Pools WP-A, WP-B and WP-C) and three smaller control pools on O'Hares Creek (Pools OC-A, OC-B and OC-C).

Monitoring of the sampling sites is conducted biannually in spring (15 September to 15 December) and autumn (15 March to 15 June).

Sampling is conducted at two random sites within the larger pools and at one site within the smaller pools. Within each site in each pool, aquatic macroinvertebrates and macrophytes are sampled using the same quantitative techniques described in Table 4 for stream monitoring. Quantitative estimates of aquatic macrophytes (i.e. emergent, floating attached and/or submerged species of aquatic plants) are collected at one site at each small pool and at two sites at each large pool. In addition, the spatial distribution of floating attached and/or submerged macrophytes (i.e. *Myriophyllum pedunculatum* and *Triglochin procerum*) are also mapped in each pool on each sampling occasion to provide a visual comparison of their distribution through time. AUSRIVAS sampling techniques are not used for pool monitoring.

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30 The sampling of Location ET3 on the Eastern Tributary commenced in spring 2009.

Table 4
Stream Monitoring Parameters and Methods

Monitoring Parameter	Monitoring Methods
• Habitat Characteristics	Information on stream characteristics is recorded at each site in accordance with the AUSRIVAS protocol (Turak *et al.*, 2004). Characteristics recorded include a visual assessment of stream width and depth, riparian conditions, signs of disturbance, water quality and percentage cover of the substratum by algae.
• Water Quality	A number of water quality variables are measured at each of the sampling sites prior to undertaking the biological sampling. Measurements of physico-chemical water quality are collected using a submersible data logger. Water quality measurements include electrical conductivity (microSiemens per centimetre [µS/cm]), dissolved oxygen (% Saturation and mg/L, pH, temperature (degrees Celsius [ºC]), turbidity (Neophlemetric Turbidity Units [NTU]) and oxygen reduction potential (millivolts [mV]). Alkalinity is determined in the field using a total alkalinity field kit. The water quality measurements provide information relevant to water quality at the time of sampling.
• Aquatic Macroinvertebrates	Two methods are used to sample aquatic macroinvertebrates at each site: sampling using the AUSRIVAS protocol and quantitative sampling, as described below.
AUSRIVAS Sampling	To sample assemblages of macroinvertebrates in accordance with the AUSRIVAS protocol (Turak *et al.*, 2004), samples of stream edge habitats are collected using a 250 µm dip net. Edge habitat is defined as areas along stream banks with little or no flow, including alcoves and backwaters, with abundant leaf litter, fine sediment deposits, beds of macrophytes, overhanging banks and areas with trailing vegetation (Turak *et al.*, 2004). At each site (approximately 100 m long), samples are collected over a total length of 10 m, usually in 1 to 2 m sections, ensuring all significant edge sub-habitats within a site (i.e. macrophytes, over-hanging bank and vegetation, leaf-litter, pool rocks, logs) are included in the sample (Turak *et al.*, 2004). The contents of each net sample are placed into a white sorting tray and animals are collected for a minimum period of 30 minutes. Thereafter, removals are carried out in 10 minute periods, up to a total of one hour (Turak *et al.*, 2004). If no new taxa are found within a 10 minute period, removals cease (Turak *et al.*, 2004). The animals collected are placed inside a labelled container and preserved with 70% alcohol. Samples are identified using a stereomicroscope. Taxa are identified to family level with the exception of Acarina (to order), Chironomidae (to sub-family), Nematoda (to phylum), Nemertea (to phylum), Oligochaeta (to class), Ostracoda (to subclass) and Polychaeta (to class). Some families of Anisoptera (dragonfly larvae) are identified to species, as they could potentially include threatened aquatic species.
Quantitative Sampling	Within each site, three replicate macroinvertebrate samples are collected using timed one minute sweeps of all habitats (edge, riffle, pools, etc.), using a 250 x 250 cm (250 µm) dip net. For each replicate sample, the contents of the net are placed into white plastic trays filled with fresh water and then placed into pre-labelled plastic sample containers filled with 70% alcohol. In the laboratory, animals are identified to family level with the exception of some families of Anisoptera (dragonfly larvae), which are identified to species, as they could potentially include threatened aquatic species.
• Aquatic Macrophytes	The distribution of submerged and emergent (occurring in-stream and in the riparian zone) macrophytes is estimated along each sampling location by assigning a cover class to each species. The cover classes are: (1) one plant or small patch (i.e. few), (2) not common, growing in a few places (i.e. scattered), and (3) widespread (i.e. common). Within each site, an assessment of the aquatic vegetation (i.e. submerged and emergent) is made by estimating the relative abundance (i.e. percentage cover) of aquatic macrophytes within five haphazardly placed 0.25 m^2 quadrats, using a stratified sampling technique.

Baseline aquatic ecology surveys of macroinvertebrates and macrophytes were conducted biannually from spring 2008 or spring 2009[31] to autumn 2010 for Longwalls 20-22 pool monitoring at Pools J, K, L, M, M1 and N on Waratah Rivulet, Pools WP, WP-A, WP-B and WP-C on the Woronora River and Pools OC, OC-A, OC-B and OC-C on O'Hares Creek (Figure 13). Baseline surveys were also conducted prior to the commencement of Longwall 23 (biannually from spring 2009 to spring 2013) for Longwalls 23-27 pool monitoring at Pools ETAG, ETAH, ETAI and ETAK on the Eastern Tributary for comparison with Pools WP, WP-A, WP-B and WP-C on the Woronora River and Pools OC, OC-A, OC-B and OC-C on O'Hares Creek (Figure 13).

Monitoring Results to Date

The results of the Longwalls 20-22 and Longwalls 23-27 aquatic ecology monitoring programs (up to and including the autumn 2018 survey) are summarised below.

Multivariate and univariate statistical procedures[32] are used to test whether there is evidence of significant change in aquatic macroinvertebrate and macrophyte indicators at selected locations and pools within areas subject to mining activities, in relation to Control (i.e. not subject to mining) locations or pools, before- versus after-commencement of mining.

Multivariate methods allow comparisons of two (or more) samples based on the degree to which these samples share particular species, at comparable levels of abundance (Clarke and Warwick, 1994). Principal Coordinates Analyses are used to present a graphical representation of relationships among samples. Similarity of percentages (SIMPER) are used to determine those taxa primarily responsible for the observed similarities (or dissimilarities) (Clarke, 1993).

Univariate analyses are used to examine the total number of taxa, total abundance and abundances of the most important taxonomic groups identified from the samples.

<u>Stream Monitoring</u>

To date (to autumn 2018), multivariate analyses of the Longwalls 20-22 stream monitoring data have not detected significant changes in assemblages of aquatic macroinvertebrates or macrophytes at Locations ET1, ET2 and ET3 on the Eastern Tributary and at Locations WT3, WT4 and WT5 on the Waratah Rivulet before-versus-after mining, in relation to the control locations.

Univariate analyses have detected:

- a significant decrease in mean numbers of the freshwater shrimp family, Atyidae, at Locations ET1 and ET2 within the after-mining period in spring 2015, in relation to the control locations, but not for subsequent surveys (i.e. autumn 2016, spring 2016, autumn 2017, spring 2017 and autumn 2018); and
- a significant change in mean diversity of aquatic macroinvertebrates at Location WT3 within the after period in spring 2016 and autumn 2018.

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[31] The sampling of larger pools N on Waratah Rivulet, WP on Woronora River and OC on O'Hares Creek commenced in spring 2008. The sampling of larger pools J and M1 on Waratah Rivulet, and smaller pools K, L and M on Waratah Rivulet, WP-A to WP-C on Woronora River and OC-A to OC-C on O'Hares Creek commenced in spring 2009.

[32] Permutational Multivariate Analyses of Variance [PERMANOVA] and Plymouth Routines in Multivariate Ecological research [PRIMER] software packages.

Multivariate analyses of the Longwalls 23-27 stream monitoring data have detected:

- a significant before-versus-after mining change in the structure of the aquatic macroinvertebrate assemblage at Location ET1 in spring 2016, but not for subsequent surveys (i.e. autumn and spring 2017 and autumn 2018);
- a significant before-versus-after mining change in the structure of assemblages of macrophytes at Location ET1 in autumn 2018; and
- a significant change in the structure of assemblages of macrophytes at Location ET2 within the after period, although changes prior to the spring 2017 survey do not appear to be related to mining activities.

Univariate analyses of the Longwalls 23-27 stream monitoring data indicate:

- mean numbers of the mayfly family, Leptophlebiidae, have increased significantly within the after-mining period since autumn 2015 at Location ET1;
- a significant decrease in mean numbers of the freshwater shrimp family, Atyidae, within the after-mining period since autumn 2016 at Location ET2;
- a decrease in diversity of macroinvertebrates at Location ET4 in autumn 2018; and
- a significant change in mean numbers of Atyidae in relation to control locations in autumn 2016 at Location ET4, but not subsequently (i.e. up to autumn 2018).

A considerable drop in water level was noted in a large pool at Location B1 on Tributary B in spring 2012. By autumn 2013, the pool had almost completely emptied and there was no surface flow along the study reach due to subsidence associated with mining of the Longwalls 20-22 underground mining area. Quantitative sampling of aquatic macroinvertebrates has not been carried out at Location B1 on Tributary B in spring 2013, or since spring 2014 due to insufficient habitat available for sampling.

Past analyses examining patterns of change in the assemblage of aquatic macroinvertebrates and key components at Location B1 on Tributary B in relation to control locations found evidence of impacts related to mining activities within the Longwalls 20-22 underground mining area. Analyses indicate that the assemblage of macrophytes at Location B1 have experienced a degree of environmental stress since spring 2012 as a result of mining activities within the Longwalls 20-22 underground mining area.

Since spring 2016, subsidence associated with extraction of Longwalls 23-27 appears to have impacted aquatic indicators at Location B2. These impacts include evidence of a reduction in availability and quality of aquatic habitat and significant changes in numbers of Leptophlebiidae and Atyidae. To date, no changes to aquatic macrophyte indicators have been evident.

The aquatic ecology subsidence impact performance indicator: *The aquatic macroinvertebrate and macrophyte assemblages in streams are not expected to experience long-term impacts as a result of mine subsidence* has been exceeded at Location B1 and Location B2 on Tributary B. Assessments have also been made against the biodiversity subsidence impact performance measure, *Negligible impact on threatened species, populations, or ecological communities.* The assessments against the biodiversity performance measure have been conducted in relation to threatened terrestrial flora and fauna; there are no threatened aquatic fauna or flora known, or considered likely to occur (Eco Logical, 2017b; Cenwest Environmental Services, 2017) and both concluded that the subsidence impact performance measure has been met.

Pool Monitoring

Monitoring of large and small pools on the Waratah Rivulet (large pools J, M1 and N; small pools K, L and M) and Eastern Tributary (large pool ETAH; small pools ETAG, ETAI and ETAK) (i.e. the pool monitoring) has been established to monitor the response of aquatic ecosystems to the implementation of future potential stream remediation works.

Pools J, K, L, M and M1 on the Waratah Rivulet have not been impacted by mine subsidence (Figure 13). Pool N was impacted by mine subsidence in September 2012, however has overflowed its rock bar since December 2014, with the exception of January/February 2017 and within the period January to May 2018 (Metropolitan Coal, 2019).

Multivariate data analyses for Pools J, K, L, M1, M and N on the Waratah Rivulet have found no evidence to suggest that assemblages of aquatic macroinvertebrates or macrophytes have changed significantly before- vs after-mining of the Longwalls 20-22 mining area in relation to the control pools.

Univariate analyses for pools on the Waratah Rivulet found:

- a significant increase in mean diversity of macroinvertebrates in Pool J (from autumn 2015 to autumn 2017) and Pool M1 (from autumn 2015 to autumn 2018) within the after-mining period in relation to the control pools;
- mean cover of macrophytes appears to have decreased significantly at Pool M1 in relation to the control pools, and the diversity of macrophytes at Pool M1 has become significantly more variable in relation to control pools, within the after-mining period since autumn 2016;
- the diversity of macrophytes appears to have decreased significantly at Pool N within the after period (since autumn 2016); and
- mean diversity of aquatic macroinvertebrates in Pools K, L and M has changed significantly in relation to the control locations since autumn 2015 as a result of a small increase in diversity in the Waratah Rivulet pools within the after-mining period, but little change within the control pools.

In December 2016 and January 2017, a number of pools on the Eastern Tributary downstream of the Longwall 26 maingate (including Pools ETAG, ETAH, ETAI and ETAK) experienced loss of pool water levels as a result of mine subsidence. This resulted in the negligible environmental consequences performance measure for the Eastern Tributary watercourse being exceeded in relation to the diversion of flows and drainage behaviour component. Stream remediation has been triggered for the Eastern Tributary.

4.3.3.2 Assessment of Monitoring Results against Predicted Subsidence Impacts and Environmental Consequences

The key potential subsidence impacts and environmental consequences for streams described in the Project EA, Preferred Project Report and Metropolitan Coal BMPs are described in Section 4.1.1.

Potential environmental consequences include impacts on aquatic habitats (e.g. alteration of hydrology, pool habitat, in-stream connectivity and water quality), and on biodiversity (e.g. aquatic macrophytes, macroinvertebrates, fish and riparian vegetation).

In summary, the key potential environmental consequences described in the Project EA, Preferred Project Report, and Metropolitan Coal BMPs include:

- 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 most noticeable during periods of low flow and on the frequency of no flow, while the effects on the frequency and magnitude of high flows would likely be negligible.
- Changes in pool water levels and in-stream connectivity - underflow has been observed to result in lower water levels in pools as they become hydraulically connected with the fracture network. During prolonged dry periods when flows recede to low levels, the number of instances where loss of flow continuity between pools occurs increases with a greater proportion of these lower flows being conveyed entirely in the subsurface fracture network.
- Impacts on water quality following cracking of the stream bed that can reduce the quality of habitat for aquatic biota (e.g. generation of iron flocculent material).
- Minor stream bank erosion, where changes in channel gradients result in increases in flow energy.
- Impacts on aquatic macrophyte plants (e.g. as a result of changes in hydrology described above) resulting in exposure and desiccation or smothering of plants by iron flocculent material. Aquatic macrophytes have evolved reproductive strategies to cope with the variable nature of flow in streams and wetlands within Australia. Obligate water plants generally require permanent water, however they can recolonise once water becomes available again.
- Localised impacts on aquatic macroinvertebrates (as a result of the changes in aquatic habitat/hydrology described above). The Project is unlikely to have any significant long-term impacts on assemblages of macroinvertebrates.
- The conveyance of surface water flows to sub-surface fractures in the area affected by subsidence has the potential to reduce available habitat for fish (e.g. aquatic macrophytes, pools) and connectivity among sections of the stream channel, impeding fish passage.

The results of aquatic ecology monitoring for Longwalls 20-22 and Longwalls 23-27 are considered to be consistent with the potential subsidence impacts and environmental consequences described in the Project EA, Preferred Project Report and the Metropolitan Coal Water Management Plans and BMPs. However, subsidence impacts on Tributary B have resulted in no surface flow along the stream in the vicinity of Location B1 for an extended period of time. This change in aquatic habitat/hydrology has resulted in impacts to the aquatic macroinvertebrate assemblage at this location (Location B1) and downstream at Location B2. Assessments have been made against the biodiversity subsidence impact performance measure, *Negligible impact on threatened species, populations or ecological communities*, by Eco Logical (2017b) and Cenwest Environmental Services (2017) and concluded the subsidence impact performance measure has been met.

4.3.4 Terrestrial Fauna and their Habitats

Amphibians were selected as the appropriate representative of terrestrial vertebrate fauna because they were/are widespread across the Project area at the time of monitoring program design, include two threatened species that are sensitive to changes in surface hydrology, and because this group is represented by at least 14 species that appear to have viable populations.

Amphibian monitoring programs have been implemented annually in spring/summer for Longwalls 20-22 (2009 – 2017), Longwalls 23-27 (2010 – 2017) and Longwalls 301-303 (2015 - 2017). Fifteen amphibian species have been monitored including three threatened species: the Giant Burrowing Frog (*Heleioporus australiacus*), Red-crowned Toadlet (*Pseudophryne australis*) and Littlejohn's Tree Frog (*Litoria littlejohni*).

Six test sites overlying Longwalls 20-22 (sites 1-6), five test sites overlying Longwalls 23-27 (sites 13-17), six test sites overlying Longwalls 301-303 (sites 23-28) and eleven control sites (sites 7-12 and 18-22) are surveyed annually in spring/summer (i.e. October to February) during suitable weather conditions. Two five-day survey periods are utilised for each spring/summer survey, typically over the periods October to December and January to February. Separation of the two survey events optimises the likelihood of observing breeding events. In some years the second survey has occurred as late as March/April due to the absence of suitable survey conditions.

The control sites for Longwalls 301-303 consist of the eleven existing sites associated with Longwalls 20-22 and Longwalls 23-27. No additional amphibian monitoring sites were established for Longwall 304. The approximate locations of the monitoring sites are shown on Figure 14. Site selection was biased towards optimising the detection of the two threatened species, the Giant Burrowing Frog and Red-crowned Toadlet.

Each site is surveyed once during a standard one hour general area day search (early morning and late afternoon) supplemented by an evening 60 minute search/playback session using hand held spotlights and head lamps.

Species are assigned to the following relative abundance categories for tadpole and adult stages:

- 0 = no sightings;
- 1 = one sighting of adult or tadpole stage;
- UC = uncommon (i.e. 2 to 10 individuals), adult or tadpole stage;
- MC = moderately common (i.e. 11 to 20 individuals), adult or tadpole stage;
- C = common (i.e. 21 to 40 individuals), adult or tadpole stage; and
- A = abundant (>40 individuals), adult or tadpole stage.

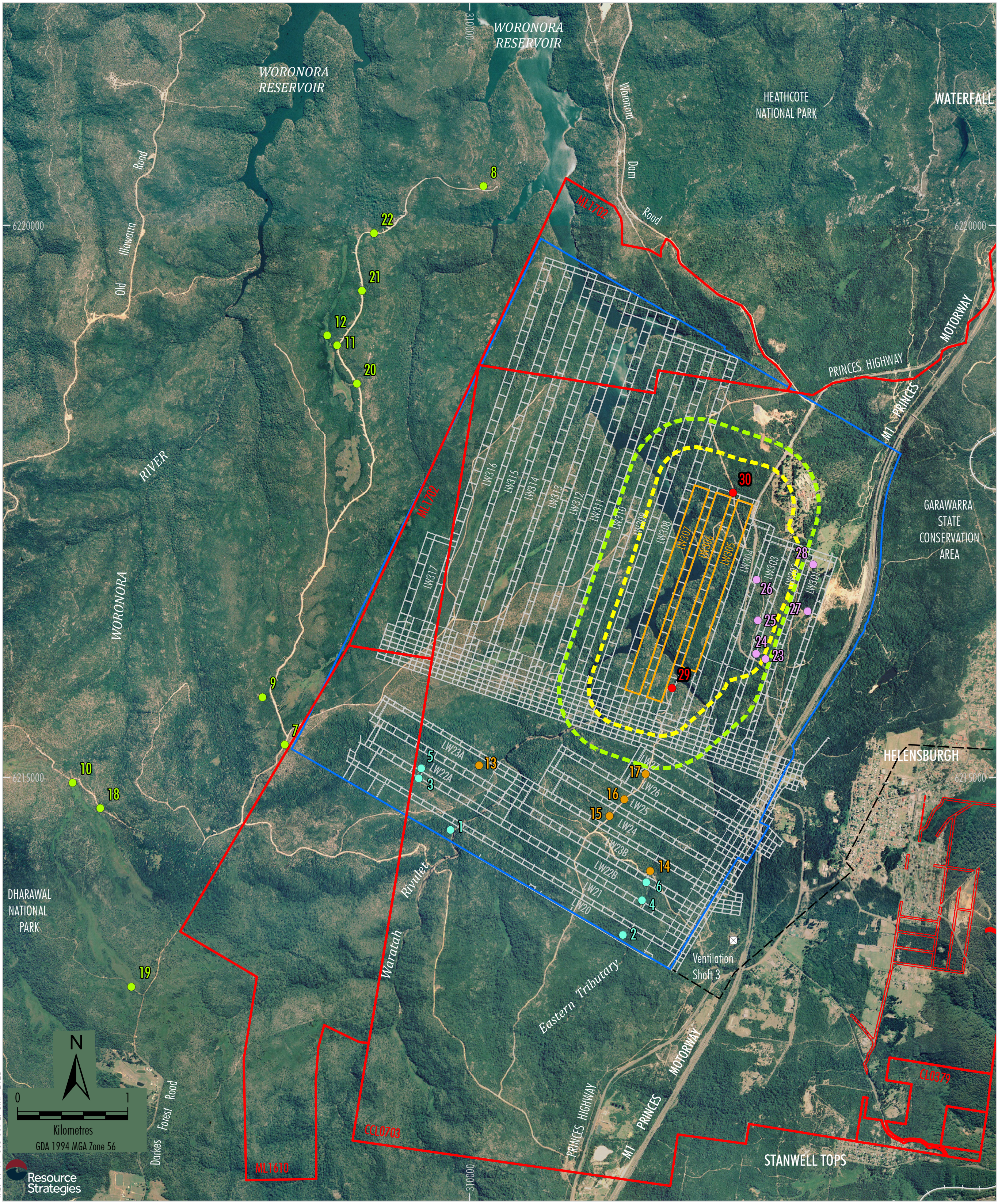
Baseline monitoring was conducted in spring/summer 2009 and 2010 for Longwalls 20-22, in spring/summer 2010 to 2013 for Longwalls 23-27 and in spring/summer 2015 and 2016 for Longwalls 301-303.

The Littlejohn's Tree Frog was recorded for the first time during the spring/summer 2016 survey at site 24 (Figure 14) during baseline monitoring for Longwalls 301-303. Metropolitan Coal commissioned a targeted survey for the Littlejohn's Tree Frog to be carried out in August or September 2017 when adult calling was likely to be at its peak under wet conditions to determine the status of the species within the Project area. However, the dry weather conditions experienced in August and September 2017 did not provide suitable weather conditions for the conduct of the targeted survey and the survey was postponed until 2018.

The spring/summer 2017 amphibian survey recorded the Littlejohn's Tree Frog at control sites 10 and 18 and test site 24 (Figure 14).

The dry weather conditions in 2018 meant the targeted survey described above was not able to be conducted until late October to early November 2018, following rain. The survey was not able to be completed as the catchment was closed due to fire risk. The survey recorded the Littlejohn's Tree Frog at control sites 7 and 18, and at test site 13 (Figure 14).

The spring/summer 2018 amphibian survey recorded the Littlejohn's Tree Frog at control sites 10 and 21 (Figure 14). No evidence of breeding has been observed for this species during surveys to date.



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

LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 305-307 Secondary Extraction
- Longwalls 305-307 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 305-307 Secondary Extraction
- Existing Underground Access Drive (Main Drift)

Monitoring Sites

- Longwalls 20-22 Amphibian Monitoring
- Longwalls 23-27 Amphibian Monitoring
- Longwalls 301-303 Amphibian Monitoring
- Longwalls 305-307 Amphibian Monitoring
- Control Site

Peabody

METROPOLITAN COAL

Amphibian Monitoring Locations

Figure 14

Subsidence impacts have been observed at a number of test sites including stream flow diversion to subterranean flows under low flow conditions, in-stream rock cracking, loss of pool numbers and/or persistence under low flow conditions, and iron staining/bacterial mats.

The data gathered since 2009 is non-normally distributed and characterised by significant occurrences of zero data. Such data require non-normal analysis to determine if potential adverse impacts are significant at the 95% confidence level. Poisson regression analysis has been used to analyse the amphibian survey results. The three datasets (Longwalls 20-22, 23-27 and 301-303) have been analysed together to increase the resolution of the analysis.

The performance indicator (null hypothesis) for the monitoring program is:

> *The amphibian assemblage is not expected to experience changes significantly different to the amphibian assemblage at control sites.*

To date (2009 – 2017), no adverse impact from mining has been detected for the amphibian assemblage at the 95% confidence level for Longwalls 20-22 and Longwalls 301-303. However, analyses undertaken following the Longwalls 23-27 spring-summer 2017 survey detected a significant difference between the test and control sites at the 95% confidence level at sites 15, 16 and 17 for the spring/summer 2014 survey (Cenwest Environmental Services, 2018). The impact was not detected by the Poisson Regression analyses conducted following the 2014, 2015 and 2016 surveys and may be a result of the improved capacity of the model over time as the data set builds. However, an ongoing impact could not be detected in the three subsequent years – 2015, 2016 and 2017.

In the 2018 survey only one of the two survey periods were able to be utilised due to prevailing drought conditions and the absence of suitable wet conditions needed to undertake an amphibian survey. Notwithstanding, the preliminary analysis of these data is similar to previous analyses – that is, no adverse impact from mining has been detected for the amphibian assemblage at the 95% confidence level (Cenwest Environmental Services, in prep).

It cannot be discounted that a delayed adverse impact might be detected at some future date. Such potential future impacts might be due to either a lag phase in the expression of any potential impact or a more immediate future adverse impact.

4.3.4.1 Assessment of Monitoring Results against Predicted Subsidence Impacts and Environmental Consequences

A Poisson regression analysis has been used to analyse the amphibian survey results obtained to spring/summer 2017. The monitoring results are consistent with the predictions described in the Project EA, Preferred Project Report, and Metropolitan Coal BMPs, specifically, that it is unlikely that any vertebrate population would be put at risk by the Project.

Threatened Flora and Fauna

A number of threatened flora and fauna species listed under the NSW *Biodiversity Conservation Act, 2016* (BC Act) or Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act) are known to occur, or have the potential to occur within the Project underground mining area or surrounds.

Figure 1-1 in Appendix 1 shows the location of threatened flora recorded by Bangalay Botanical Surveys (2008), FloraSearch (2008; 2009) and Eco Logical (2010 – 2018) in the Project underground mining area and surrounds. Figure 1-2 in Appendix 1 shows the location of threatened fauna recorded by Western Research Institute and Biosphere Environmental Consultants (2008) and Cenwest Environmental Services (2008 – 2018) in the Project underground mining area and surrounds. No threatened aquatic biota listed under the *Fisheries Management Act, 1994*, BC Act or EPBC Act has been recorded within the Project underground mining area or in the Woronora Reservoir.

In relation to threatened flora and fauna, the Project was considered unlikely to have a significant effect on threatened flora or fauna (Appendix G of the Project EA). No endangered flora or fauna populations that were listed under the BC Act at the time of Project Approval occur within the Project underground mining area or surrounds. Endangered Ecological Communities (EECs) listed under the BC Act at the time of Project Approval and identified as occurring in the Project underground mining area or surrounds includes the Southern Sydney Sheltered Forest on Transitional Sandstone Soils in the Sydney Basin Bioregion EEC (Map Unit 5a) and the O'Hares Creek Shale Forest EEC (Map Units 5b and 5r) (Figure 11).

Coastal Upland Swamp in the Sydney Basin Bioregion was listed as an EEC under the BC Act in March 2012 which post-dates the Project Approval. The predicted impacts to this community were assessed in the Project EA and subsequently approved by the Project Approval in 2009.

A research program, *Conservation of the Eastern Ground Parrot on the Woronora Plateau*, funded by Metropolitan Coal was conducted by the OEH. The research program involved a targeted survey for the Eastern Ground Parrot (*Pezoporus wallicus wallicus)* (classified as Vulnerable under the BC Act) and the establishment of a network of bio-acoustic monitoring stations (35 sites) in 2013. A total of 588 days and approximately 3,000 hours of data were recorded from the stations, however, no Eastern Ground Parrots were detected. Spot checks of recordings from a range of sites, confirmed the recogniser was performing accurately (i.e. no Eastern Ground Parrot calls).

The results of the research program were considered by OEH to indicate that Eastern Ground Parrots are not likely to be resident on the Woronora Plateau. The occasional records of single parrots on the Woronora Plateau in the past ten years suggest isolated birds are dispersing through the area and are not part of a larger resident population[33].

Assessments against the biodiversity subsidence impact performance measure, *Negligible impact on threatened species, populations or ecological communities*, to date indicate the performance measure has been met.

[33] This description is based on OEH's reporting to Metropolitan Coal on the status of the research program for inclusion in the *Metropolitan Coal 2014 Annual Review and Annual Environmental Management Report/Rehabilitation Report* (Metropolitan Coal, 2015).

5 REVISED ASSESSMENT OF POTENTIAL ENVIRONMENTAL CONSEQUENCES

5.1 LONGWALLS 305-307 EXTRACTION LAYOUT

Longwalls 305-307 and the area of land within 600 m of Longwalls 305-307 secondary extraction are shown on Figures 1 and 2. Longwall extraction will occur from north to south. The Longwall 305 layout includes a 138 m panel width (void), a 45 m tailgate pillar width and a 70 m maingate pillar width. The layout of Longwalls 306 and 307 includes 138 m panel widths (void) and 70 m pillars (solid) consistent with the PPL.

The provisional extraction schedule for Longwalls 305-307 is provided in Table 5.

Table 5
Provisional Extraction Schedule

Longwall	Estimated Start Date	Estimated Duration	Estimated Completion Date
Longwall 305	March 2020	7 Months	October 2020
Longwall 306	November 2020	8 Months	July 2021
Longwall 307	August 2021	8 Months	April 2022

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

5.2 ENVIRONMENTAL RISK ASSESSMENT

An Environmental Risk Assessment (ERA) was conducted for four of the key component plans of the Metropolitan Coal Longwalls 305-307 Extraction Plan[34] *viz.* Water Management Plan, Land Management Plan, Heritage Management Plan and this BMP 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 DPIE for the preparation of the Metropolitan Coal Longwalls 305-307 Extraction Plan participated in the ERA[35]. The ERA process involved the key steps described below.

[34] Risk assessments have been undertaken separately in relation to the Metropolitan Coal Longwalls 305-307 Built Features Management Plan and the Metropolitan Coal Longwalls 305-307 Public Safety Management Plan, and are reported in their respective documents.

[35] Participants included Mr Peter DeBono (Mine Subsidence Engineering Consultants, Subsidence and Land), Dr Noel Merrick (SLR Consulting, Groundwater), Mr Lindsay Gilbert (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 Jon Degotardi (Metropolitan Coal), Mr Stephen Love (Metropolitan Coal), Mr Shane Kornek (Metropolitan Coal), Ms Stacey Gromadzki (Resource Strategies), Mr Joe Flanagan (Resource Strategies) and Mr Sam Webber (Resource Strategies). Mr Jamie Reeves (Niche Environment and Heritage, Heritage) contributed to the risk assessment external to the workshop.

Review of Relevant Documentation and Risk Identification

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

- The 2008 *Environmental Risk Analysis* (SP Solutions, 2008) conducted for the Project EA (Appendix O of the Project EA).
- The Preferred Project Report (HCPL, 2009). During the NSW Government's assessment phase of the Project EA, and in recognition of concerns raised by key stakeholders during the formal Planning Assessment Commission (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 Longwall 304 Environmental Risk Assessment Report (Operational Risk Mentoring, 2019a) (which included consideration of the Longwalls 301-303 Environmental Risk Assessment Report).
- Figures showing the Longwalls 305-307 layout in relation to key surface features.
- Subsidence predictions for Longwalls 305-307 (including subsidence contours, Eastern Tributary, Waratah Rivulet, Woronora Reservoir, other streams, cliff sites, upland swamps and Aboriginal heritage sites).

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

ERA Workshop

The ERA workshop for Longwalls 305-307 was conducted on 16 July 2019, 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, Dr Peter Standish of Operational Risk Mentoring and conducted in accordance with Australian Standard/New Zealand Standard ISO 31000: *2009 Risk Management – Principles and Guidelines.*

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

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

ERA Report Review

All ERA participants were asked to review the draft Longwalls 305-307 ERA report that was prepared to summarise the outcomes of the risk assessment. Participants' comments were incorporated into the final Operational Risk Mentoring (2019b) report.

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

5.3 UPLAND SWAMPS

Upland swamps located within 600 m of Longwalls 305-307 secondary extraction are shown on Figure 15. Eighteen upland swamps are located within the Longwalls 305-307 35° angle of draw and/or predicted 20 mm subsidence contour (Swamps 40, 41, 46, 47, 48, 49, 50, 51/52, 53, 58, 69, 70, 71a, 71b, 72, 73, 84 and 86), and an additional 10 swamps (Swamps 35, 36, 64, 65/66, 67, 68a, 68b, 82, 88 and 89) are located within 600 m of Longwalls 305-307 (Figure 15).

5.3.1 Revised Subsidence Predictions

The maximum predicted subsidence parameters for swamps located within the Longwalls 305-307 35° angle of draw and/or predicted 20 mm subsidence contour have been prepared by MSEC (2019). Table 6 compares the revised subsidence predictions for the Longwalls 305-307 Extraction Plan layout with the subsidence predictions for the Preferred Project Layout at the completion of Longwall 307.

The maximum subsidence predictions for swamps for the Longwalls 305-307 Extraction Plan layout indicate (Tables 6 and 7):

- Maximum predicted average tilt[36] of 5 mm/m in Swamp 41 (the remaining 17 swamps have predicted tilts of 4.0 mm/m or less). A maximum predicted average tilt of 5 mm/m was also predicted for the Preferred Project Layout after Longwall 307.
- Maximum predicted hogging curvature[37] for the 18 swamps ranges from <0.01 to 0.06 km^{-1} (corresponding conventional tensile strains range from <0.5 to 1.0 mm/m). A maximum predicted hogging curvature of 0.06 km^{-1} and maximum predicted conventional tensile strain of 1.0 mm/m were also predicted for the Preferred Project Layout for Longwalls 305-307.
- Maximum predicted sagging curvature[37] for the swamps ranges from <0.01 to 0.12 km^{-1} (corresponding conventional compressive strains range from <0.5 to 2.0 mm/m). A maximum predicted sagging curvature of 0.10 km^{-1} and maximum predicted conventional compressive strain of 2 mm/m were predicted for the Preferred Project Layout for Longwalls 305-307.
- A few swamps could experience valley closure[38] movements as a result of their position in the landscape (i.e. those near to drainage lines). Valley closure movements at these swamps range from <20 to 40 mm, and the associated valley closure strains at these swamps are less than or equal to 7 mm/m.

[36] 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.

[37] 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.

[38] Closure is the reduction in the horizontal distance between the valley sides.

Table 6
Revised Maximum Subsidence Predictions for Upland Swamps – Subsidence, Tilt and Curvature

Swamp[1]	Maximum Predicted											
	Subsidence[2] (mm)			Tilt[3] (mm/m)			Hogging Curvature[4] (km^{-1})			Sagging Curvature[4] (km^{-1})		
	PPL (LW317)[5]	PPL (LW307)[6]	EPL (LW307)[7]	PPL (LW317)[5]	PPL (LW307)[6]	EPL (LW307)[7]	PPL (LW317)[5]	PPL (LW307)[6]	EPL (LW307)[7]	PPL (LW317)[5]	PPL (LW307)[6]	EPL (LW307)[7]
S40	550	550	850	3.0	3.0	4.0	0.04	0.04	0.05	0.09	0.09	0.06
S41	825	825	1050	5.0	5.0	5.0	0.04	0.04	0.04	0.10	0.10	0.12
S46	775	775	1100	2.5	2.5	0.5	0.06	0.06	0.05	0.07	0.07	0.06
S47	575	575	1050	0.5	0.5	1.5	0.03	0.03	0.03	0.04	0.04	0.03
S48	500	500	800	0.5	0.5	3.0	0.03	0.03	0.06	0.03	0.03	0.05
S49	500	500	900	0.5	0.5	2.0	0.04	0.04	0.05	0.04	0.04	0.08
S50	550	550	950	1.0	1.0	2.0	0.04	0.04	0.04	0.04	0.04	0.09
S51/52	650	650	1100	1.0	1.0	2.0	0.04	0.04	0.04	0.07	0.07	0.04
S53	750	750	1100	1.5	1.5	3.0	0.06	0.06	0.05	0.07	0.07	0.05
S58	975	975	225	2.0	2.0	2.0	0.05	0.05	0.03	0.05	0.05	0.01
S69	1150	1150	20	2.0	2.0	< 0.5	0.05	0.05	< 0.01	0.06	0.06	< 0.01
S70	1150	1150	< 20	1.0	1.0	< 0.5	0.05	0.05	< 0.01	0.07	0.07	< 0.01
S71a	975	975	40	2.0	2.0	< 0.5	0.05	0.05	< 0.01	0.05	0.05	< 0.01
S71b	725	625	20	2.5	4.0	< 0.5	0.07	0.04	< 0.01	0.06	0.05	< 0.01
S72	525	400	< 20	1.0	3.0	< 0.5	0.05	0.03	< 0.01	0.06	0.03	< 0.01
S73	450	50	< 20	1.0	< 0.5	< 0.5	0.05	< 0.01	< 0.01	0.03	< 0.01	< 0.01
S84	450	200	100	1.0	2.0	1.5	0.04	0.02	0.02	0.06	< 0.01	< 0.01
S86	450	< 20	< 20	1.5	< 0.5	< 0.5	0.05	< 0.01	< 0.01	0.06	< 0.01	< 0.01

Source: after MSEC (2019).

Swamps overlying Longwalls 305-307.

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

1. Swamps within the Longwalls 305-307 35° angle of draw and/or predicted 20 mm subsidence contour.
2. Subsidence refers to vertical displacements of the ground.
3. 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.
4. 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.
5. PPL (LW317) – after completion of Longwall 317 of the Preferred Project Layout.
6. PPL (LW307) – after completion of Longwall 307 of the Preferred Project Layout.
7. EPL (LW307) – after completion of Longwall 307 of the Extraction Plan Layout (i.e. Longwalls 305-307 subject of this BMP).

Table 7
Revised Maximum Subsidence Predictions for Upland Swamps – Tensile and Compressive Strain, Upsidence and Closure

Swamp[1]	Maximum Predicted											
	Conventional Tensile Strain[2] (mm/m)			Conventional Compressive Strain[2] (mm/m)			Upsidence[3] (mm)			Closure[4] (mm)		
	PPL (LW317)[5]	PPL (LW307)[6]	EPL (LW307)[7]	PPL (LW317)[5]	PPL (LW307)[6]	EPL (LW307)[7]	PPL (LW317)[5]	PPL (LW307)[6]	EPL (LW307)[7]	PPL (LW317)[5]	PPL (LW307)[6]	EPL (LW307)[7]
S40	1.00	1.00	1.00	1.50	1.50	1.00	-	-	-	-	-	-
S41	1.00	1.00	1.00	2.00	2.00	2.00	-	-	-	-	-	-
S46	1.00	1.00	1.00	1.50	1.50	1.00	-	-	-	-	-	-
S47	1.00	1.00	0.50	1.00	1.00	0.50	-	-	-	-	-	-
S48	< 0.5	< 0.5	1.00	1.00	1.00	1.00	-	-	-	-	-	-
S49	1.00	1.00	1.00	1.00	1.00	1.50	-	-	-	-	-	-
S50	1.00	1.00	1.00	1.00	1.00	1.50	-	-	-	-	-	-
S51/52	1.00	1.00	1.00	1.50	1.50	1.00	50	50	90	40	40	40
S53	1.00	1.00	1.00	1.50	1.50	1.00	100	100	100	40	40	40
S58	1.00	1.00	< 0.5	1.00	1.00	< 0.5	40	40	< 20	30	30	< 20
S69	1.00	1.00	< 0.5	1.00	1.00	< 0.5	-	-	-	-	-	-
S70	1.00	1.00	< 0.5	1.00	1.00	< 0.5	-	-	-	-	-	-
S71a	1.00	1.00	< 0.5	1.00	1.00	< 0.5	-	-	-	-	-	-
S71b	1.00	1.00	< 0.5	1.00	1.00	< 0.5	-	-	-	-	-	-
S72	1.00	< 0.5	< 0.5	1.00	< 0.5	< 0.5	-	-	-	-	-	-
S73	1.00	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-	-	-
S84	1.00	< 0.5	< 0.5	1.00	< 0.5	< 0.5	-	-	-	-	-	-
S86	1.00	< 0.5	< 0.5	1.00	< 0.5	< 0.5	-	-	-	-	-	-

Source: after MSEC (2019).

Swamps overlying Longwalls 305-307.

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

1 Swamps within the Longwalls 305-307 35° angle of draw and/or predicted 20 mm subsidence contour.

2 Conventional strain based on 15 times curvature. Strain is the relative differential horizontal movements of the ground. Tensile strains occur where the distance between two points increases and compressive strains occur when the distance between two points decreases.

3 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.

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

5 PPL (LW317) – after completion of Longwall 317 of the Preferred Project Layout.

6 PPL (LW307) – after completion of Longwall 307 of the Preferred Project Layout.

7 EPL (LW307) – after completion of Longwall 307 of the Extraction Plan Layout (i.e. Longwalls 305-307 subject of this BMP).

5.3.2 Revised Assessment of Potential Subsidence Impacts and Environmental Consequences

The potential subsidence impacts and environmental consequences to upland swamps described in the Project EA and Preferred Project Report (as described in Section 4.1.2) have been reviewed in consideration of the information obtained since Project approval and the revised subsidence predictions. There is potential for surface cracking from mine subsidence to result in impacts to swamp substrate water levels and upland swamp vegetation; however, based on the experience at Metropolitan Coal to date (described in Sections 4.1.2 and 4.3.1), it is considered unlikely that a significant number of swamps within the Project underground mining area would suffer such consequences.

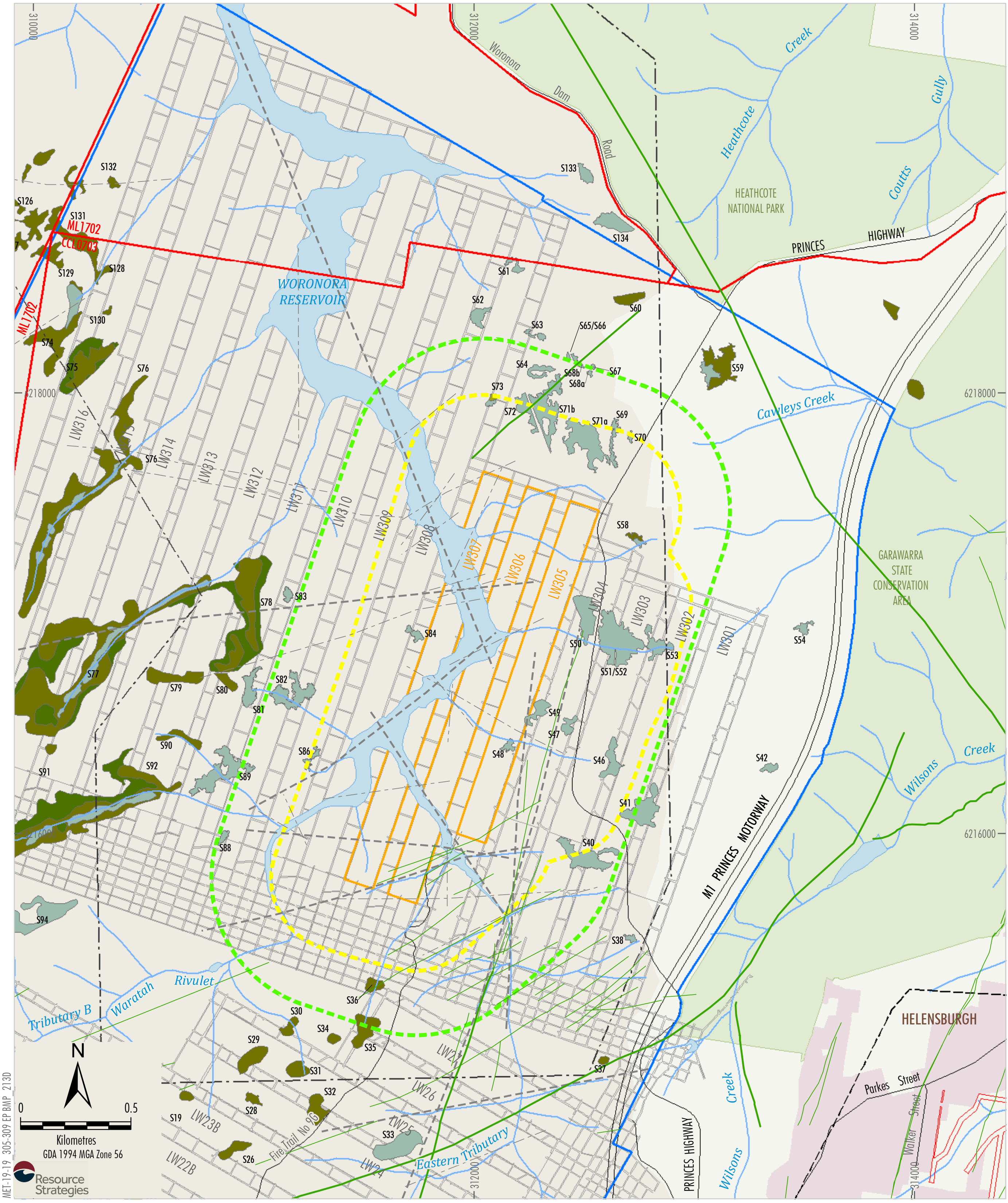
The Independent Expert Scientific Committee's (IESC's) *Advice to decision maker on coal mining – Further advice on impacts to swamps* (24 July 2015) (IESC advice) and IEPMC (2018) Initial Report contend that areas containing lineaments may experience greater than normal subsidence. Surface lineaments are linear features in the surface landscape, preferentially eroded, that may be the surface expression of an underlying geological structure, fault or dyke or simply a result of surface joint sets.

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. 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 swamps. Metropolitan Coal has also considered the potential impacts of mining near and under lineaments on swamps for this BMP.

Lineaments and faults mapped by Metropolitan Coal proximal to swamps within 600 m of Longwalls 305-307 are shown on Figure 15. Figure 15 indicates that there is no distinct correlation between lineaments and swamp locations; it is probable that lineaments are not causative for swamp formation at Metropolitan. The lineaments mapped adjacent to Swamp 40 and Swamp 41 do not correspond with any underground faults (mapped at the coal seam) adjacent to the swamps. Longwall 301 passed Swamp 41 in December 2017, Longwall 302 passed Swamps 41 and 40 in July 2018 and Longwall 303 was completed in May 2019.

A lineament that runs north-south across Longwalls 20-27 extends to the south-western edge of Swamp 50 over Longwall 304. Over Longwalls 20-27, this lineament is associated with an underground fault and it is possible that this extends over Longwall 304. It is noted that the lineament does not continue through, or to the north of, Swamp 50 (Figure 15). 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). If during the extraction of Longwall 304, the fault is found to occur along the alignment of the lineament over Longwall 304, it is considered likely that that the fault would have similar characteristics and behave in a similar manner to that experienced over Longwalls 20-27.

The potential for hydraulic connectivity via lineaments to impact adversely on upland swamps as a result of the mining of Longwalls 305-307 is considered highly unlikely.



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 305-307 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 305-307 Secondary Extraction
- Woronora Notification Area
- Existing Underground Access Drive (Main Drift)
- Faults and Dykes (vertical displacement >1m)
- Faults and Dykes (vertical displacement <1m)
- Lineament (prominent)
- Lineament (minor)

Map Unit	Vegetation Community
3a	Upland Swamp: Banksia Thicket
3b	Upland Swamps: Tea Tree Thicket
3c	Upland Swamp: Sedgeland-heath Complex
3d	Upland Swamp: Fringing Eucalypt Woodland

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)

Note: 1. The NSW Native Vegetation Interim Type Standard 2009 requires patches of vegetation to be mapped if the dimensions of the representative polygon on a map sheet are 2 mm x 2 mm or greater (i.e. 0.25 hectares or greater at a scale of 1:25,000). Eco Logical Australia conducted field inspections of upland swamp vegetation previously mapped by Bangalay Botanical Surveys (2008) overlying or proximal to Longwalls 301-310 to confirm the upland swamp vegetation communities present and to confirm or update the swamp vegetation boundaries. It is noted that the revised boundaries of a number of upland swamps (Swamps 37, 38, 42, 48, 54, 58, 61, 63, 65/66, 67, 68a, 70, 73, 83, 86 and 88) are less than 0.25 hectares in area and consistent with NSW vegetation mapping guidelines are not required to be mapped. Notwithstanding, the revised swamp vegetation mapping boundaries (including those swamps less than 0.25 hectares in area) are shown on this figure to document the changes to previous vegetation mapping.

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Upland Swamps over Longwalls 305-307 and Surrounds

Figure 15

5.4 RIPARIAN ZONE AND AQUATIC BIOTA AND THEIR HABITATS

Riparian vegetation and habitats for aquatic biota occur along streams which flow to the Woronora Reservoir (including the Waratah Rivulet and Eastern Tributary), and some of their tributaries (Figures 1 and 2).

Vegetation mapping within 600 m of Longwalls 305-307 secondary extraction is shown on Figure 16. Riparian vegetation includes vegetation mapped as community 4a (Sandstone Riparian Scrub).

5.4.1 Revised Subsidence Predictions

The subsidence predictions for Longwalls 305-307 in relation to streams have been prepared by MSEC (2019).

Waratah Rivulet

The Waratah Rivulet flows to the north-east and into the full supply level of the Woronora Reservoir, approximately 330 m to the south-west of Longwall 307 (Figures 1 and 2). The predicted profiles of subsidence, upsidence and closure along the Waratah Rivulet, resulting from the extraction of Longwalls 305-307, are shown on Figure 17 (MSEC, 2019).

The maximum predicted values of total subsidence, tilt, curvature, upsidence and closure for the Waratah Rivulet, after Longwall 304 and resulting from the extraction of Longwalls 305-307, is provided in Table 8 (MSEC, 2019). The values are the predicted maxima within the Longwalls 305-307 35° angle of draw and/or predicted 20 mm subsidence contour.

The maximum predicted conventional tilt for the Waratah Rivulet is less than 0.5 mm/m (i.e. 0.05 %, or 1 in 2,000) (MSEC, 2019). The maximum predicted conventional curvatures are less than 0.01 km^{-1} hogging and sagging, which equate to minimum radii of curvature of greater than 100 km. The predicted conventional strains for the Waratah Rivulet (based on 15 times the curvature) are less than 0.5 mm/m tensile and compressive (MSEC, 2019). The maximum predicted total closure on the Waratah Rivulet resulting from the extraction of Longwalls 305-307 is 70 mm (MSEC, 2019).

Table 8
Maximum Predicted Subsidence, Tilt, Curvature, Upsidence and Closure for the Waratah Rivulet Resulting from Longwalls 304-307 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)
LW304	<20	<0.5	<0.01	<0.01	20	40
LW305	<20	<0.5	<0.01	<0.01	20	40
LW306	<20	<0.5	<0.01	<0.01	20	50
LW307	<20	<0.5	<0.01	<0.01	30	70

Source: after MSEC (2019).

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

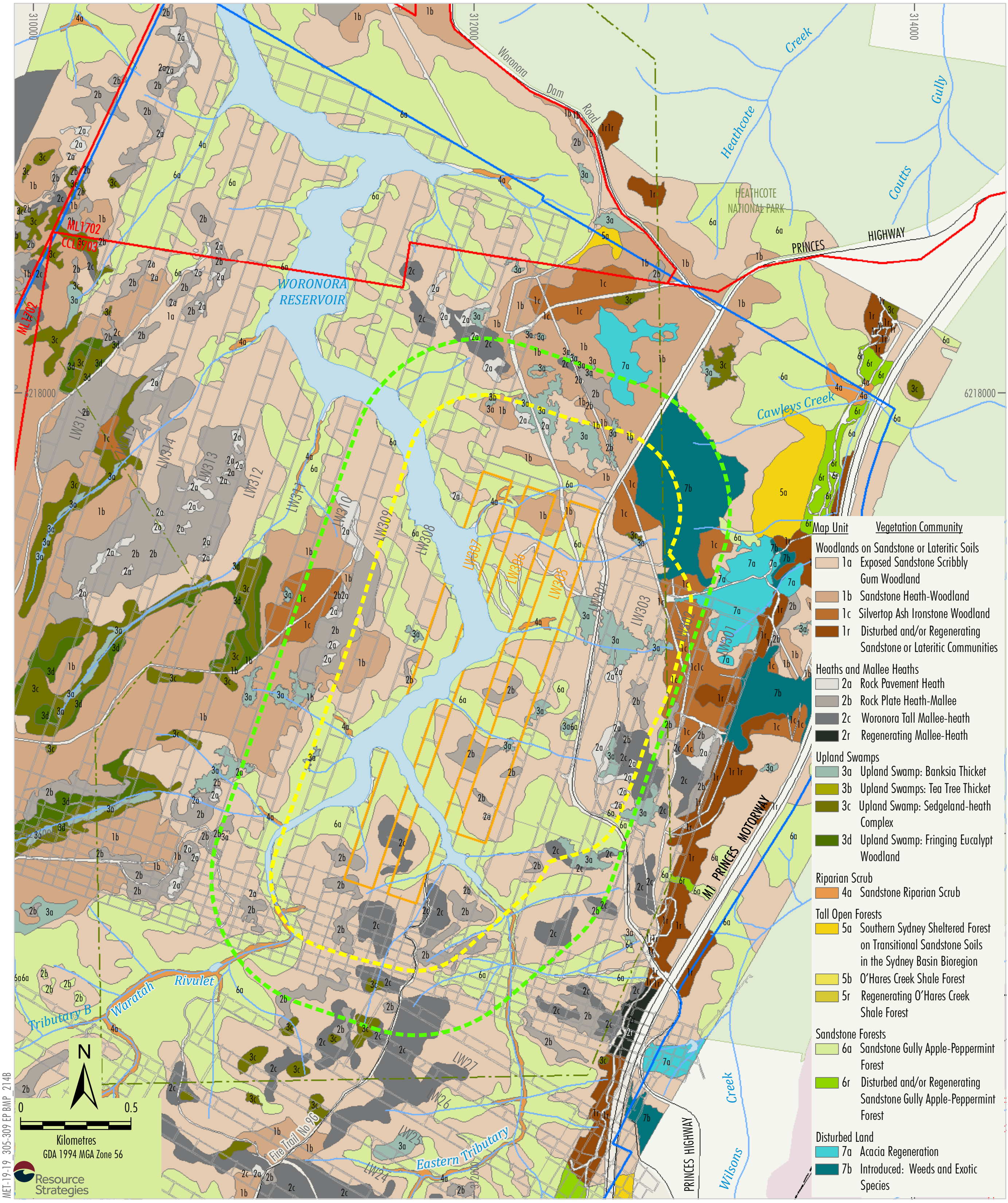
1 Subsidence refers to vertical displacements of the ground.

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.



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 305-307 Secondary Extraction
- Longwalls 305-307 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 305-307 Secondary Extraction
- Woronora Notification Area
- Existing Underground Access Drive (Main Drift)

Note: The NSW Native Vegetation Interim Type Standard 2009 requires patches of vegetation to be mapped if the dimensions of the representative polygon on a map sheet are 2 mm x 2 mm or greater (i.e. 0.25 hectares or greater at a scale of 1:25,000). Eco Logical Australia conducted field inspections of upland swamp vegetation previously mapped by Bangalay Botanical Surveys (2008) overlying or proximal to Longwalls 301-310 to confirm the upland swamp vegetation communities present and to confirm or update the swamp vegetation boundaries. It is noted that the revised boundaries of a number of upland swamps (Swamps 37, 38, 42, 48, 54, 58, 61, 63, 65/66, 67, 68a, 68b, 70, 73, 83, 86 and 88) are less than 0.25 hectares in area and consistent with NSW vegetation mapping guidelines are not required to be mapped. Notwithstanding, the revised swamp vegetation mapping boundaries (including those swamps less than 0.25 hectares in area) are shown on this figure to document the changes to previous vegetation mapping.

Source: Land and Property Information (2015); 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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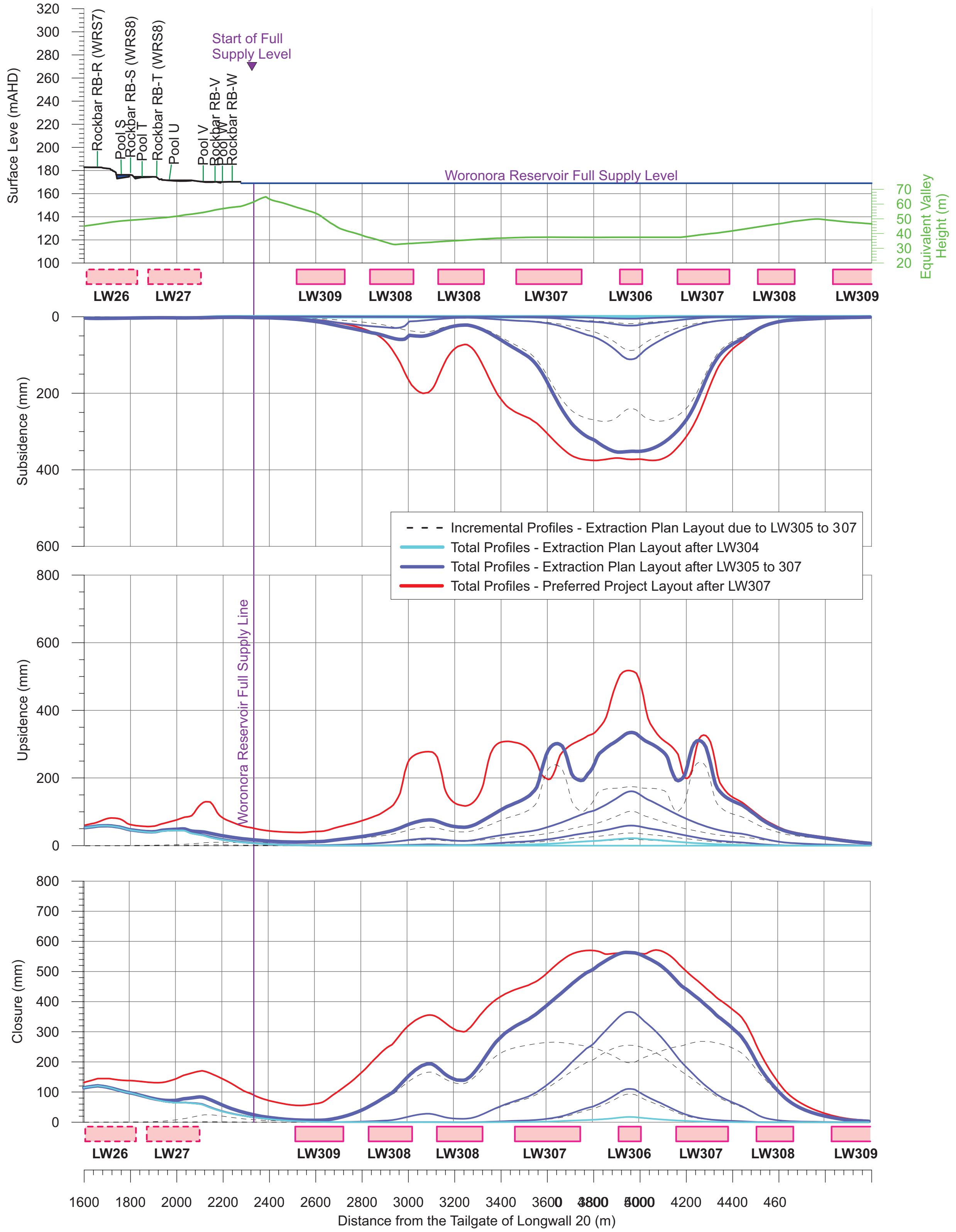
Longwalls 305-307 Vegetation Mapping

Figure 16



MET-19-19_305-309 EP BMP_004B

Source: MSEC (2019)

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Predicted Profiles of Subsidence, Upsidence and Closure along the Waratah Rivulet and Woronora Reservoir due to Longwalls 305-307

Figure 17

The maximum predicted valley closure for the rock bars/boulder field downstream of Pool P, resulting from Longwalls 305-307 is provided in Table 9. The rock bar downstream of Pool P is approximately 1.1 km from Longwall 307. The rock bars downstream of Pool T are within 600 m of Longwalls 305-307. Rock bars V and W are located near the Longwalls 305-307 35° angle of draw and/or predicted 20 mm subsidence contour.

Table 9
Maximum Predicted Total Closure at Rock bars/Boulder field along the Waratah Rivulet

Longwall	Maximum Predicted Total Closure (mm)							
	RB-P	**RB-Q**	**RB-R**	**RB-S**	**RB-T**	**B-U**	**RB-V**	**RB-W**
After LW304	125	100	125	100	80	70	50	30
After LW305	125	100	125	100	80	70	50	30
After LW306	125	100	125	100	80	70	50	30
After LW307	125	100	125	100	80	80	70	50

Source: after MSEC (2019)
mm = millimetres

Table 9 indicates that no additional predicted closure occurs at the rock bars from the extraction of Longwalls 305 and 306. The maximum additional predicted total closure due to the extraction of Longwalls 305-307 is 10 mm at boulder field U and 20 mm at rock bars V and W (MSEC, 2019).

A comparison of the maximum predicted closure for the rock bars, resulting from the Extraction Plan Layout of Longwalls 305-307, with those based on the Preferred Project Layout is provided in Table 10.

Table 10
Comparison of Maximum Predicted Closure for the Waratah Rivulet Rock bars based on the Preferred Project Layout and the Extraction Plan Layout

Layout	**Maximum Predicted Total Closure (mm)**							
	RB-P	**RB-Q**	**RB-R**	**RB-S**	**RB-T**	**B-U**	**RB-V**	**RB-W**
Preferred Project Layout (after LW307)	125	100	125	125	100	150	150	125
Extraction Plan Layout	125	100	125	100	80	80	70	50

Source: after MSEC (2019)
mm = millimetres

The maximum predicted closure for the rock bars downstream of Pool P, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout at rock bars S, T, V, W and at boulder field U, and the maximum predicted closure is the same at rock bars P, Q and R (MSEC, 2019).

Eastern Tributary

The Eastern Tributary flows in a northerly direction into the full supply level of the Woronora Reservoir approximately 300 m to the south-east of Longwalls 305 and 306. The Eastern Tributary is over 500 m from Longwall 307 at its nearest point.

The predicted profiles of subsidence, upsidence and closure along the Eastern Tributary, resulting from the extraction of Longwalls 305-307, are shown on Figure 18.

The maximum predicted values of total subsidence, tilt, curvature, upsidence and closure for the Eastern Tributary, after Longwall 304 and resulting from the extraction of Longwalls 305-307, is provided in Table 11 (MSEC, 2019). The values are the predicted maxima within the Longwalls 305-307 35° angle of draw and/or predicted 20 mm subsidence contour.

Table 11
Maximum Predicted Subsidence, Tilt, Curvature, Upsidence and Closure for the Eastern Tributary Resulting from Longwalls 305-307 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)
LW304	40	<0.5	<0.01	<0.01	40	60
LW305	40	<0.5	<0.01	<0.01	50	70
LW306	60	<0.5	<0.01	<0.01	60	80
LW307	60	<0.5	<0.01	<0.01	60	80

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 conventional tilt for the Eastern Tributary is less than 0.5 mm/m (i.e. 0.05 %, or 1 in 2,000), which is orientated across its alignment (i.e. towards Longwalls 305-307) (MSEC, 2019). The maximum predicted conventional curvatures are less than 0.01 km^{-1} hogging and sagging, which equate to minimum radii of curvature of greater than 100 km (MSEC, 2019). The predicted conventional strains for the Eastern Tributary (based on 15 times the curvature) are less than 0.5 mm/m tensile and compressive (MSEC, 2019). The maximum predicted valley closure on the Eastern Tributary resulting from the extraction of Longwalls 305-307 is 80 mm total closure (MSEC, 2019).

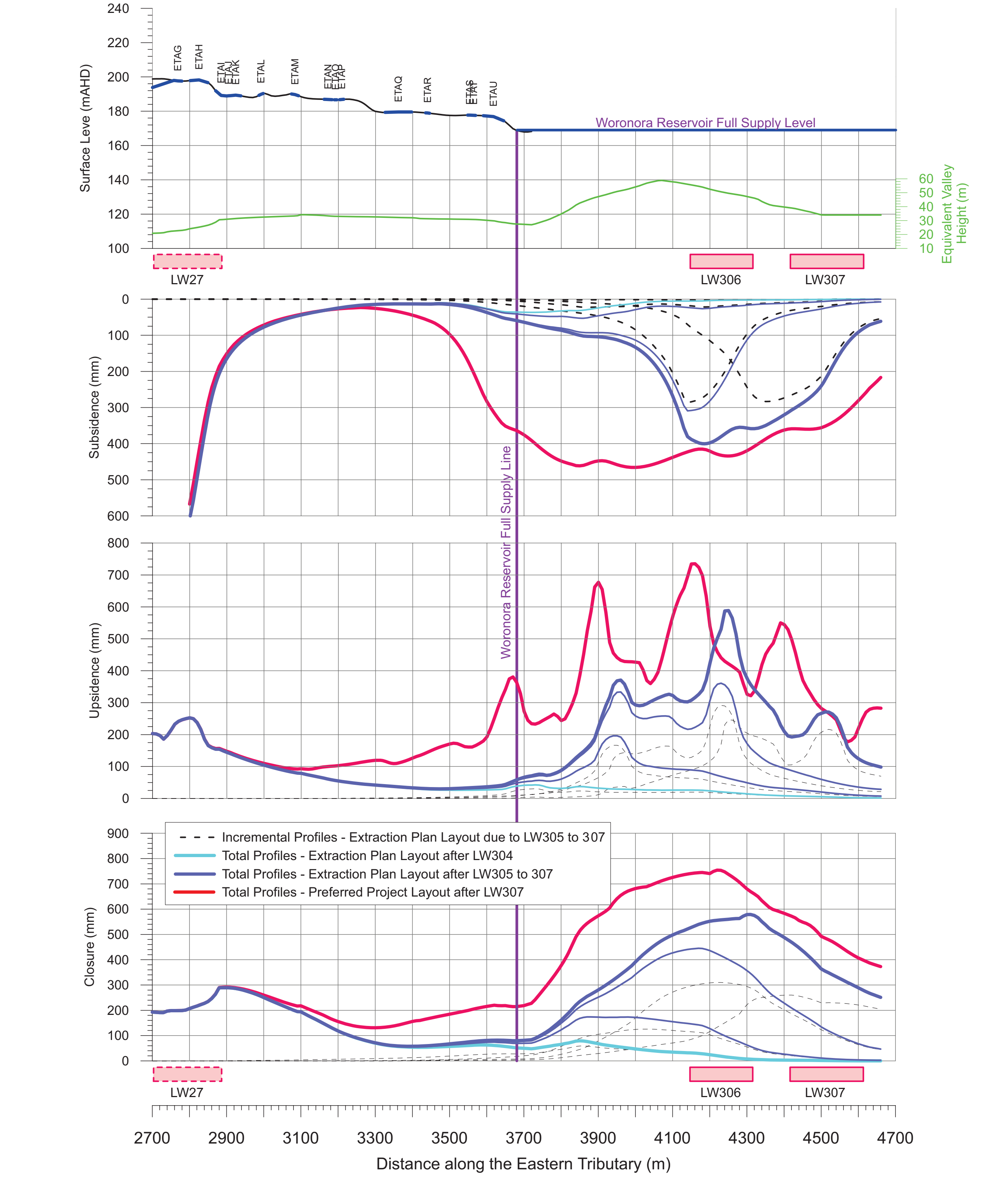
The maximum predicted valley closure for Pools ETAS/ETAT and ETAU on the Eastern Tributary resulting from Longwalls 305-307 is provided in Table 12. The additional predicted total closure due to the extraction of Longwalls 305 and 306 at Pools ETAS/ETAT and ETAU is 20 mm.

Table 12
Maximum Predicted Total Closure at Rock bars Downstream of Pools ETAS/ETAT and ETAU

Longwall	Maximum Predicted Total Closure (mm)	
	ETAS/ETAT	ETAU
After LW304	60	60
After LW305	70	70
After LW306	80	80
After LW307	80	80

Source: after MSEC (2019)

mm = millimetres



MET-19-19_305-309 EP BMP_003C

Source: MSEC (2019)

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Predicted Profiles of Subsidence, Upsidence and Closure along the Eastern Tributary and Woronora Reservoir due to Longwalls 305-307

Figure 18

Woronora Reservoir

Longwalls 306 and 307 extend beneath the Woronora Reservoir full supply level and the Woronora Reservoir is within the Longwalls 305-307 35° angle of draw and/or predicted 20 mm subsidence contour. The area of the Woronora Reservoir full supply level immediately downstream of the Waratah Rivulet and Eastern Tributary is referred to as an inundation area. When the Woronora Reservoir is at full capacity, this area is flooded. When the water level is below the full supply level, portions of the inundation area form temporary pools above exposed rock bars.

The predicted profiles of vertical subsidence, upsidence and closure for the Woronora Reservoir full supply level, resulting from the extraction of Longwalls 305-307, are shown on Figure 17 (for the alignment of the Waratah Rivulet) and Figure 18 (for the alignment of the Eastern Tributary).

A summary of the maximum predicted values of total subsidence, tilt, curvature, upsidence and closure for the Woronora Reservoir full supply level, after Longwall 304 and resulting from the extraction of Longwalls 305-307 is provided in Table 13. The values are the predicted maxima within the 35° angle of draw and/or predicted 20 mm subsidence contour for Longwalls 305-307.

The maximum predicted conventional tilt for the Woronora Reservoir full supply level is 1.0 mm/m (i.e. 0.1 %, or 1 in 1000). The maximum predicted conventional curvatures are 0.02 km^{-1} hogging and 0.04 km^{-1} sagging, which equate to minimum radii of curvature of 50 km and 25 km respectively (MSEC, 2019). The predicted conventional strains for the Woronora Reservoir full supply level (based on 15 times the curvature) are < 0.5 mm/m tensile and 1 mm/m compressive (MSEC, 2019).

Table 13
Maximum Predicted Subsidence, Tilt, Curvature, Upsidence and Closure for the Woronora Reservoir Resulting from Longwalls 305-307 Extraction

Longwall	Maximum Predicted					
	Subsidence (mm)	Tilt (mm/m)	Hogging Curvature (km^{-1})	Sagging Curvature (km^{-1})	Upsidence (mm)	Closure (mm)
LW304	40	<0.5	<0.01	<0.01	40	80
LW305	50	<0.5	<0.01	<0.01	200	175
LW306	300	1	0.02	0.03	350	450
LW307	400	1	0.02	0.04	600	575

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

A comparison of the maximum predicted vertical subsidence, upsidence and closure for the Woronora Reservoir full supply level resulting from the Extraction Plan Layout of Longwalls 305-307, with those based on the Preferred Project Layout after Longwall 307, is provided in Table 14. 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 Longwalls 305-307 is 575 mm (Table 14).

Table 14
Comparison of Maximum Predicted Conventional Subsidence Parameters for the Woronora Reservoir based on the Preferred Project Layout and the Extraction Plan Layout

Layout	Maximum Predicted Total Conventional		
	Subsidence (mm)	**Upsidence (mm)**	**Closure (mm)**
Preferred Project Layout (after LW307)	475	775	800
Extraction Plan Layout	400	600	575

Source: after MSEC (2019)
mm = millimetres

Other Drainage Lines/Streams

First and second order streams are also located within the Longwalls 305-307 35° angle of draw and/or predicted 20 mm subsidence contour (Figure 2). These streams consist of shallow drainage lines from the topographical high points, forming streams where valley heights increase and drain into the Woronora Reservoir. The streams are located above Longwalls 305-307, and could experience the full range of predicted subsidence movements, with maximum predicted closure up to 700 mm (MSEC, 2019).

5.4.2 Revised Assessment of Potential Subsidence Impacts and Environmental Consequences

The maximum predicted subsidence parameters for the Waratah Rivulet and 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 Longwall 27, have occurred at predicted values of total valley closure of less than 200 mm resulting in a higher proportion of impacted pools at lower magnitudes of predicted total valley closure. As a result of the observed impacts to the Eastern Tributary, the finishing ends of Longwalls 303, 304 and 305 have been set back to minimise predicted valley closure at the Eastern Tributary.

As described in Section 4.1, Metropolitan Coal has established a comprehensive monitoring and adaptive management program to identify subsidence related movements at the Eastern Tributary to minimise the risk of further exceedance of the Eastern Tributary performance measure. The Eastern Tributary Valley Closure TARP has been successfully implemented by Metropolitan Coal for Longwall 303. The same monitoring and adaptive management program will be used for the extraction of Longwall 304 (as described in the Longwall 304 Extraction Plan) and for the extraction of Longwalls 305 and 306. 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 Eastern Tributary Valley Closure TARP for Longwalls 305 and 306 is provided in the Longwalls 305-307 Water Management Plan.

As discussed in Section 4.1.1, the restriction of predicted total valley closure to 200 mm has been a successful design tool for complying with the negligible environmental consequence performance measure on the Waratah Rivulet. Furthermore, the geotechnical study of the Waratah Rivulet (detailed in Section 4.1.1) concluded that the geological features identified along the Eastern Tributary are considered to be unique, compared to the Waratah Rivulet. The Eastern Tributary is therefore more likely to be susceptible to subsidence movements. Restricting valley closure to 200 mm therefore continues to be an appropriate design tool for the Waratah Rivulet.

Given that the maximum predicted closure for the rock bars downstream of Pool P, based on the Extraction Plan Layout, are less than or equal to the maxima predicted based on the Preferred Project Layout, and that the maximum predicted total valley closure for the rock bars downstream of Pool P is 125 mm (Table 10), the potential subsidence impacts and environmental consequences described in the Project EA, Preferred Project Report, and Metropolitan Coal Water Management Plans in relation to the Waratah Rivulet continue to be applicable for Longwalls 305-307.

Further to advice from the IEPMC, and at the request of the DPIE, specific regard was given in the Longwall 304 Extraction Plan to the potential impacts of mining near and under lineaments on surface water features, including waterfalls. A similar assessment has been conducted for the Longwalls 305-307 Extraction Plan[39].

Lineaments and faults mapped by Metropolitan Coal proximal to streams within 600 m of Longwalls 305-307 are shown on Figure 15. 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 this fault partially 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 15) is aligned with a 20 mm wide minor strike-slip fault, F-0021, 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 F-0008 during an underground inspection on 19 March 2019[40]. WaterNSW representatives concurred that the faults are not readily apparent without the assistance of Metropolitan Coal's geologist.

It is considered likely that Fault F-0008 and Fault F-0021, would have similar characteristics and behave in a similar manner to that experienced by mine extraction and development to date. Similar to the assessment for Longwall 304, hydraulic connectivity via lineaments to the waterfall at rock bar ETAU on the Eastern Tributary is considered to be highly unlikely as a result of the extraction of Longwalls 305-307.

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 Longwalls 305-307 extends beneath the Woronora Reservoir full supply level. Longwall 305 of the Extraction Plan Layout does not extend beneath the Woronora Reservoir full supply level. The potential impacts on the Woronora Reservoir based on the Extraction Plan Layout are predicted to be consistent with those based on the Preferred Project Layout (including cracking at the base of valleys and fracturing and dilation of the underlying strata when the reservoir level is lower than the full supply level).

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

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

The first and second order streams located above Longwalls 305-307 (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 Section 4.1.

5.5 SLOPES AND RIDGETOPS

Vegetation communities mapped on slopes and ridgetops within 600 m of Longwalls 305-307 secondary extraction include woodlands on sandstone or lateritic soils (vegetation communities 1a, 1b and 1c), heaths and mallee heaths (vegetation communities 2a, 2b and 2c), sandstone forests (vegetation community 6a) and disturbed land (vegetation communities 7a and 7b) (Figure 16).

Figure 10 shows the location of the cliffs and associated overhangs, steep slopes, and land in general that occur within 600 m of Longwalls 305-307 secondary extraction and wider Project underground mining area in accordance with the Metropolitan Coal Longwalls 305-307 Land Management Plan.

5.5.1 Revised Subsidence Predictions

The subsidence predictions for slopes and ridgetops have been prepared by MSEC (2019) for the Longwalls 305-307 Extraction Plan layout.

Five cliff and overhang sites (COH11, COH12, COH13, COH16 and COH17) have been identified within the 35° angle of draw and/or predicted 20 mm subsidence contour of Longwalls 305-307 (Figure 10). Table 15 compares the predicted subsidence parameters for the Longwalls 305-307 Extraction Plan with those for the Preferred Project Layout (at the completion of Longwall 307).

The maximum predicted vertical subsidence for the cliffs based on the Extraction Plan Layout is less than the maxima predicted based on the Preferred Project Layout at four sites and the same as the Preferred Project Layout at one site (COH16, <20 mm) (Table 15). The maximum predicted tilt for the cliffs based on the Extraction Plan Layout is less than or the same as the maxima predicted based on the Preferred Project Layout (Table 15).

The maximum predicted hogging curvature and sagging curvature based on the Extraction Plan Layout are less than or the same as the maxima predicted based on the Preferred Project Layout, with the exception of hogging curvature at Cliff COH13, which is slightly higher (Table 15). Whilst hogging curvature increases at COH13 as a result of the Extraction Plan Layout, the maximum predicted conventional hogging curvature for cliffs, based on the Extraction Plan Layout, (0.02 km^{-1}) is the same as the maxima based on the Preferred Project Layout after Longwall 307 (MSEC, 2019).

Table 15
Revised Subsidence Predictions for Cliffs and Overhangs

Cliff Site	Maximum Predicted Total Conventional Subsidence (mm)[1]		Maximum Predicted Total Conventional Tilt (mm/m)[2]		Maximum Predicted Total Conventional Hogging Curvature (km^{-1})[3]		Maximum Predicted Total Conventional Sagging Curvature (km^{-1})[3]	
	PPL	EPL	PPL	EPL	PPL	EPL	PPL	EPL
COH11	70	40	1.0	< 0.5	0.01	< 0.01	< 0.01	< 0.01
COH12	125	40	1.5	< 0.5	0.02	< 0.01	< 0.01	< 0.01
COH13	300	90	2.0	1.0	0.01	0.02	0.02	< 0.01
COH16	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
COH17	475	125	0.5	< 0.5	0.01	< 0.01	0.03	< 0.01

Source: after MSEC (2019).

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.

PPL = After completion of Longwall 307 of the Preferred Project Layout.

EPL = After completion of Longwall 307 of the Extraction Plan Layout.

mm = millimetres

mm/m= millimetres per metre

km^{-1} =1/kilometres

5.5.2 Revised Assessment of Potential Subsidence Impacts and Environmental Consequences

The potential for impacts on the cliffs and overhangs, based on the Extraction Plan Layout, are similar to those based on the Preferred Project Layout. Based on comparisons with other mines in the Southern Coalfield where cliff lines have been undermined, the lengths of potential cliff instabilities are expected to be less than 3% of the lengths of these cliffs (MSEC, 2019). Although isolated rock falls have been observed over solid coal outside the extracted goaf areas of longwall mining in the Southern Coalfield, there have been no recorded cliff instabilities outside the extracted goaf areas of longwall mining in the Southern Coalfield. It is possible that isolated rock falls could occur as a result of the extraction of the proposed longwalls. It is not expected, however, that any large cliff instabilities would occur outside the longwall footprints as a result of the extraction of the longwalls (MSEC, 2019).

The potential impacts on steep slopes and land in general, for the Extraction Plan Layout, are the same as those assessed for the Preferred Project Layout, specifically, surface tension cracking of sandstone and rock falls, particularly where rock ledges are marginally stable.

The subsidence predictions and impact assessment for the Extraction Plan Layout do not change the assessment of environmental consequences on slope and ridgetop vegetation and terrestrial fauna habitats provided in the Project EA and Preferred Project Report:

- The magnitude of expected surface cracking is considered too small to influence the hydrological processes in the slope and ridgetop areas and is unlikely to have any biologically significant effect on the soil moisture regime that sustains the existing vegetation.
- Rock falls occur naturally in the slope and ridgetop areas, however subsidence has the potential to further reduce the stability of features and thereby increase the incidence of rock fall. Impacts to vegetation from rock falls are expected to be isolated and small. The potential impacts on terrestrial fauna are described in Section 5.6.

5.6 TERRESTRIAL FAUNA AND THEIR HABITATS

Terrestrial fauna habitats include the habitat types discussed in Section 5.3 (upland swamps), Section 5.4 (riparian zone and aquatic biota and their habitats) and Section 5.5 (slopes and ridgetops).

5.6.1 Revised Subsidence Predictions

The subsidence predictions for the Extraction Plan Layout for upland swamps, riparian vegetation and aquatic habitats, and slopes/ridgetops are discussed in Sections 5.3 to 5.5, respectively.

5.6.2 Revised Assessment of Potential Subsidence Impacts and Environmental Consequences

Sections 5.3 to 5.5 describe the revised subsidence predictions for the Extraction Plan Layout for terrestrial fauna habitats (i.e. upland swamps, riparian vegetation and aquatic habitats, and slopes/ridgetops).

The subsidence impact assessment for the Extraction Plan Layout does not change the assessment of environmental consequences on terrestrial fauna and their habitats provided in the Project EA and Preferred Project Report. In summary, the key potential environmental consequences include:

- The potential for surface cracks within some upland swamps and impacts on surface hydrological processes and/or upland swamp vegetation (such as those observed in Swamp 20 and Swamp 28) however, it is considered unlikely that any vertebrate population would be put at risk.
- Localised and limited impacts on riparian vegetation, which may reduce the habitat resources available to terrestrial fauna in the riparian zone. However, the nature of the impacts on riparian habitat is unlikely to significantly impact this habitat type or any terrestrial fauna species.
- The potential for surface cracking to form areas capable of ‘trapping’ some ground dwelling fauna (e.g. frogs and reptiles) in the same way that pitfall traps operate. The size and extent of surface cracking is expected to be minor. Any impacts on vertebrate fauna due to surface cracking are likely to be relatively minor and very unlikely to result in an impact that would threaten the viability of any vertebrate species population.
- The potential for a reduction in terrestrial fauna habitat resources (e.g. roost sites for bats, nest sites for birds, and shelter for reptiles and some amphibian species) as a result of rock falls, or the loss of individuals in a few cases, either by entrapment or direct fatal rock fall. It is predicted that the incidence of rock falls would be low.
- The potential for a reduction in water level in pools (in the inundation area of the Woronora Reservoir and first and second order tributaries) as they become hydraulically connected with the fracture network, reduced continuity of flow between affected pools during dry weather and changes in water quality leading to changes in fauna habitats. Metropolitan Coal has established a comprehensive monitoring and adaptive management program for the Eastern Tributary to avoid the diversion of flows/changes in the natural drainage behaviour of Pools ETAS/ETAT and ETAU on the Eastern Tributary.

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.

Two subsidence impact performance measures are specified in Table 1 of Condition 1, Schedule 3 in relation to biodiversity:

Table 1: Subsidence Impact Performance Measures

Biodiversity	
Threatened species, populations, or ecological communities	*Negligible impact*
Swamps 76, 77 and 92	*Set through condition 4 below*

In relation to the subsidence impact performance measure for Swamps 76, 77 and 92, these swamps will not be undermined by Longwalls 305-307. Swamps 76, 77 and 92 will be subject to assessment in future Extraction Plan(s) and revisions of this BMP.

In relation to the subsidence impact performance measure for threatened species, populations or ecological communities, *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 following biodiversity performance indicators to monitor environmental performance consistent with the TARPs detailed in Section 8.7:

> *The vegetation in upland swamps is not expected to experience changes significantly different to vegetation in control swamps.*
>
> *Surface cracking within upland swamps resulting from mine subsidence is not expected to result in measurable changes to swamp groundwater levels when compared to control swamps or seasonal variations in water levels experienced by upland swamps prior to mining.*
>
> *Impacts to riparian vegetation are expected to be localised and limited in extent, similar to the impacts previously experienced at Metropolitan Coal.*
>
> *The aquatic macroinvertebrate and macrophyte assemblages in streams are not expected to experience long-term impacts as a result of mine subsidence.*
>
> *The amphibian assemblage is not expected to experience changes significantly different to the amphibian assemblage at control sites.*

If data analysis indicates a biodiversity performance indicator has been exceeded, Metropolitan Coal will initiate an assessment against the performance measure and consider the need for management measures (Section 9).

Other subsidence impact performance measures (Table 1 of Condition 1, Schedule 3) of relevance to the BMP include:

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)*
Land	
Cliffs	*Less than 3% of the total length of cliffs (and associated overhangs) within the mining area experience mining-induced rock fall*

Other performance indicators of relevance to the BMP include those detailed in the Metropolitan Coal Longwalls 305-307 Water Management Plan and Metropolitan Coal Longwalls 305-307 Land Management Plan.

If data analysis indicates a water resource, watercourse or land performance indicator has been exceeded, Metropolitan Coal will initiate an assessment against the relevant water resource, watercourse or land performance measure and consider the need for management measures. If a water resource, watercourse or land performance measure is considered to have been exceeded, the relevant Contingency Plan will be implemented and Metropolitan Coal will initiate an assessment against the biodiversity performance measure.

Section 8 describes the monitoring that will be conducted to assess the Project against the biodiversity performance indicators and subsidence impact performance measure for threatened species, populations and ecological communities. The monitoring program includes monitoring of:

- upland swamps (Sections 8.1 and 8.2);
- riparian vegetation (Section 8.3);
- slopes and ridgetops (Section 8.4);
- aquatic biota and their habitats (Section 8.5); and
- terrestrial fauna and their habitats (Section 8.6).

Section 8.7 provides the detailed TARPs to assess the biodiversity subsidence impact performance indicators and measures.

7 BASELINE DATA

In accordance with Condition 2, Schedule 7 of the Project Approval, this section outlines the biodiversity baseline information and data available for Longwalls 305-307.

The Longwalls 305-307 biodiversity monitoring program is described in Section 8.

7.1 UPLAND SWAMPS

7.1.1 Swamp Types

As described in Section 4.3.1, several types of upland swamps have been defined within the Metropolitan Coal Project underground mining area and surrounds according to the geomorphological settings in which they occur, namely, headwater swamps, valley side swamps and in-valley swamps.

Similar to the Longwalls 301-304 mining area, the terrain over Longwalls 305-307 is highly dissected with narrow ridges. All swamps mapped in the Longwalls 305-307 mining area are valley side swamps (Figure 15).

7.1.2 Swamp Vegetation Mapping

Field inspections of upland swamp vegetation mapped by Bangalay Botanical Surveys (2008) in the vicinity of Longwalls 301-303 were conducted by Eco Logical in 2015. The revised upland swamp mapping is shown on Figures 9 and 15 and was detailed in Eco Logical (2016) (provided as Appendix 2 of the Longwalls 301-303 BMP).

Field inspections of upland swamp vegetation mapped by Bangalay Botanical Surveys (2008) overlying or proximal to Longwalls 304-310 secondary extraction were conducted by Eco Logical in 2016 and 2017 to confirm the upland swamp vegetation communities present and to check the swamp boundaries. The revised upland swamp mapping is shown on Figures 9 and 15 and was detailed in Eco Logical (2018) (Appendix 2).

All of the upland swamps overlying or within 600 m of Longwalls 305-307 (namely, Swamps 35, 36, 40, 41, 46, 47, 48, 49, 50, 51/52, 53, 58, 64, 65, 67, 68a, 68b, 69, 70, 71a, 71b, 72, 73, 82, 84, 86, 88 and 89) were included in Eco Logical's field inspections for the Longwalls 301-303 and Longwall 304 BMPs.

The field surveys undertaken by Eco Logical (2016, 2018) indicate that all upland swamps within the 35° angle of draw and/or predicted 20 mm subsidence contour for Longwalls 305-307 consist of Banksia Thicket, with the exception of Swamps 58 and 73. Swamp 58 was mapped as a combination of Banksia Thicket and Sedgeland-heath Complex, while Swamp 73 was mapped as a combination of Banksia Thicket and Tea Tree Thicket (Figures 9 and 15).

As described in Section 4.3.1.4, Swamps 46, 51/52, 69, 70, 71a and 71b were subject to WaterNSW hazard reduction burns in 2016 and/or 2017. It is recognised that while these swamps were all mapped as containing Banksia Thicket vegetation (Appendix 2), the hazard reduction burns are likely to have affected the vegetation communities that are now present.

7.1.3 Swamp Vegetation Data

As described in Section 4.1.3.4, a number of swamps proximal to Longwalls 305-307 have been monitored for Longwalls 301-303 or Longwall 304. This includes transect/quadrat monitoring at Swamps 40, 41, 46, 48, 50, 51/52 and 53 (Figure 15). Note that Swamp 48 is located over Longwall 305 (adjacent to Longwall 304). Swamp 48 is a very small valley-side swamp (approximately 0.1 ha in area) comprised of Banksia Thicket vegetation with well-defined boundaries (Eco Logical, 2016). A terminal rocky step is present along the north-western boundary of the swamp.

Visual inspections of swamps proximal to Longwalls 305-307 have also been conducted as a component of the Longwalls 301-303[41] upland swamp vegetation monitoring program, namely Swamps 40, 41, 46, 47, 48, 49, 50, 51/52, 53 and 58 (Figure 15).

Baseline transect and quadrat data for Longwalls 305-307 has been obtained for Swamp 71a located to the north of Longwalls 305 and 306[42] (Figures 9 and 15) biannually (i.e. in spring and autumn) since spring 2015, consistent with the methods used for the Longwalls 20-22, 23-27, 301-303 and 304 upland swamp vegetation monitoring programs. Additional baseline data will be collected for Swamp 71a prior to subsidence effects occurring at the swamp from Longwalls 305-307.

Swamp 71a is a valley-side swamp (approximately 2.1 ha in area) comprised of Banksia Thicket vegetation (Eco Logical, 2016). While Swamp 71a was re-mapped as containing Banksia Thicket vegetation (Appendix 2), the hazard reduction burns are likely to have affected the vegetation that is now present (Section 4.3.1.3).

7.1.4 Swamp Groundwater Data

As described in the Longwalls 301-303 BMP, 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 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. This review covered all swamps located within the Longwall 304 35° angle of draw and/or predicted 20 mm subsidence contour.

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 (Figures 9 and 15), 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.

Paired piezometers (i.e. one swamp substrate piezometer [at approximately 1 m depth] and one sandstone piezometer [at a depth of approximately 10 m]) were installed in Swamps 60, 62, 64, 72, 133 and 134 in October 2018 (prior to the shortening of the commencing ends of Longwalls 305-307) (Figures 9 and 15).

[41] All swamps located within the 35° angle of draw and/or predicted 20 mm subsidence contour for Longwall 304 are subject to visual inspections as a component of the Longwalls 301-303 upland swamp vegetation monitoring program.

[42] Swamp 71a was previously located over Longwalls 305 and 306 prior to the shortening of the commencing ends of these longwalls.

Consistent with the Longwall 304 BMP, piezometers are not proposed to be installed in Swamps 73, 84 and 86 as these swamps are small (<0.25 ha, 0.256 ha and <0.25 ha, respectively), and Swamps 84 and 86 are considered to be marginal upland swamps (i.e. they contain non-swamp vegetation more consistent with sandstone woodland). Swamps 84 and 86 are also difficult to access.

7.2 RIPARIAN VEGETATION

Visual, transect/quadrat and indicator species monitoring has been conducted for the Eastern Tributary and Waratah Rivulet riparian vegetation for Longwalls 20-22 and Longwalls 23-27 as described in Section 4.3.2.

Site MRIP10 on the Waratah Rivulet is located near the 35° angle of draw and/or predicted 20 mm subsidence contour boundary for Longwalls 305-307. Site MRIP04 on the Waratah Rivulet and sites MRIP07 and MRIP08 on the Eastern Tributary are located within 600 m of Longwalls 305-307.

No additional monitoring sites have been established in relation to Longwalls 301-303, 304 or 305-307.

7.3 SLOPES AND RIDGETOPS

Five cliff and overhang sites (namely COH11, COH12, COH13, COH16 and COH17) are located within the 35° angle of draw and/or predicted 20 mm subsidence contour for Longwalls 305-307. The baseline characteristics of these sites have been recorded.

The data obtained includes:

- photographic records of the cliff and overhang;
- sketches of the overhang; and
- mapping of the approximate location of the cliff/overhang face and the rear extent of the overhang/undercut.

The baseline record is provided in the Longwalls 305-307 Land Management Plan.

No surface tension cracks as a result of previous mining have been observed within the 35º angle of draw and/or predicted 20 mm subsidence contour of Longwalls 305-307 to date (i.e. at the time of BMP development).

7.4 AQUATIC BIOTA AND THEIR HABITATS

The Eastern Tributary and Waratah Rivulet flow in a northerly direction into the full supply level of the Woronora Reservoir within the 35° angle of draw and/or predicted 20 mm subsidence contour for Longwalls 305-307 (Figure 2). Prior to the commencement of Longwall 20, MSEC compiled a comprehensive survey and photographic record of the Eastern Tributary (from the east-west headings to the Woronora Reservoir full supply level) and the Waratah Rivulet (from Flat Rock Crossing to the Woronora Reservoir full supply level). The detailed mapping and photographic record of the Eastern Tributary and Waratah Rivulet are provided in the Metropolitan Coal Longwalls 305-307 Water Management Plan.

Baseline surface water data (e.g. surface water flow, pool water levels and water quality) are also available for the Eastern Tributary and Waratah Rivulet at the sites shown on Figures 6 and 7 and as described in the Metropolitan Coal Longwalls 305-307 Water Management Plan.

As described in Section 5.4.1, small first and second order streams are located within the 35° angle of draw and/or predicted 20 mm subsidence contour for Longwalls 305-307 (Figures 2 and 4). These streams consist of shallow drainage lines from the topographical high point above Longwalls 301-304 and Longwalls 308-310, forming streams where valley heights increase and drain into the Woronora Reservoir.

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, 2019b). The visual inspection and photographic survey report is provided in Appendix 3.

Monitoring of macroinvertebrates and macrophytes has been conducted at sites on the Eastern Tributary and Waratah Rivulet for Longwalls 20-22 and Longwalls 23-27 as described in Section 4.3.3. Aquatic ecology monitoring Locations ET2 on the Eastern Tributary and WT5 on the Waratah Rivulet are situated within 600 m of Longwalls 305-307 (Figure 13).

No additional monitoring sites have been established in relation to Longwalls 301-303, 304 or 305-307.

7.5 TERRESTRIAL FAUNA AND THEIR HABITATS

Baseline data are available for terrestrial fauna habitats, i.e. upland swamps, riparian vegetation, slopes and ridgetops, and aquatic habitats, as described in Sections 7.1 to 7.4, respectively.

Amphibians were selected as the appropriate representative of terrestrial vertebrate fauna because they were/are widespread across the Project area at the time of monitoring program design, and included two threatened species that are sensitive to changes in surface hydrology. This group is represented by at least 14 species that appear to have viable populations. Amphibian monitoring has been conducted for Longwalls 20-22, 23-27 and 301-303 as described in Section 4.3.4 and shown on Figure 14.

No additional monitoring sites were established in relation to Longwall 304.

Two amphibian monitoring sites (sites 29 and 30) have been established proximal to Longwalls 305 and 306. Monitoring of these sites commenced in spring 2018/summer 2019. No additional control sites were required to ensure a continually robust experimental design.

A total of 30 amphibian survey sites have been established, including 19 test sites overlying or adjacent to Longwalls 20-307 to monitor amphibian species, with a focus on the habitats of the Giant Burrowing Frog, Red-crowned Toadlet and Littlejohn’s Tree Frog.

8 MONITORING PROGRAM

Subsidence parameters will be measured in accordance with the Longwalls 305-307 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.

The Longwalls 305-307 Water Management Plan describes the monitoring and adaptive management approach that will be implemented to monitor subsidence effects on the Eastern Tributary.

A monitoring program will be implemented to monitor the impacts and environmental performance of the Project on aquatic and terrestrial flora and fauna during the mining of Longwalls 305-307. The monitoring program is described in Sections 8.1 to 8.6 and will be implemented at the commencement of Longwall 305 extraction. The monitoring program includes monitoring for Longwalls 305-307, as well as the post-mining monitoring to be implemented for Longwalls 20-22, Longwalls 23-27, Longwalls 301-303 and Longwall 304[43]. As described in Section 1.1, the Metropolitan Coal Longwall 304 BMP will be superseded by this document following the completion of Longwall 304 consistent with the recommended approach in the DP&E and DRE (2015) *Guidelines for the Preparation of Extraction Plans*.

Section 8.7 provides detailed TARPs to assess the biodiversity subsidence impact performance indicators and measures. The Longwalls 305-307 Water Management Plan provides a detailed TARP to assess subsidence effects on the Eastern Tributary during the mining of Longwalls 305 and 306.

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

8.1 UPLAND SWAMP VEGETATION MONITORING

Visual Inspections

Visual inspections will continue to be conducted of Swamps 16, 17, 18, 19, 20, 24, 25, 28, 30, 31, 32, 33, 34, 35, 36 and 94 overlying or adjacent to Longwalls 20-27 to record evidence of potential subsidence impacts. The majority of these swamps are also subject to biannual transect/quadrat and/or indicator species monitoring (as described below). None of these swamps are located within the Longwalls 305-307 35° angle of draw and/or predicted 20 mm subsidence contour (Figure 9).

Visual inspections will continue to be conducted of Swamps 40, 41, 46, 47, 48, 49, 50, 51/52, 53 and 58 overlying or adjacent to Longwalls 301-304 to record evidence of potential subsidence impacts (Figures 9 and 15).

Visual inspections will also be conducted of Swamps 69, 70, 71a, 71b, 72 and 73, located within the Longwalls 305-307 35° angle of draw and/or predicted 20 mm subsidence contour, however it is noted that subsidence impacts are unlikely given the subsidence predictions for these swamps (Section 5.3.1).

Visual inspections will also continue to be conducted in control Swamps 101, 111a, 125, 135, 136, 137a, 137b, 138, Bee Creek Swamp, Woronora River 1, Woronora River south arm and Dahlia Swamp (Figure 9).

Traverses over the swamp will be conducted biannually in autumn and spring, to record:

- cracking of exposed bedrock areas and/or swamp substrate;
- areas of increased erosion, particularly along any existing drainage line;
- any changes in water colour, particularly evidence of iron precipitation;
- changes in vegetation condition, including areas of stressed vegetation (i.e. plants that demonstrate symptoms of stress) and dead/dying plants that appear unusual; and
- whether the amount of seepage (at the terminal step/over exposed surfaces of the swamp) at the time of inspection appears unusual (relative to recent rainfall).

[43] The Metropolitan Coal Longwall 304 BMP will be implemented until the commencement of Longwall 305.

Photographs of any cracking, erosion, water colour changes and stressed vegetation will be taken, concurrently with a description of the nature and extent of the observations, and appropriate global positioning system (GPS) readings. If changes in vegetation condition are observed in a swamp that are not similar to that in control swamp(s), the extent of change will be noted, and where practicable, mapped. Seepage will be documented by photographs of flow over exposed surfaces, e.g. terminal step.

The visual inspections will assess the changes in the observed physical condition of the swamps over time (Table 16 in Section 8.7).

Transect/Quadrat Monitoring

Transect and quadrat monitoring will continue to be conducted biannually (in autumn and spring) in Swamps 16, 17, 18, 20, 24 and 25 overlying Longwalls 20-22, Swamps 28, 30, 33, 35 and 94 overlying or adjacent to Longwalls 23-27 and in control Swamps 101, 111a, 125, 135, 136, 137a, 137b, 138, Bee Creek Swamp, Woronora River 1, Woronora River south arm and Dahlia Swamp (Figure 9) for Longwalls 20-27 consistent with the monitoring methods described in Section 4.3.1.4. None of these swamps are located within the Longwalls 305-307 35° angle of draw and/or predicted 20 mm subsidence contour.

Transect and quadrat monitoring will also continue to be conducted in Swamps 40, 41, 46, 48, 50, 51/52 and 53 over or adjacent to Longwalls 301-304 and in control Swamps 101, 135, 136, 137a and 137b (Figures 9 and 15) biannually consistent with the monitoring methods described in Section 4.3.1.4. As described in Section 4.3.1.4, portions of Swamp 46 and Swamp 51/52 were subject to WaterNSW hazard reduction burns after the autumn 2017 survey (baseline) and before the spring 2017 survey.

The data collected for each quadrat will continue to include:

- vegetation structure;
- dominant species;
- estimated cover and height for each stratum;
- full floristics;
- estimated cover abundance for each species using seven point Braun-Blanquet scale; and

  Modified Braun-Blanquet Scale

  1 = cover less than 5% of site and rare
  2 = cover less than 5% of site and uncommon
  3 = cover of less than 5% and common
  4 = cover of 5-20% of site
  5 = cover of 21-50% of site
  6 = cover of 51-75% of site
  7 = cover of greater than 75%

- condition/health rating for each species in the quadrat:

  Condition Scale

  1 severe damage/dieback
  2 many dead stems
  3 some dead branches
  4 minor damage
  5 healthy

Table 16 in Section 8.7 details the analysis of the quadrat/transect data that will be conducted to assess the vegetation monitoring results against the upland swamp vegetation performance indicator, *The vegetation in upland swamps is not expected to experience changes significantly different to vegetation in control swamps*.

Indicator Species Monitoring

Population monitoring will continue to be conducted for Longwalls 20-22 during the extraction of Longwalls 305-307, specifically, 20 tagged individuals of:

- *Epacris obtusifolia* in each of Swamps 18, 24 and 25 (longwall swamps) and control Swamps 101, 111a and 125;
- *Sprengelia incarnata* in each of Swamp 24 (longwall swamp) and control Swamps 101 and 125; and
- *Pultenaea aristata* in each of Swamps 18, 24 (from autumn 2010) and 25 (longwall swamps) and control Swamps 101 and 111a.

Three indicator species characteristic of the Tea Tree Thicket vegetation namely, *Banksia robur, Callistemon citrinus* and *Leptospermum juniperinum* will also continue to be monitored in Swamp 20 and at associated control sites (Woronora River 1, Woronora River south arm and Dahlia Swamp). The twenty tagged individuals will continue to be monitored in each swamp.

Population monitoring will also continue to be conducted for Longwalls 23-27 during the extraction of Longwalls 305-307, specifically, 20 tagged individuals of:

- *Epacris obtusifolia* in each of Swamps 19, 30, 33, 35 and 94 (longwall swamps) and control Swamps 135, 136, 137a, 137b and 138;
- *Sprengelia incarnata* in each of Swamps 19, 33, 35 and 94 (longwall swamps) and control Swamps 135, 136, 137a and 138;
- *Pultenaea aristata* in each of Swamps 19, 30, 33, 35 and 94 (longwall swamps) and control Swamps 135, 136, 137a and 138; and
- *Banksia robur* and *Callistemon citrinus* in Swamp 28 (longwall swamp) and control Swamps Woronora River 1, Woronora River south arm and Dahlia Swamp.

Population monitoring will also continue to be conducted for Longwalls 301-303 during the extraction of Longwalls 305-307, specifically, 20 tagged individuals of[44]:

- *Epacris obtusifolia* will be monitored in each of Swamps 40 and 53 (longwall swamps) and control Swamps 101, 136 and 137a; and
- *Sprengelia incarnata* will be monitored in each of Swamps 40 and 53 (longwall swamps) and control Swamps 101, 136 and 137b.

[44] Insufficient individuals of *Pultenaea aristata* were available in the swamps over Longwalls 301-303 for monitoring.

Population monitoring for Longwalls 20-22, 23-27 and 301-303 will continue to be conducted in the abovementioned swamps using the methods described in Section 4.3.1.4. Population monitoring data collected will include:

- condition/health rating for each plant; and

  Condition Scale

  1 severe damage/dieback
  2 many dead stems
  3 some dead branches
  4 minor damage
  5 healthy

- reproductive rating:

  Reproductive Rating

  1 nil
  2 sparse (occasional flowers only)
  3 low (under 25 percent of potential)
  4 moderate (25 to 75 percent)
  5 high (over 75 percent of potential flowering)

Surveys will be conducted biannually in autumn and spring.

Table 16 in Section 8.7 details the analysis of the indicator species data that will be conducted to assess the vegetation monitoring results against the upland swamp vegetation performance indicator, *The vegetation in upland swamps is not expected to experience changes significantly different to vegetation in control swamps*.

8.2 UPLAND SWAMP GROUNDWATER MONITORING

The approach taken to the development of the upland swamp groundwater monitoring program is described in Section 7.1.4 in relation to the collection of baseline data. Groundwater monitoring of upland swamps has included 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).

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, Swamp 50 for Longwall 304 and in control Swamps 101, 137a, 137b, Bee Creek Swamp and Woronora River 1 (WRSWAMP 1) (Figure 9). Upland swamp groundwater monitoring will be conducted in Swamps 71a and 72 for Longwalls 305-307 (Figure 9).

Paired piezometers have also been installed in Swamps 60, 62, 64, 133 and 134, which can also be used as potential reference sites during the mining of Longwalls 305-307.

Table 17 in Section 8.7 details the data analysis that will be conducted to assess the upland swamp substrate groundwater monitoring results against the upland swamp groundwater performance indicator, *Surface cracking within upland swamps resulting from mine subsidence is not expected to result in measurable changes to swamp groundwater levels when compared to control swamps or seasonal variations in water levels experienced by upland swamps prior to mining*, consistent with the previously approved upland swamp groundwater monitoring program.

8.3 RIPARIAN VEGETATION

Riparian areas along the Waratah Rivulet and Eastern Tributary will continue to be monitored at sites MRIP01 to MRIP12[45] established previously for Longwalls 20-22 and/or Longwalls 23-27 (Figure 12). Sites MRIP01, MRIP02, MRIP05, MRIP06 and MRIP09 are situated over Longwalls 20-22 and sites MRIP11 and MRIP12 are situated over Longwalls 23-27. Sites MRIP03, MRIP04 and MRIP10 are situated downstream of Longwall 23A on the Waratah Rivulet. Sites MRIP07 and MRIP08 are situated on the Eastern Tributary downstream of Longwalls 23-27.

No additional riparian vegetation monitoring sites have been established for Longwalls 301-303, 304 or 305-307.

Visual Inspections

Visual inspections of riparian areas will continue to be conducted in locations adjacent to riparian vegetation monitoring sites (sites MRIP01 to MRIP12), and areas traversed whilst accessing the monitoring sites during the mining of Longwalls 305-307 to record evidence of subsidence impacts including:

- areas of new water ponding;
- any cracking or rock displacement; and
- changes in vegetation condition, including areas of stressed vegetation that appear unusual.

Photographs of any new water ponding, cracking/rock displacement and stressed vegetation will be taken, concurrently with a description of the nature and extent of the observations, and appropriate GPS readings. Flora species that have been subject to vegetation dieback will be noted. The visual inspections will be conducted biannually in autumn and spring.

The visual inspections will assess the changes in the observed physical condition of the riparian zone over time (Table 18 in Section 8.7).

Quadrat Monitoring

The existing permanent quadrat (20 m x 2 m) will continue to be used to monitor riparian vegetation at (Figure 12):

- sites MRIP01, MRIP02, MRIP05 and MRIP06 overlying Longwalls 20-22;
- sites MRIP11 and MRIP12 overlying Longwalls 23-27;
- sites MRIP03 and MRIP04 downstream of Longwall 23A; and
- sites MRIP07 and MRIP08 downstream of Longwalls 23-27.

The data collected for each quadrat will include:

- vegetation structure;
- dominant species;
- estimated cover and height for each stratum;

[45] Sites MRIP01, MRIP02, MRIP03, MRIP04 and MRIP10 are situated in the vicinity of pools J, N, Q, U and W, respectively on the Waratah Rivulet. Sites MRIP05, MRIP06, MRIP07, MRIP08, MRIP09, MRIP11 and MRIP12 are situated in the vicinity of pools ETJ, ETM, ETAQ, ETAS, ETF, ETV and ETAG, respectively, on the Eastern Tributary.

- full floristics;
- estimated cover abundance for each species using seven point Braun-Blanquet scale; and

  Modified Braun-Blanquet Scale

  1 = cover less than 5% of site and rare
  2 = cover less than 5% of site and uncommon
  3 = cover of less than 5% and common
  4 = cover of 5-20% of site
  5 = cover of 21-50% of site
  6 = cover of 51-75% of site
  7 = cover of greater than 75%

- condition/health rating for each species in the quadrat:

  Condition Scale

  1 severe damage/dieback
  2 many dead stems
  3 some dead branches
  4 minor damage
  5 healthy

Permanent photo points have been established for each quadrat.

Surveys of the quadrats will continue to be conducted biannually in autumn and spring.

The monitoring conducted at quadrats along the streams will inform the assessment of vegetation dieback for the assessment against the riparian vegetation performance indicator, *Impacts to riparian vegetation are expected to be localised and limited in extent, similar to the impacts previously experienced at Metropolitan Coal*.

Indicator Species Monitoring

Three indicator species will continue to be monitored within the riparian vegetation of Waratah Rivulet and the Eastern Tributary, namely, *Prostanthera linearis*, *Schoenus melanostachys* and *Lomatia myricoides*. The existing tagged individuals[46] will continue to be monitored at:

- sites MRIP01, MRIP02, MRIP05, MRIP06 and MRIP09 overlying Longwalls 20-22;
- sites MRIP11 and MRIP12 overlying Longwalls 23-27;
- sites MRIP03, MRIP04 and MRIP10 downstream of Longwall 23A; and
- sites MRIP07 and MRIP08[47] downstream of Longwalls 23-27.

Population monitoring data collected includes:

- condition/health rating for each plant; and

  Condition Scale

  1 severe damage/dieback
  2 many dead stems
  3 some dead branches
  4 minor damage
  5 healthy

[46] Twenty individuals were selected and tagged for monitoring at the commencement of the Longwalls 20-22 and Longwalls 23-27 programs.

[47] Note: Twenty individuals of *Prostanthera linearis* were not available for tagging at site MRIP08.

- reproductive rating:

  Reproductive Rating

  1 nil

  2 sparse (occasional flowers only)

  3 low (under 25 percent of potential)

  4 moderate (25 to 75 percent)

  5 high (over 75 percent of potential flowering)

Surveys will be conducted biannually in autumn and spring.

The monitoring conducted of indicator species along the streams will inform the assessment of vegetation dieback for the assessment against the riparian vegetation performance indicator, *Impacts to riparian vegetation are expected to be localised and limited in extent, similar to the impacts previously experienced at Metropolitan Coal*.

8.4 SLOPES AND RIDGETOPS

Potential subsidence impacts and environmental consequences on cliffs and overhangs, steep slopes, and land in general will be monitored in accordance with the Metropolitan Coal Longwalls 305-307 Land Management Plan, a summary of which is provided in Sections 8.4.1 and 8.4.2. As described in Section 4.2 and Section 5, subsidence impacts on cliffs and overhangs, steep slopes, and land in general have the potential to result in environmental consequences to aquatic and terrestrial biota and their habitats.

8.4.1 Cliffs and Overhangs

Following the completion of Longwall 27 extraction, cliff sites COH1, COH2, COH3, COH4, COH5, COH6, COH6A, COH7, COH8, COH9, COH10, COH14, COH15 and COH16 were inspected to record any additional subsidence impacts (e.g. cliff instabilities and cracking) to those previously recorded. The visual inspections did not record any additional subsidence impacts.

In accordance with the Longwall 304 Land Management Plan, visual inspections for subsidence impacts on cliff site COH17 will be conducted monthly when Longwall 304 extraction is within 400 m of the site and at the completion of Longwall 304.

Visual inspections for subsidence impacts for Longwalls 305-307 will be conducted at sites COH11, COH12, COH13, COH16 and COH17:

- prior to the commencement of Longwall 305 extraction.
- monthly at cliff site(s) located within 400 m of longwall extraction; and
- within three months of the completion of Longwall 305, Longwall 306 and Longwall 307.

Additional visual observations of subsidence impacts will be conducted during routine works and sampling by Metropolitan Coal and its contractors. In the event subsidence impacts are identified on cliff and overhang sites, the following details will be noted and/or photographed:

- the date of the inspection;
- the location of longwall extraction (i.e. the longwall chainage);
- the location of the cliff instability (i.e. freshly exposed rock face and debris scattered around the base of the cliff or overhang) relative to the cliff face or overhang;

- the nature and extent of the cliff instability (including an estimate of volume);
- the length of the cliff instability;
- other relevant aspects such as water seepage (which can indicate weaknesses in the rock);
- whether any actions are required (for example, implementation of appropriate safety controls, review of public safety etc.); and
- any other relevant information.

The information obtained will be recorded in the Land Management Plan – Subsidence Impact Register and reported in accordance with the Project Approval conditions.

The information obtained will be used to assess the potential environmental consequences of the subsidence impact on flora, fauna and/or their habitats. Specific details that will be noted and/or photographed to assess the potential environmental consequences of the subsidence impact include:

- the nature and extent of impacts on the aesthetic values of the land feature;
- any areas of erosion or sedimentation arising from mining activities;
- the co-ordinates of the subsidence impact to assess impacts on known Aboriginal heritage sites;
- nature and extent of impacts on potential flora and fauna habitats;
- evidence of impacts on terrestrial fauna (e.g. observed fauna mortality); and
- any impacts on the serviceability of fire trails/vehicular tracks and/or stream crossings.

Metropolitan Coal will document the assessment of potential environmental consequences in the Land Management Plan – Subsidence Impact Register Assessment Form.

8.4.2 Steep Slopes and Land in General

In accordance with the Longwalls 305-307 Land Management Plan, visual inspections for subsidence impacts on steep slopes and land in general within 600 m of Longwalls 20-27 and Longwalls 301-307 extraction will be conducted by Metropolitan Coal and its contractors during catchment visits, sampling and routine works conducted in the catchment.

In the event subsidence impacts are identified within 600 m of Longwalls 20-27 or Longwalls 301-304 (that were not previously recorded during the mining of Longwalls 20-27 or Longwalls 301-304), or within 600 m of Longwalls 305-307, the following details will be noted and/or photographed:

- the location, approximate dimensions (length, width and depth), and orientation of surface tension cracks;
- the location of the surface tension crack in relation to fire trails or vehicular tracks;
- the location and approximate dimensions of rock falls (e.g. rock ledges);
- whether any actions are required (for example, implementation of appropriate safety controls, review of public safety etc.); and
- any other relevant information.

The date of the observation, details of the observer and the location of longwall extraction will also be documented. The information obtained will be recorded in the Land Management Plan – Subsidence Impact Register and reported in accordance with the Project Approval conditions.

The information obtained will be used to assess the potential environmental consequences of the subsidence impact on flora, fauna and/or their habitats. Specific details that will be noted and/or photographed to assess the potential environmental consequences of the subsidence impact include:

- any areas of erosion or sedimentation arising from mining activities;
- nature and extent of impacts on potential flora and fauna habitats;
- evidence of impacts on terrestrial fauna (e.g. observed fauna mortality); and

Metropolitan Coal will document the assessment of potential environmental consequences in the Land Management Plan – Subsidence Impact Register Assessment Form.

8.5 AQUATIC BIOTA AND THEIR HABITATS

Metropolitan Coal will assess the subsidence impacts and environmental consequences on surface water resources and watercourses (aquatic habitats) in accordance with the Metropolitan Coal Longwalls 305-307 Water Management Plan (Figure 3 and Section 6).

As indicated in Section 7.4, no additional aquatic ecology monitoring sites have been established in relation to Longwalls 301-303, 304 or 305-307. Existing monitoring Locations ET2 on the Eastern Tributary and WT5 on the Waratah Rivulet are situated within 600 m of Longwalls 305-307 (Figure 13).

Consistent with the Project EA, the aquatic ecology monitoring programs previously established for Longwalls 20-22 and Longwalls 23-27 were designed to:

- monitor subsidence-induced impacts on aquatic ecology (stream monitoring); and
- monitor the response of aquatic ecosystems to the implementation of future potential stream remediation works (pool monitoring).

The design of the monitoring programs uses a “Beyond BACI” experimental design and focuses on representative sampling within streams and pools in mining areas and in suitable control streams and pools (i.e. not subject to mine subsidence).

The aquatic ecology monitoring programs include the monitoring of aquatic habitat characteristics, water quality, macroinvertebrates and aquatic macrophytes. Observations of surface cracking, iron staining and gas releases will also be made during the conduct of the aquatic ecology surveys.

Stream Monitoring

Monitoring of aquatic biota will continue to be conducted (if sufficient aquatic habitat is available for sampling) at two sampling sites (approximately 100 m long) at the following stream sampling locations:

- Location WT3 on Waratah Rivulet and Locations ET1, ET3 and ET4 on the Eastern Tributary overlying Longwalls 20-27.
- Location WT4 on Waratah Rivulet adjacent to Longwalls 20-27.
- Location WT5 on Waratah Rivulet and Location ET2 on the Eastern Tributary, downstream of Longwalls 20-27.
- Control Locations: WR1 on Woronora River and OC on O’Hares Creek.

The approximate locations of the sampling sites are shown on Figure 13.

Monitoring of the sampling sites on the Waratah Rivulet, Eastern Tributary, Woronora River and O'Hares Creek will be conducted biannually in spring (15 September to 15 December) and autumn (15 March to 15 June), consistent with the timing required by the AUSRIVAS protocol.

The monitoring parameters and methods are described in Table 4 (in Section 4.3.3).

Table 19 in Section 8.7 details the data analysis that will be conducted to assess the monitoring results against the aquatic ecology performance indicator:

> *The aquatic macroinvertebrate and macrophyte assemblages in streams are not expected to experience long-term impacts as a result of mine subsidence.*

Pool Monitoring

As described in Section 4.3.3, Pools ETAG, ETAH, ETAI and ETAK on the Eastern Tributary monitored by the previous pool monitoring program were impacted by mine subsidence in late 2016 or early 2017. Since that time, Pools ETAG, ETAH, ETAI and ETAK have often been dry or contained insufficient aquatic habitat for sampling as a result of the mine subsidence impacts. As described in Section 9.1, Metropolitan Coal will conduct stream remediation activities on the Eastern Tributary in accordance with the Metropolitan Coal Stream Remediation Plan.

Monitoring of Pools ETAG and ETAH will recommence subsequent to the conduct of stream remediation activities at Pool ETAH and will be conducted bi-annually[48]. Monitoring of Pools ETAI and ETAK will recommence subsequent to the conduct of stream remediation activities at Pool ETAK and will be conducted bi-annually[49]. The sampling of pools will be conducted consistent with the parameters and methods described for pool monitoring in Section 4.3.3, in spring (15 September to 15 December) and autumn (15 March to 15 June).

The relevant control pools on the Woronora River (larger Pool WP and/or smaller Pools WP-A, WP-B and WP-C) and O'Hares Creek (larger Pool OC and/or smaller Pools OC-A, OC-B and OC-C) will be monitored bi-annually when sampling of the pools described above recommences.

8.6 TERRESTRIAL FAUNA AND THEIR HABITATS

Terrestrial fauna habitats (upland swamps, riparian vegetation, slopes and ridgetops, and aquatic habitats/streams) will be monitored as described in Sections 8.1 to 8.5, respectively. Observations of any surface cracking and loss of flow in streams will also be noted at amphibian monitoring sites during the conduct of the amphibian surveys.

Amphibians were selected as the appropriate representative of terrestrial vertebrate fauna because they are widespread across the study area, including three threatened species that are sensitive to changes in surface hydrology, and because this group is represented by at least 14 species that appear to have viable populations.

The objective of the monitoring programs is to determine if longwall mining adversely impacts amphibian species as expressed in the null hypothesis:

> *The amphibian assemblage is not expected to experience changes significantly different to the amphibian assemblage at control sites.*

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48 Monitoring will commence after the first stream remediation campaign at Pool ETAH has been completed (i.e. once the stream remediation activities have moved from the site).

49 Monitoring will commence after the first stream remediation campaign at Pool ETAK has been conducted (i.e. once the stream remediation activities have moved from the site).

The Longwalls 20-22, 23-27 and 301-303 amphibian monitoring programs described in Section 4.3.4.1 will continue during the mining of Longwalls 305-307 to monitor amphibian species, with a focus on the habitats of the Giant Burrowing Frog, Red-crowned Toadlet and Littlejohn's Tree Frog associated with tributaries.

The Longwalls 20-22 amphibian monitoring program includes six test sites (sites 1 to 6) and six control sites (sites 7 to 12), the Longwalls 23-27 amphibian monitoring program includes five test sites (sites 13 to 17) and five control sites (sites 18 to 22) and the Longwalls 301-303 amphibian monitoring program includes six test sites (sites 23 to 28). The approximate locations of the monitoring sites are shown on Figure 14. No additional amphibian monitoring sites were established for Longwall 304.

The Longwalls 305-307 amphibian monitoring program includes two test sites (sites 29 and 30) proximal to Longwalls 305-307. No additional control sites are required for Longwalls 305-307 to ensure a continually robust experimental design.

A total of 30 amphibian survey sites have been established for Longwalls 20-307 (including 19 test sites overlying or adjacent to longwalls) to monitor amphibian species, with a focus on the habitats of the Giant Burrowing Frog, Red-crowned Toadlet and Littlejohn's Tree Frog.

The monitoring sites will be surveyed annually in spring/summer (i.e. October to February) during suitable weather conditions. As described in Section 4.3.4, occasionally the survey period has been extended to early autumn, because of lack of rain in the spring/summer period. It is possible that future survey periods are also delayed to coincide with suitable weather conditions.

Each site will be surveyed once during a standard one hour general area day search (early morning and late afternoon) supplemented by an evening 60 minute search/playback session using hand held spotlights and head lamps.

Species will be assigned to the following relative abundance categories for tadpole and adult stages:

- 0 = no sightings;
- 1 = one sighting of adult or tadpole stage;
- UC = uncommon (i.e. 2 to 10 individuals), adult or tadpole stage;
- MC = moderately common (i.e. 11 to 20 individuals), adult or tadpole stage;
- C = common (i.e. 21 to 40 individuals), adult or tadpole stage; and
- A = abundant (>40 individuals), adult or tadpole stage.

Poisson regression analysis will be used to analyse the amphibian survey results. Table 20 in Section 8.7 details the data analysis that will be conducted to assess the monitoring results against the amphibian performance indicator, *The amphibian assemblage is not expected to experience changes significantly different to the amphibian assemblage at control sites.*

8.7 TRIGGER ACTION RESPONSE PLANS AND ASSESSMENT AGAINST PERFORMANCE INDICATORS AND MEASURES

The results of the monitoring program described in Sections 8.1 to 8.6 will be used to assess the Project against the performance indicators and performance measures using the TARPs detailed in Tables 16 to 20.

If data analysis indicates a biodiversity performance indicator has been exceeded, an assessment will be made against the biodiversity performance measure and the need for management measures will be considered (Section 9).

The key assessment considerations that will be taken into account when assessing the biodiversity performance measure are outlined in Table 21. Threatened species, populations and ecological communities include those listed under the BC Act, EPBC Act or *Fisheries Management Act, 1994* at the time of Project Approval (i.e. the lists current as at 22 June 2009).

If the biodiversity performance measure is considered likely to have been exceeded, the Contingency Plan will be implemented (Section 10). Metropolitan Coal will implement suitable contingency measures (Section 10) and continue to monitor (Section 8).

Table 16
Trigger Action Response Plan – Upland Swamp Vegetation Monitoring

Performance Measure	Performance Indicator	Monitoring Sites	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers		Action/Response
Negligible impact on Threatened Species, Populations, or Ecological Communities	*The vegetation in upland swamps is not expected to experience changes significantly different to vegetation in control swamps*	• Swamps 16, 17, 18, 20, 24 and 25 overlying or adjacent to Longwalls (LW) 20-22. • Swamps 19, 28, 30, 31, 32, 33, 34, 35, 36 and 94 overlying or adjacent to LW23-27. • Swamps 40, 41, 47, 48, 49, 50, 53 and 58 overlying or adjacent to LW301-303 and Longwall 304. • Swamp 72 within the 35° angle of draw and/or predicted 20 mm subsidence contour of LW305-307. • Control Swamps 101, 111a, 125, 135, 136, 137a, 137b, 138, Bee Creek Swamp, Woronora River 1, Woronora River south arm and Dahlia Swamp.	• Visual inspections[1]. • Transect/ quadrat data[2]. • Population monitoring of indicator species[3].	Biannually, in autumn and spring.	• Visual assessment of changes in the condition of the swamps over time. • Qualitative analysis of collected vegetation data. • Statistical analysis of species diversity (e.g. ANOVA[4] or cluster analysis[5]). • Qualitative analysis of proportions of plants surviving, and differences in health and reproduction ratings over time and relative to control swamps.	• Subjective nature of visual observations and qualitative analysis. • Statistical significance levels. Significant = $P < 0.05$	• LW20-22 swamps, as detailed in the LW20-22 vegetation monitoring report for the spring 2008 to autumn 2010 surveys[6]. • LW23-27 swamps, as detailed in the LW23-27 vegetation monitoring report for the spring 2010 to spring 2013 surveys[7]. • LW301-303 swamps, as detailed in the LW301-303 vegetation monitoring report for the spring 2015 to autumn 2017 surveys[8]. • LW304 Swamps 48 and 50, spring 2015 to autumn 2019 surveys. Other swamps visually inspected as detailed in the LW301-303 vegetation monitoring reports. • Visual monitoring in LW305-307 Swamp 72 to commence in spring 2019.	Level 1	Data analysis indicates: - there is not a declining trend in the condition of longwall swamp vegetation; and - there are no significant changes in vegetation between the mined and control swamps.	Continue monitoring. Six monthly reporting.
								Level 2	Data analysis indicates: - there is a declining trend in the condition of longwall swamp vegetation over time, however a similar trend is occurring in control swamp vegetation; or - there are significant differences in vegetation between the mined and control swamps, however, the data indicates longwall swamp vegetation is consistent with the baseline monitoring results.	Consider swamp groundwater monitoring data. Six monthly reporting.
								Level 3	Data analysis indicates: - there is a declining trend in the condition of longwall swamp vegetation over time that is not occurring in control swamp vegetation; or - there are significant differences in vegetation between the mined and control swamps, and the data indicates longwall swamp vegetation is not consistent with the baseline monitoring results.	Consider swamp groundwater monitoring data. Initiate assessment against the performance measure[9]. Consider the need for management measures, in accordance with Sections 8 and 9.

[1] Visual inspections will be conducted in all swamps listed under 'Monitoring Sites' in this table, as well as Swamp 46, Swamp 51/52 and Swamps 69, 70, 71a and 71b which were subject to WaterNSW hazard reduction burns. Not subject to TARP.

[2] Transect/quadrat monitoring will continue to be conducted in Swamps 16, 17, 18, 20, 24 and 25 overlying Longwalls 20-22, Swamps 28, 30, 33, 35 and 94 overlying or adjacent to Longwalls 23-27, Swamps 40, 41, 46, 51/52 and 53 over Longwalls 301-303, Swamps 48 and 50 over or adjacent to Longwall 304 and in control swamps. Transect/quadrat monitoring will be conducted in Swamp 71a within the 35° angle of draw and/or predicted 20 mm subsidence contour of Longwalls 305-307. Swamp 71a, subject to hazard reduction burns is not subject to TARP.

[3] Indicator species monitoring will continue to be conducted in Swamps 18, 20, 24 and 25 overlying Longwalls 20-22, Swamps 19, 28, 30, 33, 35 and 94 overlying or adjacent to Longwalls 23-27, Swamps 40 and 53 over Longwalls 301-303, and in control swamps.

[4] In general, the purpose of ANOVA is to test for significant differences between means.

[5] The term cluster analysis encompasses a number of different algorithms and methods for grouping objects of similar kind into respective categories.

[6] Eco Logical Australia (2010) *Metropolitan Coal Vegetation Monitoring Longwalls 20-22 - Baseline Data*. Report prepared for Metropolitan Coal.

[7] Eco Logical Australia (2013) *Metropolitan Coal Vegetation Monitoring Longwalls 23-27 - Baseline data*. Report prepared for Metropolitan Coal.

[8] Eco Logical Australia (2018) *Metropolitan Coal Vegetation Monitoring Longwalls 301-303 - Baseline data*. Report prepared for Metropolitan Coal.

[9] Threatened species, populations and ecological communities include those listed under the BC Act, EPBC Act or Fisheries Management Act at the time of Project Approval (i.e. the lists current as at 22 June 2009).

Table 17
Trigger Action Response Plan – Upland Swamp Groundwater Monitoring

Performance Measure	Performance Indicator	Monitoring Sites	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers[2, 3]		Action/Response
Negligible impact on Threatened Species, Populations, or Ecological Communities	*Surface cracking within upland swamps resulting from mine subsidence is not expected to result in measurable changes to swamp groundwater levels when compared to control swamps or seasonal variations in water levels experienced by upland swamps prior to mining*[1]	• Swamp 25 overlying Longwalls (LW) 20-22. • Swamps 30, 33 and 35 overlying LW23-27. • Swamps 40, 41, 46, 51, 52 and 53 overlying LW301-303. • Swamp 50 overlying LW304. • Swamps 71a and 72 within the 35° angle of draw and/or predicted 20 mm subsidence contour of LW305-307. • Control Swamps 101, 137a and 137b.	Groundwater levels.	Continuous water level monitoring with data logger, downloaded monthly.	Analysis of swamp substrate groundwater levels, six monthly, within one month of download.	Data logger precision and download error.	<u>LW20-27 Swamps</u> • Swamp 25, 5th percentile of substrate water levels = 270.7 m AHD • Swamp 30, 5th percentile of substrate water levels = 235.3 m AHD • Swamp 33, 5th percentile of substrate water levels = 240.5 m AHD • Swamp 35 substrate water levels two standard deviations below the mean = 255.0 m AHD <u>LW301-303 Swamps</u> • Swamp 40, baseline minimum substrate water level = 230.38 m AHD • Swamp 41, baseline minimum substrate water level = 277.71 m AHD • Swamp 46, baseline minimum substrate water level = 280.64 m AHD • Swamp 51, baseline minimum substrate water level = 273.18 m AHD • Swamp 52, baseline minimum substrate water level = 281.73 m AHD • Swamp 53, baseline minimum substrate water level = 293.0 m AHD <u>LW304 Swamps</u> • Swamp 50, baseline minimum substrate water level = 265.59 m AHD <u>LW305-307 Swamps</u> • Swamp 71a and Swamp 72 baseline minimum substrate water levels to be determined[2]	Level 1	Data analysis for LW20-27 swamps indicates: - the seven day moving average for Swamps 25, 30 and 33 is within the 5th percentile established for the swamp's full length of record; and - the seven day moving average for Swamp 35 is within two standard deviations below the mean established for the swamp's full length of record. Data analysis for Longwalls 301-307 swamps indicates: - the seven day moving average for Swamps 40, 41, 46, 50, 51, 52, 53, 71a and 72 is at or above the minimum established for the swamp's full length of record.	Continue monitoring. Six monthly reporting.
								Level 2	Data analysis for LW20-27 swamps indicates: - the seven day moving average for Swamps 25, 30 and 33 is below the 5th percentile established for the swamp's full length of record; - the seven day moving average for Swamp 35 lie outside two standard deviations below the mean established for the swamp's full length of record; and - semi-quantitative comparisons with control swamps and rainfall record indicates that dry swamp conditions are natural. Data analysis for LW301-307 swamps indicates: - the seven day moving average for Swamps 40, 41, 46, 50, 51, 52, 53, 71a and 72 is below the minimum established for the swamp's full length of record; and - semi-quantitative comparisons with control swamps and rainfall record indicates that dry swamp conditions are natural.	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	Data analysis for LW20-27 swamps indicates: - the seven day moving average for Swamps 25, 30 and 33 is below the 5th percentile established for the swamp's full length of record; - the seven day moving average for Swamp 35 lie outside two standard deviations below the mean established for the swamp's full length of record; and - semi-quantitative comparisons with control swamps and rainfall record indicates that dry swamp conditions are not natural. Data analysis for LW301-307 swamps indicates: - the seven day moving average for Swamps 40, 41, 46, 50, 51, 52, 53, 71a and 72 is below the minimum established for the swamp's full length of record; and - semi-quantitative comparisons with control swamps and rainfall record indicates that dry swamp conditions are not natural.	Increase the frequency of data analysis to quarterly (until such time that data analysis indicates a return to Level 1). Initiate assessment against the performance measure for threatened species. Consider the need for management measures, in accordance with Sections 8 and 9.

[1] This performance indicator has been exceeded at Swamp 20 since 2012 and at Swamp 28 since 2016. Swamp water levels at Swamp 20 and Swamp 28 will continue to be analysed on a six monthly basis and assessments against the performance measure will be conducted annually.

[2] The 'full length of record' relates to the groundwater swamp substrate dataset for Longwalls 20-22 swamps to 31 May 2012, for Longwalls 23-27 swamps to 30 June 2014, for Longwalls 301-303 swamps to 30 June 2017 and for Longwall 304 Swamp 50 to 30 July 2019. The full length of record for Longwalls 305-307 swamps will be determined prior to subsidence effects occurring at these swamps.

[3] Consistent with the OEH (2016) *Addendum to NSW Biodiversity Offsets Policy for Major Projects: Upland swamps impacted by longwall mining subsidence*, the Level 2 and 3 triggers include semi-quantitative analysis of swamp substrate groundwater levels in comparison to control swamps. The semi-quantitative analysis includes analysis of the rate of recession from high to low water levels and analysis of rates of recovery from low to high water levels, compared to control swamps. The TARP method complies with the tenor of the OEH (2016) proposed analysis of recession rates.

Table 18
Trigger Action Response Plan – Riparian Vegetation Monitoring

Performance Measure	Performance Indicator	Monitoring Sites	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers		Action/Response
Negligible impact on Threatened Species, Populations, or Ecological Communities	*Impacts to riparian vegetation are expected to be localised and limited in extent, similar to the impacts previously experienced at Metropolitan Coal*	Locations adjacent to riparian vegetation monitoring sites (MRIP01 to MRIP12) and areas traversed whilst accessing the monitoring sites: • sites MRIP01, MRIP02, MRIP05, MRIP06 and MRIP09 overlying Longwalls (LW) 20-22; • sites MRIP11 and MRIP12 overlying LW23-27; • sites MRIP03, MRIP04 and MRIP10 downstream of LW23A; and • sites MRIP07 and MRIP08 downstream of LW23-27.	The extent of vegetation subject to vegetation dieback.	Biannually, in autumn and spring.	Assessment of the extent of riparian vegetation dieback.	Subjective nature of visual observations.	No dieback of riparian vegetation prior to the commencement of LW20 as a result of mining. Dieback of riparian vegetation greater than 50 cm from the stream identified at site MRIP02 on the Waratah Rivulet and between sites MRIP05 and MRIP09 on the Eastern Tributary as a result of mine subsidence up to and including the autumn 2018 survey.	Level 1	No dieback of riparian vegetation as a result of mine subsidence.	Continue monitoring. Six monthly reporting.
								Level 2	Vegetation monitoring: - does not identify an increase in the extent of vegetation dieback at site MRIP02 on the Waratah Rivulet and between sites MRIP05 and MRIP09 on the Eastern Tributary compared to that observed up to and including the autumn 2018 vegetation survey; and - does not identify vegetation dieback greater than 50 cm from the stream at sites MRIP01, MRIP03, MRIP04, MRIP06, MRIP07, MRIP08, MRIP10, MRIP11 or MRIP12, as a result of mine subsidence.	Consider recent stream features mapping results and pool water level monitoring data. Consider extent of erosion associated with areas of vegetation dieback and whether management measures are required. Six monthly reporting.
								Level 3	Vegetation monitoring: - identifies an increase in the extent of vegetation dieback at site MRIP02 on the Waratah Rivulet and between sites MRIP05 and MRIP09 on the Eastern Tributary compared to that observed up to and including the autumn 2018 vegetation survey; and - identifies vegetation dieback greater than 50 cm from the stream at sites MRIP01, MRIP03, MRIP04, MRIP06, MRIP07, MRIP08, MRIP10, MRIP11 or MRIP12, as a result of mine subsidence.	Consider recent stream features mapping results and pool water level monitoring data. Initiate assessment against the performance measure[1]. Consider the need for management measures, in accordance with Sections 8 and 9.

[1] Threatened species, populations and ecological communities include those listed under the BC Act, EPBC Act or Fisheries Management Act at the time of Project Approval (i.e. the lists current as at 22 June 2009).

Table 19
Trigger Action Response Plan – Monitoring of Aquatic Biota, Stream Monitoring

Performance Measure	Performance Indicator	Monitoring Sites	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers		Action/Response
Negligible impact on Threatened Species, Populations, or Ecological Communities	*The aquatic macroinvertebrate and macrophyte assemblages in streams are not expected to experience long-term impacts as a result of mine subsidence.*	Two sampling sites (approximately 100 m in length) at the following locations: • Location WT3 on Waratah Rivulet and Locations ET1, ET3 and ET4 on the Eastern Tributary overlying Longwalls (LW) 20-27. • Location WT4 on Waratah Rivulet adjacent to LW20-27. • Location WT5 on the Waratah Rivulet and Location ET2 on the Eastern Tributary, downstream of LW20-27. • Control Locations: WR1 on Woronora River; and OC on O'Hares Creek.	• Aquatic macroinvertebrates. • Aquatic macrophytes.	Biannually, in autumn and spring.	• Analysis of macroinvertebrate and macrophyte multivariate[1] and univariate[2] data using PERMANOVA to test the null hypothesis of no significant change in relation to control places, bi-annually following completion of survey.	Statistical significance levels. Significant = $P < 0.05$	• LW20-22 stream sites, as detailed in the LW20-22 aquatic ecology monitoring reports for the spring 2008 to autumn 2010 surveys[3]. • LW23-27 stream sites, as detailed in the LW23-27 aquatic ecology monitoring reports for the spring 2009 to spring 2013 surveys[4].	Level 1	Data analysis indicates no significant changes in relation to control places pre-mining[6] compared to post-extraction[7] occur in the aquatic macroinvertebrate and/or macrophyte assemblages at Locations WT3, WT4 or WT5 on the Waratah Rivulet or Locations ET1, ET2, ET3 or ET4 on the Eastern Tributary during the mining of LW305-307.	Continue monitoring. Six monthly reporting.
								Level 2	Data analysis indicates significant (not long-term[8]), changes in relation to control places pre-mining[6] compared to post-extraction[7] occur in the aquatic macroinvertebrate and/or macrophyte assemblages at Locations WT3, WT4 or WT5 on the Waratah Rivulet or Locations ET1, ET2, ET3 or ET4 on the Eastern Tributary during the mining of LW305-307.	Consider recent stream features mapping results and pool water level monitoring data. Consider status/progress of stream remediation activities. Six monthly reporting.
								Level 3	Data analysis indicates significant long-term changes[8] in relation to control places pre-mining[6] compared to post-extraction[7] occur in the aquatic macroinvertebrate and/or macrophyte assemblages at Locations WT3, WT4 or WT5 on the Waratah Rivulet or Locations ET1, ET2, ET3 or ET4 on the Eastern Tributary during the mining of LW305-307.	Initiate assessment against the performance measure[9]. Consider the need for management measures, in accordance with Sections 8 and 9.

1 Multivariate Analysis: comparisons of two (or more) samples based on the degree to which these samples share particular species, at comparable levels of abundance.

2 Univariate Analysis: comparison of individual variables (e.g. total number of taxa, total abundance, abundances of individual taxa).

3 Cummins, S. P., Roberts, D. E. (2009a; 2009b; 2010a; 2010b). Aquatic Ecology Monitoring: Metropolitan Coal Longwalls 20-22 Spring 2008 to Autumn 2010 Survey Reports. Prepared for Metropolitan Coal Pty Ltd. BIO-ANALYSIS: Marine, Estuarine & Freshwater Ecology.

4 Cummins, S. P., Roberts, D. E. (2010a; 2010b; 2011; 2012a; 2012b; 2012c; 2013a; 2013b, 2014). Aquatic Ecology Monitoring: Metropolitan Coal Longwalls 23-27 Spring 2009 to Spring 2013 Survey Reports. Prepared for Metropolitan Coal Pty Ltd. BIO-ANALYSIS: Marine, Estuarine & Freshwater Ecology.

6 Pre-mining data is as follows: sites WT3 and ET1 (spring 2008 to autumn 2010); site ET3 (spring 2009 to autumn 2010); site ET4 (spring 2009 to spring 2013); site ET2 (will be assessed for two periods: spring 2008 to autumn 2010 [i.e. pre-mining of Longwalls 20-22] and spring 2009 to spring 2013 [i.e. pre-mining of Longwalls 23-27]).

7 Post-extraction data is represented as follows: sites WT3 and ET1 (from spring 2010 on); site ET3 (from spring 2010 on); site ET4 (from autumn 2014 on); site ET2 (will be assessed for two periods: spring 2010 on [Longwalls 20-22] and autumn 2014 on [Longwalls 23-27]).

8 Long-term changes to the macroinvertebrate and macrophyte assemblages are considered to be significant changes that are persistent (over time) and resulting from mining.

9 Threatened species, populations and ecological communities include those listed under the BC Act, EPBC Act or Fisheries Management Act at the time of Project Approval (i.e. the lists current as at 22 June 2009).

Table 20
Trigger Action Response Plan – Amphibian Monitoring

Performance Measure	Performance Indicator	Monitoring Sites	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers		Action/Response
Negligible impact on Threatened Species, Populations, or Ecological Communities	*The amphibian assemblage is not expected to experience changes significantly different to the amphibian assemblage at control sites.*	• Test sites 1 to 6 overlying Longwalls (LW) 20-22. • Test sites 13 to 17 overlying LW23-27. • Test sites 23 to 28 overlying LW301-303. • Test sites 29 and 30 overlying LW305-307. • Control sites 7 to 12 and 18 to 22.	• Amphibian species diversity and relative abundance.	Annually in spring/summer	Analysis using Poisson regression[1] analysis to determine if the null hypothesis remains intact, following completion of survey.	The Poisson analysis can determine impacts on the amphibian assemblage at the 95% confidence level.	• LW20-22 amphibian sites, as detailed in the spring/summer 2009 LW20-22 amphibian monitoring report[2]. • LW23-27 amphibian sites, as detailed in the spring/summer 2010, 2011, 2012 and 2013 LW23-27 amphibian monitoring reports[3]. • LW301-303 amphibian sites, as detailed in the LW301-303 amphibian monitoring reports for the spring/summer 2015 and spring/summer 2016 surveys[4]. • LW305-307 amphibian sites data obtained in spring/summer 2018[5].	Level 1	Data analysis does not identify a significant change in the amphibian population.	Continue monitoring. Six monthly reporting.
								Level 2	Data analysis identifies a significant change in the amphibian population for one survey period.	Investigate whether additional analyses can be conducted in relation to the threatened amphibian species. Six monthly reporting.
								Level 3	Data analysis identifies a significant change in the amphibian population for more than one survey period.	Investigate whether additional analyses can be conducted in relation to the threatened amphibian species. Initiate assessment against the performance measure[6]. Consider the need for management measures, in accordance with Sections 8 and 9.

1 Poisson regression is a generalized linear model form of regression analysis used to model count data and contingency tables.

2 Cenwest Environmental Services (2010) *Metropolitan Coal Longwalls 20-22 Spring/Summer 2009 Amphibian Survey.* Report prepared for Metropolitan Coal.

3 Cenwest Environmental Services (2010; 2011; 2012; 2013) Metropolitan Coal Longwalls 23-27 Spring/Summer 2010 to 2013 Amphibian Survey Reports. Reports prepared for Metropolitan Coal.

4 Cenwest Environmental Services (2015; 2016) Metropolitan Coal Longwalls 301-303 Spring/Summer 2015 to 2016 Amphibian Survey Reports. Reports prepared for Metropolitan Coal.

5 Sites 29 and 30 were established to allow for the collection of two years of baseline data, however this may now not be possible due to the shortening of Longwalls 303 and 304. Longwall 305 is currently scheduled to commence in February 2020. It is noted however that a number of sites have been established in the future mine plan and monitoring of these sites will commence in spring 2019/summer 2020.

6 Threatened species, populations and ecological communities include those listed under the BC Act, EPBC Act or Fisheries Management Act at the time of Project Approval (i.e. the lists current as at 22 June 2009).

Table 21
Key Assessment Considerations for Assessing Negligible Impact on Threatened Species, Populations and Ecological Communities

Negligible Impact on:	Key Assessment Considerations
Threatened species	1. What is the nature of the environmental consequence (e.g. the potential for adverse impacts on upland swamps, riparian vegetation, slopes and ridgetops or aquatic habitats)? 2. What are the potential factors that may have contributed to the environmental consequence (e.g. the degree of subsidence effects, ineffective management measures or prevailing climatic conditions)? 3. Which threatened species have the potential to be impacted? 4. What are the potential impacts on the lifecycle of the potential threatened species (e.g. foraging, breeding/reproduction, nesting, shelter and movement/dispersal)? 5. What are the potential impacts on the habitat of the potential threatened species (e.g. area affected)? 6. Has the habitat connectivity of the threatened species been affected? 7. What actions, if any, are most appropriate to mitigate the impacts and/or to minimise future impacts?
Threatened populations	1. What is the nature of the environmental consequence (e.g. the potential for adverse impacts on upland swamps, riparian vegetation, slopes and ridgetops or aquatic habitats)? 2. What are the potential factors that may have contributed to the environmental consequence (e.g. the degree of subsidence effects, ineffective management measures or prevailing climatic conditions)? 3. Are there any threatened populations that have the potential to be impacted? 4. What are the potential impacts on the lifecycle of the threatened population? 5. What are the potential impacts on the habitat of the threatened population (e.g. area affected)? 6. Has the habitat connectivity of the threatened population been affected? 7. What actions, if any, are most appropriate to mitigate the impacts and/or to minimise future impacts?
Threatened Ecological Communities	1. Can any subsidence impacts (e.g. surface cracking, subsidence-induced erosion) be observed within the occurrence of the Southern Sydney Sheltered Forest on Transitional Sandstone Soils in the Sydney Basin Bioregion EEC situated to the north-east of Longwall 304? 2. If yes, over what area has been affected? 3. What are the potential environmental consequences of the change in subsidence effects? 4. What actions, if any, are most appropriate to mitigate the impacts and/or to minimise future impacts?

8.8 MONITORING PROGRAM REVIEW

Each of the ongoing monitoring programs described in this BMP will be reviewed at the completion of Longwall 305, Longwall 306 and Longwall 307, and thereafter at the completion of each future longwall. The review will include consideration of changes to the monitoring programs, including site locations, parameters measured and the frequency of measurement based on the data obtained to date and the planned future mining activities. Any proposed changes to the monitoring programs will be undertaken in consultation with the BCD and DPI - Fisheries, and to the satisfaction of the DPIE.

9 MANAGEMENT MEASURES

This section describes the management measures that will be implemented to remediate impacts, including subsidence impacts and impacts associated with surface activities in the underground mining area and surrounds. Management measures will be implemented, as appropriate, to comply with the relevant statutory requirements and the subsidence impact performance measure.

Systematic and/or valley related movements associated with the Project have the potential to result in fracturing and dilation of the underlying strata of streams above and immediately adjacent to the longwalls. Cracking and dilation of bedrock may result in the localised diversion of a portion of the surface flow into subterranean flows or leakage from pools. Stream remediation measures required to be implemented on the Waratah Rivulet and Eastern Tributary are described in Section 9.1.

Other potential subsidence impacts and associated management measures such as stream bank erosion, ponding of stream bank vegetation, cliff falls and surface tension cracks, and swamp remediation measures are described in Section 9.2.

Vegetation clearance management measures are described in Section 9.3.1.

Metropolitan Coal personnel and contractors will be required to access the underground mining area and surrounds to conduct a range of surface activities including various monitoring, exploration, construction and remediation/rehabilitation activities. Management measures will be implemented to minimise the potential for impacts of such activities on flora and fauna, and their habitats. These measures are described in Section 9.4.

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).

9.1 STREAM REMEDIATION

In accordance with Condition 1, Schedule 6 of the Project Approval, Metropolitan Coal is required to achieve the rehabilitation objective: *Restore surface flow and pool holding capacity as soon as reasonably practicable* for (Figure 4):

- Waratah Rivulet, between the downstream edge of Flat Rock Swamp and the full supply level of the Woronora Reservoir; and
- Eastern Tributary, between the full supply level of the Woronora Reservoir and the maingate of Longwall 26.

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 (at the time of BMP development) (Figure 5).

As described in Section 6, 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.

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.

Metropolitan Coal will conduct stream remediation works in accordance with the Metropolitan Coal Stream Remediation Plan. The Metropolitan Coal Stream Remediation Plan was approved by the DPIE 1 November 2019, and is included as Appendix 6 of the Metropolitan Coal Water Management Plan.

Section 8.5 describes the monitoring that will be conducted to monitor the response of aquatic biota to the implementation of stream remediation works.

9.2 OTHER SUBSIDENCE IMPACT MANAGEMENT MEASURES

9.2.1 Stream Bank Erosion

Visual inspections (particularly along Waratah Rivulet and the Eastern Tributary) will be conducted to identify any areas subject to excessive erosion and sedimentation. Where visual observations indicate 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.

These management measures will be implemented in accordance with the Metropolitan Coal Longwalls 305-307 Water Management Plan.

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 result in 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.

9.2.2 Vegetation

Potential management measures for impacts on vegetation include the implementation of weed control measures (e.g. mechanical removal or the application of approved herbicides), the planting of endemic plant species and brush matting, should monitoring indicate the need.

Weed management measures in the Woronora Special Area will be conducted in consultation with WaterNSW.

Any active planting program will utilise flora species characteristic of the particular vegetation community in that area and will utilise seed collected from the Woronora Special Area. Consultation will be undertaken with the DPIE and BCD for any proposed revegetation works associated with subsidence impacts (e.g. impacts to riparian vegetation).

To date, brush matting has been used at stream remediation sites in conjunction with locally collected vegetative material to encourage the regeneration of native vegetation.

9.2.3 Cliff Falls

Cliff and overhang sites COH7, COH8, COH9, COH10, COH11, COH12, COH13, COH16 and COH17 will be monitored to record evidence of potential subsidence impacts in accordance with the Metropolitan Coal Longwalls 305-307 Land Management Plan. The monitoring results will be used to assess the potential environmental consequences of the recorded subsidence impact and identify management measures, where appropriate.

In relation to impacts on aquatic or terrestrial flora, fauna, or their habitats, potential management measures include:

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

The implementation of management measures will be considered with regard to the specific circumstances of the subsidence impact (e.g. the location, nature and extent of the impact) and the assessment of the environmental consequences in accordance with the Metropolitan Coal Longwalls 305-307 Land Management Plan.

9.2.4 Surface Tension Cracks

As described in Section 8.4, visual inspections for surface tension cracks will be conducted by Metropolitan Coal and its contractors as part of routine works conducted in the catchment in accordance with the Metropolitan Coal Longwalls 305-307 Land Management Plan.

Metropolitan Coal will use the subsidence impact monitoring results to assess the potential environmental consequences of the recorded subsidence impact, including the nature and extent of impacts on flora and fauna habitats and evidence of impacts on terrestrial fauna (e.g. observed fauna mortality). 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 consequence.

Potential management measures include the permanent filling of the surface tension crack. Consistent with the Metropolitan Coal Longwalls 305-307 Land Management Plan, WaterNSW will be consulted in the event Metropolitan Coal propose to in-fill any surface tension cracks in the Woronora Special Area.

9.2.5 Swamp Remediation Measures

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 DPIE, BCD, WaterNSW, DPI - Fisheries and DRG.

Potential remediation measures for impacts on upland swamps that could be used or are being investigated, include:

- installation of coir log dams (i.e. erosion control structures) at any knick points in a swamp;
- use of surface 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 of rock substrate where fracturing has occurred.

A summary of these techniques is provided below. Installation of the erosion control works can be undertaken promptly as the need arises and installed within a few weeks.

Knick Point Control

Coir log dams can be installed at knick points (e.g. areas of erosion or scour) if detected during monitoring. Coir logs trap sediment by slowing water and allowing particulate matter to settle and for slow repair to occur. A shallow, narrow trench is cut into the swamp soils such that the first layer of coir logs sits on the underlying substrate or the top of the first coir log is at ground level. The coir logs are held in place by wooden stakes and bound together with wire (Good *et al*., unpublished in BHPIC, 2009). The small coir log dams are constructed at intervals down the erosion channel.

Where increased filtering of flows is required, the coir logs can be wrapped in jute fibre matting. Coir log dams have been successfully used during a number of swamp rehabilitation programs in recent years in the Blue Mountains and Snowy Mountains. The soft-engineering materials used eventually degrade (totally biodegradable) and become integrated into the soil/organic matter complex of the swamps (Good *et al*., unpublished in BHPIC, 2009).

Water Spreading

The maintenance of the swamp moisture regime can also be enhanced by additional water spreading techniques, involving long lengths of coir logs and hessian 'sausages' linked together across the contour such that water flow builds up behind them then slowly seeps through the water spreaders (Good *et al*., unpublished in BHPIC, 2009). The logs can be positioned as required within shallow trenches within a swamp. The soft-engineering materials eventually degrades (totally biodegradable) and becomes integrated into the soil/organic matter complex of the swamps (*ibid*.).

Injection Grouting

Where piezometer data indicate that a fracture has developed under a swamp leading to the potential/actual drying of a swamp substrate, then injection grouting to repair the fracture may be a possibility. If the rock fractures are very narrow, then self-healing may occur via transport of sediments. In cases where self-healing cannot occur because of fracture characteristics, then the use of grouting may be a possibility. The major issues are: (1) identifying the location and scale of the rock fracture, (2) injecting grout to seal the fracture network, and (3) implementing (1) and (2) with minimal impacts on the swamp in question. A variety of inert grouts and filler materials can be injected to fill the voids in the fractured strata intercepted by the drill holes, thereby preventing water loss from an impacted swamp.

9.2.6 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.

9.3 SURFACE DISTURBANCE

The Metropolitan Coal Construction Management Plan describes the management measures that will be implemented for surface construction works (excluding remediation or rehabilitation works) in the Woronora Special Area. The Metropolitan Coal Stream Remediation Plan and Metropolitan Coal Rehabilitation Management Plan describe the management measures that will be implemented for remediation and rehabilitation works. Management measures include those described in Sections 9.3.1 and 9.3.2 below.

9.3.1 Vegetation Clearance/Habitat Disturbance

Vegetation clearance activities may be required for ongoing surface exploration activities, the upgrade and extension of surface infrastructure, access tracks, environmental monitoring and management activities, stream restoration activities and other mine-related surface activities.

The environmental management of vegetation clearance sites will include:

- Detailed site inspections to identify the specific flora characteristics of the areas proposed to be disturbed.
- Identification of areas in which specific surface works involving vegetation clearance will be avoided or limited (e.g. within swamps, EECs and areas where threatened flora species are present).
- Final site selection and works design so as to minimise the amount of vegetation clearance required.
- Identification of management measures to minimise impacts on flora, prior to, during and/or following the completion of the surface works including natural regeneration and/or rehabilitation measures.

9.3.2 Weed Management

Weed management will be implemented to limit the spread and colonisation of noxious and environmental weeds, where weeds are found to occur in areas subject to mine-related surface activities.

Weed management will include:

- Limiting activities that cause soil disturbance.
- The inspection of vehicles and mechanical equipment brought to the site to avoid importation of foreign material and organic matter.
- Inspections of mine-related surface disturbance areas to identify areas requiring weed management measures to be implemented.
- Implementation of weed management measures (e.g. mechanical removal and application of approved herbicides in authorised areas). Prior to the use of any chemical controls, the chemicals will be approved by the relevant landholder and the Material Safety Data Sheet for the chemical obtained prior to spraying. The implementation of measures that favour the restoration of native vegetation (where appropriate) is also considered an effective method of weed management.
- Follow-up inspections to assess the effectiveness of the weed management measures implemented and the requirement for any additional management measures.
- Consultation with WaterNSW and other relevant land holders in relation to weed management activities.

The weed management activities will be reported in the Annual Review (Section 12).

9.4 OTHER MANAGEMENT MEASURES

9.4.1 Bushfire Hazard

Fire awareness and fire safety training will be included in the induction of all Metropolitan Coal personnel and contractors required to access the Woronora Special Area to reduce the risk of bushfire.

9.4.2 Introduced Pests

Vegetation clearance associated with the Project (e.g. for access tracks) has the potential to increase the occurrence of vertebrate pest species. In accordance with the Metropolitan Coal Construction Management Plan, surface construction works will occupy only small areas of the surface, will involve minimal clearance and disturbed areas will be allowed to naturally regenerate from the soil seed bank when no longer needed. Active planting may be undertaken in areas where natural regeneration is not considered to be progressing.

Management measures for introduced pests will include:

- Maintenance of a clean, rubbish-free environment in order to discourage scavenging and reduce the potential for colonisation of these areas by non-endemic fauna. Employees and contractors will not be permitted to take domestic pets into the Woronora Special Area.
- Reporting sightings of vertebrate pest species to WaterNSW, and the BCD for inclusion in the Atlas of NSW Wildlife in order for the distribution and abundance of the vertebrate pests to be better understood. This is particularly relevant to Feral Deer.

- Subject to consultation with WaterNSW, implementation of pest control measures where observations indicate the need (e.g. the control of Feral Cats and Foxes, or the destruction of rabbit burrows).
- The inclusion of general vertebrate pest awareness in Metropolitan Coal inductions, particularly for staff and contractors accessing the Woronora Special Area.
- Ongoing consultation with WaterNSW and the BCD in relation to the management of vertebrate pest species.

Pest management activities will be reported in the Annual Review (Section 12).

9.4.3 Infection of Native Plants by *Phytophthora cinnamomi*

Measures for the management of *P. cinnamomi* have been developed in consideration of *Management of Phytophthora cinnamomi for Biodiversity Conservation in Australia* (Commonwealth Department of the Environment and Heritage, 2006). Management measures that will be implemented to minimise the potential for the introduction or spread of *P. cinnamomi* include:

- restricting the movement of vehicles to formed tracks and pre-existing roads, where practicable;
- limiting activities that cause soil disturbance; and
- encouraging natural regeneration in areas requiring revegetation.

Measures that will be implemented in the event infestation areas are identified include:

- limiting access to infestation areas;
- limiting access to un-infested areas following entry to infested sites;
- development of hygiene protocols (e.g. clean footwear, equipment, vehicles and/or hygiene stations) to access known infestation areas; and
- the inclusion of *P. cinnamomi* general awareness and procedure information in Metropolitan Coal personnel and contractor inductions, particularly for those requiring access to identified infestation areas.

9.4.4 Amphibian Chytrid Fungus

Personnel conducting amphibian surveys in the Waratah Rivulet and Woronora River catchments, including movement between these two catchments, will be required to observe the following hygiene protocols in accordance with the *Hygiene Protocols for the Control of Disease in Frogs* (NPWS, 2001):

- The thorough cleaning and disinfecting of footwear.
- The thorough cleaning and disinfecting of equipment (such as nets, callipers, headlamps and waders).
- Restricting the movement of vehicles to formed tracks and pre-existing roads, where practicable.
- In the event the amphibian *Chytrid* fungus is known to be present at a site, that site would be the last site surveyed/sampled, where practicable.

10 CONTINGENCY PLAN

In the event the subsidence impact biodiversity performance measure for threatened species, populations or ecological communities detailed in Section 6 is considered to have been exceeded, Metropolitan Coal will implement the following Contingency Plan:

- the exceedance will be reported to the Technical Services Manager and/or the Environment & Community Superintendent within 24 hours.
- the Technical Services Manager and/or the Environment & Community Superintendent will report the likely exceedance to the General Manager as soon as practicable after becoming aware of the exceedance.
- Metropolitan Coal will report the likely exceedance of the biodiversity performance measure to the DPIE, BCD and DPI – Fisheries 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 include management measures described in this BMP, the Metropolitan Coal Longwalls 305-307 Land Management Plan and Metropolitan Coal Longwalls 305-307 Water Management Plan.

- Metropolitan Coal will submit the proposed course of action to the DPIE for approval.
- Metropolitan Coal will implement the approved course of action to the satisfaction of the DPIE.

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 DPIE if either the contingency measures implemented by Metropolitan Coal have failed to remediate the impact or the Secretary of the DPIE determines that it is not reasonable or feasible to remediate the impact.

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 (i.e. Longwalls 308 on). The collection of baseline data for upland swamps, riparian vegetation, slopes and ridgetops, aquatic biota and their habitats, and terrestrial fauna and their habitats is described in Sections 11.1 to 11.5.

11.1 UPLAND SWAMPS

Vegetation Community Mapping and Swamp Extent

The upland swamps situated to the north or north-west of Longwalls 305-307 (Figure 15) were inspected by Eco Logical to confirm the extent of the upland swamps and the vegetation communities present in July/August 2015 (Swamps 59, 69, 70, 71a and 71b) or July/August 2016 (Swamps 60, 61, 62, 63, 64, 65, 66, 67, 68a, 68b, 72, 73, 133 and 134). This mapping was included in the Longwalls 301-303 BMP.

Upland swamps situated to the west of the Woronora Reservoir overlying or proximal to Longwalls 307-310 (Swamps 81, 82, 83, 84, 86, 88 and 89, Figure 15) were inspected in July 2017 by Eco Logical. This mapping is included in Appendix 2.

Field surveys of the larger headwater Swamps 76, 77, 92 and 106 located to the west of Longwall 310 (Figure 9) were conducted by FloraSearch in February 2016 to confirm the extent of the upland swamps and the vegetation communities present (FloraSearch, 2016c). In June/July 2019 Ecoplanning conducted field surveys to confirm the non-swamp vegetation communities adjacent to the FloraSearch (2016c) upland swamp vegetation community mapping. This revised mapping will be included in the next Extraction Plan (i.e. the revised mapping is not shown on Figures 9 or 15 of this BMP).

Additional upland swamps (Swamps 78, 79, 80, 90 and 91) situated to the west of Longwall 310 (Figure 15) were inspected by Ecoplanning in June/July 2019 to confirm the extent of the upland swamps and the vegetation communities present. This revised mapping will also be included in the next Extraction Plan.

The *NSW Native Vegetation Interim Type Standard* (Sivertsen 2009) requires patches of vegetation to be mapped if the dimensions of the representative polygon on a map sheet are 2 mm x 2 mm or greater (i.e. at a map scale of 1:25,000, patches of vegetation equal to or greater than 0.25 ha). However, the revised swamp vegetation mapping boundaries (including those swamps less than 0.25 ha in area) are shown on Figures 9 and 15 to document the changes to the previous Bangalay Botanical Surveys (2008) vegetation mapping. It is noted that many of the revised swamp boundaries comprising vegetation characteristic of the upland swamp vegetation communities are very small in size and doubtfully represent an upland swamp (Appendix 2). For example, Swamps 61, 63, 65/66, 67, 68a, 73, 83, 86 and 88 are all less than 0.25 ha in area.

Further to the above, Swamp 84 and Swamp 86 are considered to be marginal upland swamps in that they contain non-swamp vegetation more consistent with sandstone woodland (Figure 15 and Appendix 2).

Metropolitan Coal will also assess the logistics/access and suitability of Swamps 62, 78, 79, 80, 81, 82, 89 and 90 for vegetation transect/quadrat monitoring for the next Extraction Plan. Consistent with baseline data collected for the Longwalls 20-22, 23-27, 301-303 and 304 BMP's, the timing for the baseline data in relation to the next Extraction Plan (i.e. Longwalls 308 on) is to ensure that at least two years of baseline data is collected before extraction occurs within 600 m of these swamps.

A program will also be developed to collect baseline vegetation data for the three larger swamps (Swamps 76, 77 and 92) located further to the west by the completion of Longwall 306.

Piezometers and Soil Moisture Probes

Metropolitan Coal installed paired piezometers in Swamps 60, 62, 64, 133 and 134 overlying or proximal to the commencing ends of Longwalls 308 and 309 in October 2018, and will assess the logistics/ access and suitability of installing paired piezometers in Swamps 78, 79, 80, 81, 82, 89 and 90 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 the abovementioned swamps adjacent to paired piezometers. Soil moisture probes will also be installed in control Swamps 101, 137a and 137b.

In early 2019, Metropolitan Coal installed a soil moisture probe adjacent to the swamp substrate piezometer in Swamp 92 (SWAMP3, Figure 9). The data obtained by the soil moisture probe in Swamp 92 will inform selection of the location, depth and type of the soil moisture probes proposed to be installed in the selected swamps.

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.

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 by the completion of Longwall 306.

Swamp Contributions to Catchment Baseflows

As noted in the IEPMC Initial Report, it has been proposed that swamps provide an ecologically important component of base flow to watercourses during dry periods (IESC, 2018; Advisian, 2016).

Metropolitan Coal has investigated the potential to install a small flow measuring flume immediately downstream of Swamp 92, Swamp 77 and Swamp 76 (Figure 9). Based on the initial site investigations, there is potential to install flow measuring flumes immediately downstream of Swamp 92 and Swamp 76. Further investigations are required to be conducted to assess the feasibility of installing a flow measuring flume downstream of Swamp 77. Further investigation and survey of the sites will be conducted prior to the commencement of Longwall 306.

11.2 RIPARIAN VEGETATION

No significant streams (i.e. streams which are third order or higher) are located over Longwalls 308-317. The Waratah Rivulet is located to the south of Longwalls 308-312. Riparian vegetation monitoring data is available for the Waratah Rivulet as described in Section 7.

11.3 SLOPES AND RIDGETOPS

A number of cliff and overhang sites (Figure 10) have been identified by MSEC (2008) adjacent to the Waratah Rivulet and Woronora Reservoir in the vicinity of, or to the south of, Longwalls 308-310.

The detailed baseline information for all cliff and overhang sites identified to date (i.e. COH1, COH2, COH3, COH4, COH5, COH6, COH6A, COH7, COH8, COH9, COH10, COH11, COH12, COH13, COH14, COH15, COH16, and COH17) is included in the Longwalls 305-307 Land Management Plan.

Baseline data obtained for these cliff sites includes:

- photographic records of each cliff and overhang;
- sketches of overhangs; and
- mapping of the approximate location of the cliff/overhang face and the rear extent of the overhang/undercut.

In accordance with the Longwalls 305-307 Land Management Plan, baseline data collection for the next Extraction Plan will also include a description of steep slopes and land in general and a description of the recorded subsidence impacts (i.e. where mining of Longwall 304 or Longwalls 305-307 has resulted in subsidence impacts overlying the next Extraction Plan longwall layout [if any] at the time of Extraction Plan preparation).

11.4 AQUATIC BIOTA AND THEIR HABITATS

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

The results of visual and photographic surveys of the Waratah Rivulet prior to the commencement of Longwall 20, and during the mining of Longwalls 20-27 and Longwalls 301-304 provide information on aquatic habitats. Monitoring of macroinvertebrates and macrophytes has been conducted at sites on the Waratah Rivulet as described in Section 4.3.3.

Hydro Engineering & Consulting (2019b) conducted a visual inspection and photographic survey of the first and second order streams in the vicinity of Longwalls 304-310 (not previously inspected for Longwalls 301-303) in April 2018. The visual inspection and photographic survey report provides information on the aquatic habitats available (Appendix 3). Visual inspection and photographic survey of the larger first order streams located further to the west of the Woronora Reservoir (over Longwalls 313-316) will be conducted in advance of future longwalls.

Metropolitan Coal has investigated the potential to install pool water level meters in:

- the large pool mapped on the lower reaches of the stream that overlies Longwalls 309 to 311, downstream of Swamp 92 (Appendix 3); and
- two of the large pools mapped on the lower reaches of the stream that overlies Longwall 311, downstream of Swamp 77 (Appendix 3).

to monitor predicted impacts on pools/aquatic habitat in advance of future mining.

The pool water level meters were installed on 23 May 2019 (Pool SR1 and Pool SR2) and 3 June 2019 (Pool SP1), respectively, and will provide baseline data for the next Extraction Plan.

11.5 TERRESTRIAL FAUNA AND THEIR HABITATS

Baseline data has been, or will be, collected for terrestrial fauna habitats (i.e. upland swamps, riparian vegetation, slopes and ridgetops, and aquatic habitats), as described in Sections 11.1 to 11.4.

An additional nine amphibian monitoring sites (sites 31 to 39) have been established proximal to Longwalls 310-317 and monitoring will commence in spring 2019/summer 2020. No additional control sites are required to ensure a continually robust experimental design.

A total of 39 amphibian survey sites have been established to date, including 28 test sites overlying or adjacent to longwalls to monitor amphibian species, with a focus on the habitats of the Giant Burrowing Frog, Red-crowned Toadlet and Littlejohn's Tree Frog.

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 BMP 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.

The Annual Review will also review the current monitoring programs, including if and when cessation of some monitoring activities is appropriate.

As described in Section 2, this BMP 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 DPIE and any other relevant agencies of any incident associated with the Project as soon as practicable after Metropolitan Coal becomes aware of the incident. Within seven days of the date of the incident, Metropolitan Coal will provide the Secretary and any relevant agencies with a detailed report on the incident.

14 COMPLAINTS

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

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

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

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

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

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

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

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

15 NON-COMPLIANCES WITH STATUTORY REQUIREMENTS

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

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

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

As described in Section 13, Metropolitan Coal will notify the Secretary of the DPIE 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 DPIE 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 DPIE 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 DPIE.

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

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

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

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

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

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

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

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

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

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

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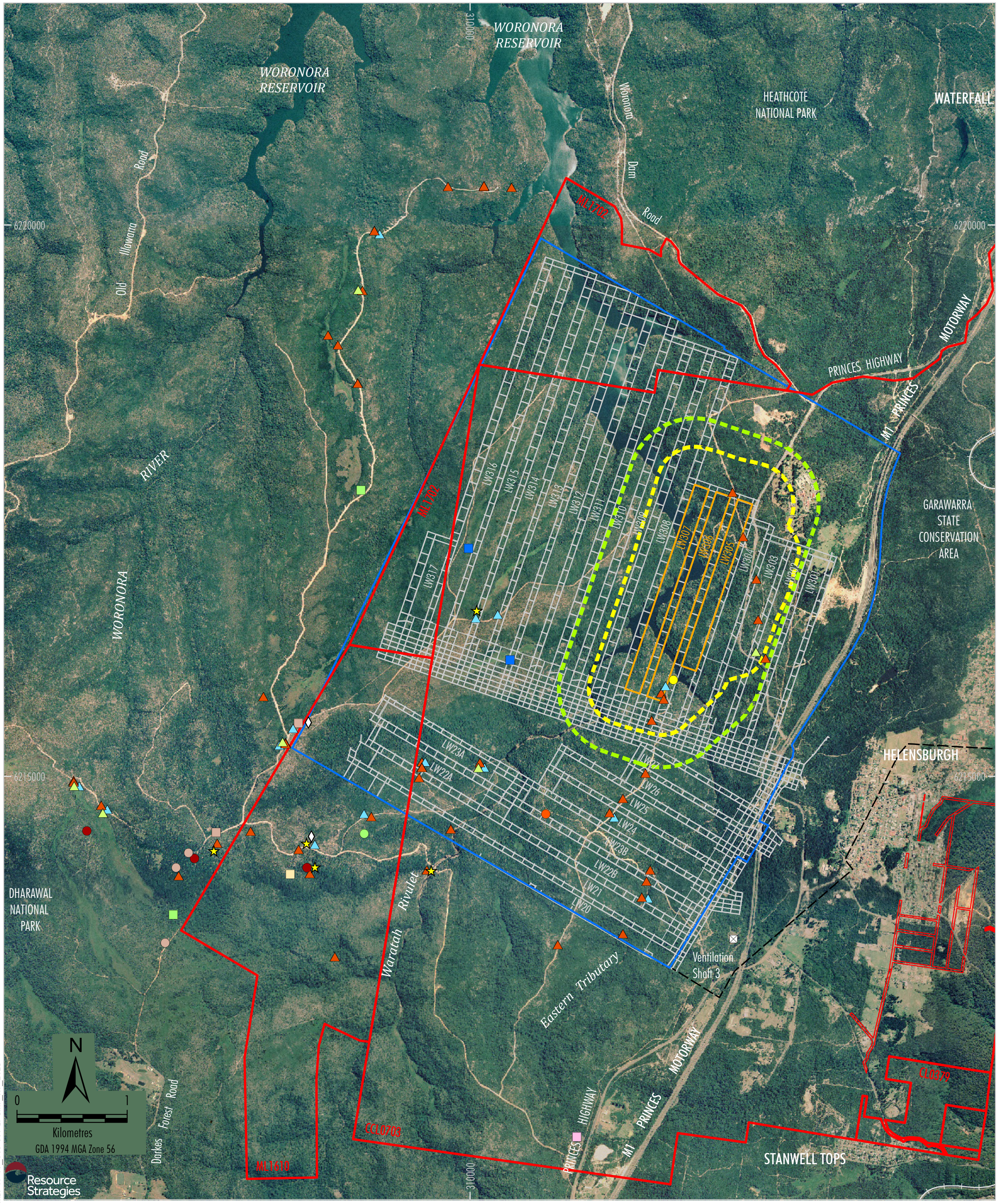
APPENDIX 1

THREATENED FLORA AND FAUNA SPECIES RECORDS



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 305-307 Secondary Extraction
- Longwalls 305-307 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 305-307 Secondary Extraction
- Existing Underground Access Drive (Main Drift)

Threatened Fauna

- Giant Burrowing Frog
- Littlejohn's Tree Frog
- Red-crowned Toadlet
- Grey Falcon
- Square-tailed Kite
- Black-necked Stork
- Eastern Ground Parrot
- Turquoise Parrot
- Grey-headed Flying Fox
- Large-footed Myotis
- Squirrel Glider
- Eastern Pygmy-possum
- Eastern Bentwing Bat
- Broad-headed Snake
- Diggings that could potentially belong to the threatened Southern Brown Bandicoot or Long-nosed Potoroo, or the Protected Long-nosed Bandicoot

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2019); MSEC (2019); Threatened Species recorded by Western Research Institute and Biosphere Environmental Consultants (2008); Cenwest Environmental Services (2008-2019)

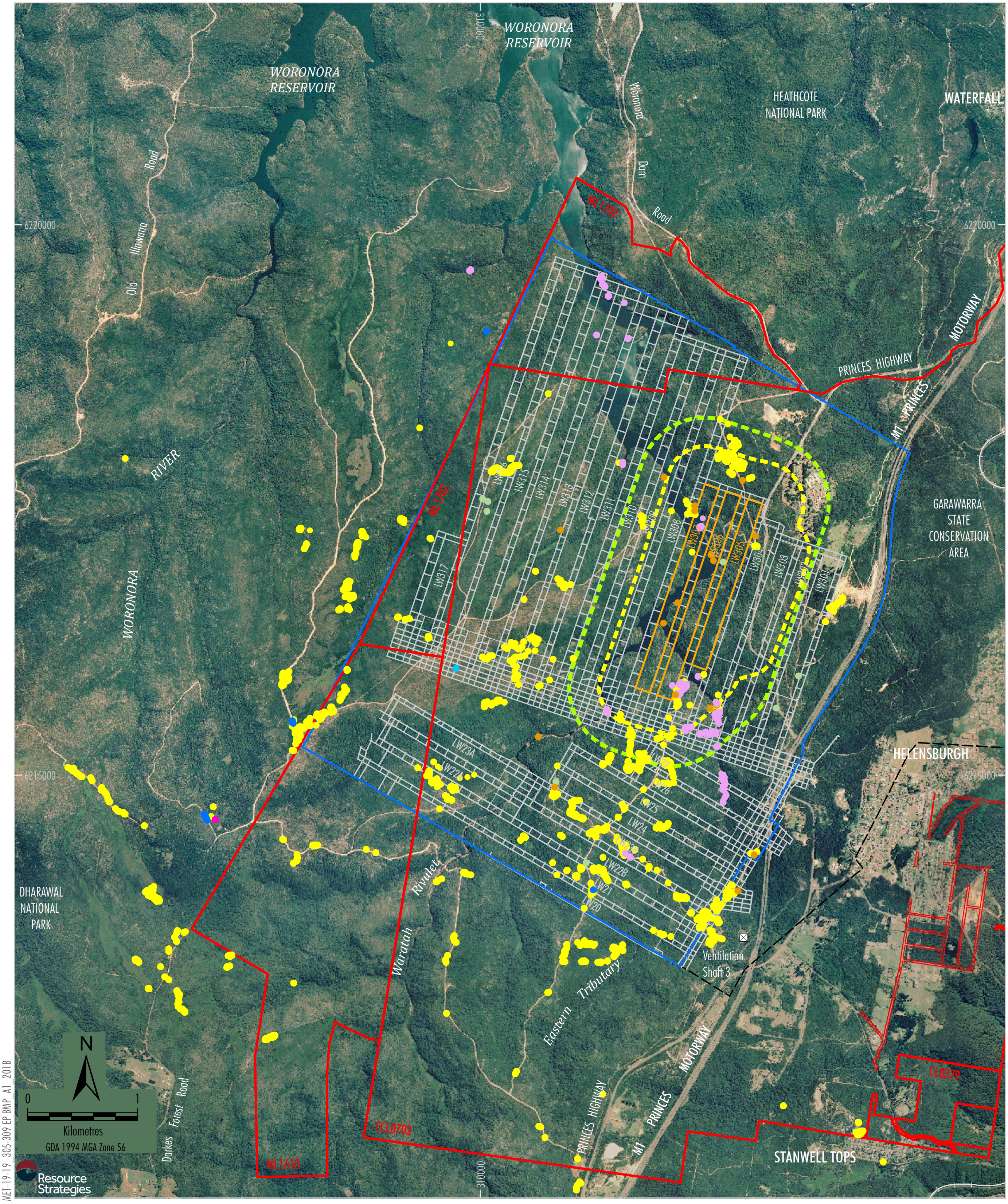
Notes: 1. Includes threatened species records up to March 2019.
2. Each symbol is indicative of a specific location rather than the number of individuals of each species.

Peabody

METROPOLITAN COAL

Threatened Fauna Recorded During Metropolitan Coal Surveys

Figure 1-2



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 305-307 Secondary Extraction
- Longwalls 305-307 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 305-307 Secondary Extraction
- Existing Underground Access Drive (Main Drift)

Confirmed Threatened Species

- *Astrotricha crassifolia*
- *Acacia bynoeana*
- *Acacia baueri* subsp. *aspera*
- *Melaleuca deanei*
- *Pultenaea aristata*
- *Cryptostylis hunteriana*

Potential (Unconfirmed) Threatened Species

- *Epacris purpurascens* var. *purpurascens*
- *Leucopogon exolasius*

Notes 1. Includes threatened species records up to and including the Autumn 2018 surveys.
2. Each symbol is indicative of a specific location rather than the number of individuals of each species.

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2019); MSEC (2019); Threatened species recorded by Bangalay Botanical Surveys (2008); FloraSearch (2008, 2009); Eco Logical (2010-2018)

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METROPOLITAN COAL

Threatened Flora Recorded During Metropolitan Coal Surveys

Figure 1-1

APPENDIX 2

REVISED LONGWALLS 304-310 UPLAND SWAMP VEGETATION MAPPING

Revised Longwalls 304-310 Upland Swamp Vegetation Mapping

Prepared for
Metropolitan Coal

DOCUMENT TRACKING

Item	Detail
Project Name	Longwalls 304-310 Upland Swamp Vegetation Mapping
Project Number	16SUT-4772
Project Manager	Elizabeth Norris (02) 8536 8686 Level 3, Suite 2 668 – 672 Old Princes Highway Sutherland NSW 2232
Prepared by	Brian Towle, Elizabeth Norris and Suzanne Eacott
Reviewed by	Elizabeth Norris
Approved by	Elizabeth Norris
Status	Final
Version Number	2
Last saved on	11 February 2019
Cover photo	Upland swamps overlying Longwalls 304-306, Elizabeth Norris and Brian Towle, July 2016

This report should be cited as 'Eco Logical Australia 2018. *Longwalls 304-310 Upland Swamp Vegetation Mapping*. Prepared for Metropolitan Coal.'

ACKNOWLEDGEMENTS

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Contents

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List of Tables

1 Introduction

Metropolitan Coal was granted approval (08_0149) for the Metropolitan Coal Project in accordance with Section 75J of the *Environmental Planning and Assessment Act, 1979* on 22 June 2009. In accordance with Project Approval Condition 6, Schedule 3, an Extraction Plan is to be prepared for all second workings which includes a Biodiversity Management Plan to manage the potential environmental consequences of the Extraction Plan on aquatic and terrestrial flora and fauna, with a specific focus on swamps. The term ‘swamps’ in this report is used to refer to all vegetation communities identified as forming the Upland Swamps Complex, as described by New South Wales (NSW) National Parks and Wildlife Services (NPWS 2003).

This report has been prepared to update previous vegetation mapping of upland swamps overlying or proximal to Longwalls 304-310, and to inform the preparation of future Biodiversity Management Plans. Specifically, the aims of this report are to:

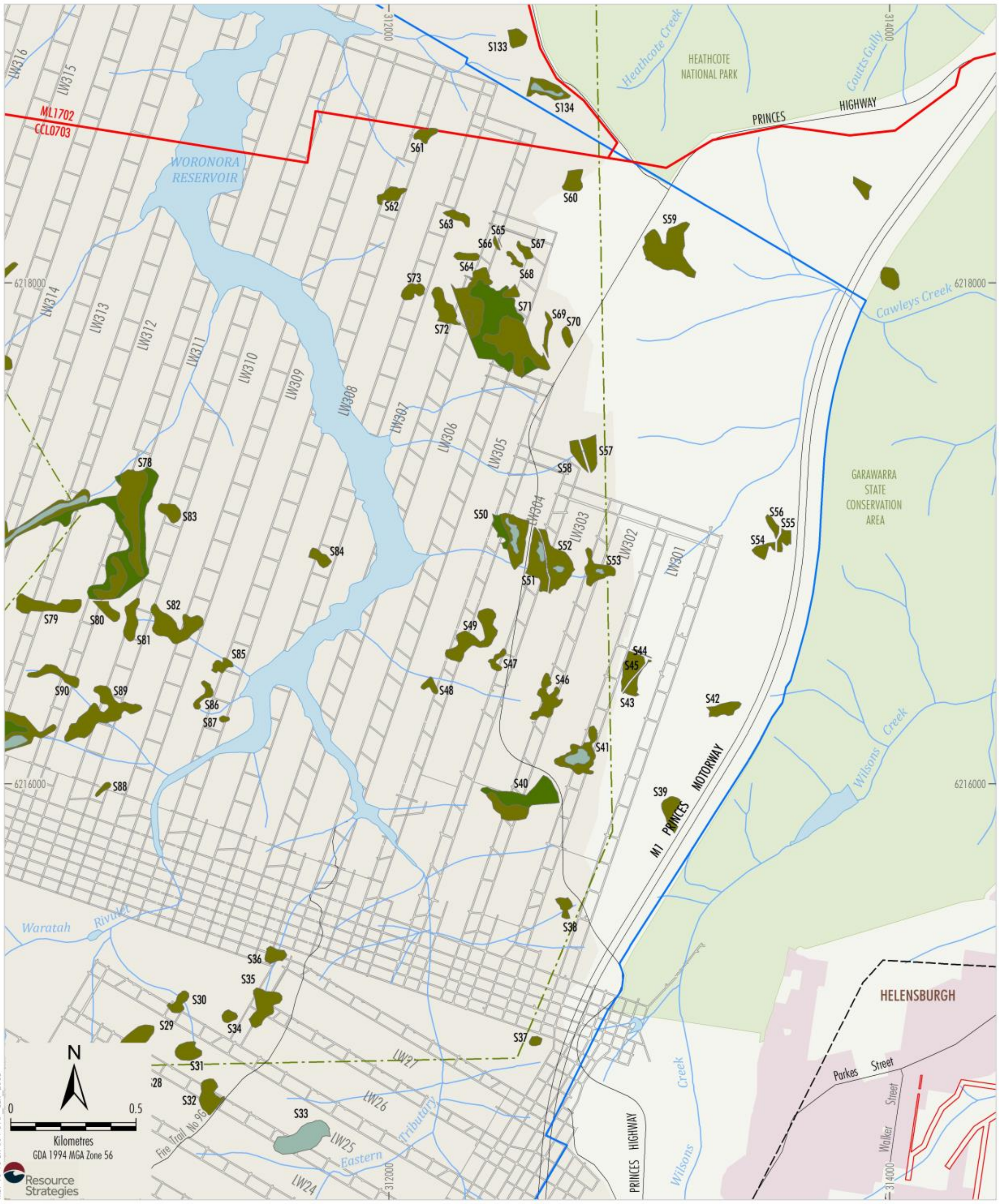
- Validate existing mapping of upland swamp vegetation overlying or proximal to Longwalls 304-310, and where appropriate update vegetation mapping.
- Document any revisions to the existing vegetation mapping.
- Document the vegetation characteristics of each swamp.
- Conduct searches for indicator species within the swamps to inform potential vegetation monitoring.

2 Bangalay Botanical Surveys (2008) Vegetation Mapping

Bangalay Botanical Surveys (2008) conducted a baseline flora survey and mapped vegetation communities within the Project underground mining area for the Metropolitan Coal Project Environmental Assessment (Helensburgh Coal Pty Ltd 2008).

Swamps were mapped by Bangalay Botanical Surveys (2008) consistent with vegetation mapping by the NSW National Parks and Wildlife Service (NPWS) (2003) as either vegetation community 3a (Banksia Thicket), 3b (Tea Tree Thicket), 3c (Sedgeland-heath Complex), 3d (Fringing Eucalypt Woodland), or a combination of these communities.

The Bangalay Botanical Surveys (2008) mapping of upland swamps overlying or proximal to Longwalls 304-310 is shown on Figure 1.



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Woronora Notification Area
- Existing Underground Access Drive (Main Drift)
- 3a - Upland Swamp: Banksia Thicket
- 3b - Upland Swamp: Tea Tree Thicket
- 3c - Upland Swamp: Sedgeland-heath Complex
- 3d - Upland Swamp: Fringing Eucalypt Woodland

Source: Land and Property Information (2015); Department of Industry (2015); Bangalay Botanical Surveys (2008)

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Upland Swamp Vegetation Mapping by Bangalay Botanical Surveys (2008)

Figure 1

3 Revised Upland Swamp Mapping for Longwalls 301-303

Field inspections of upland swamp vegetation mapped by Bangalay Botanical Surveys (2008) within 600 m of Longwalls 301-303 secondary extraction were conducted by Eco Logical Australia (Eco Logical) in 2015. At each upland swamp mapped by Bangalay Botanical Surveys (2008), the extent of the mapped polygon was traversed to confirm the presence of upland swamp vegetation communities, confirm the boundaries and extent of these vegetation communities and identify the specific vegetation community present (i.e. Banksia Thicket, Tea Tree Thicket, Sedgeland-heath Complex or Fringing Eucalypt Woodland).

For each upland swamp, a description of the vegetation was recorded including the different strata present, the dominant species and an estimation of percent foliage cover for each stratum to assign vegetation communities described by NPWS (2003) and Bangalay Botanical Surveys (2008). Final delineation of vegetation community boundaries was undertaken by interpretation of recent aerial photographs. Patterns identified on aerial photographs were related to the field observations and used to delineate the boundaries of vegetation communities.

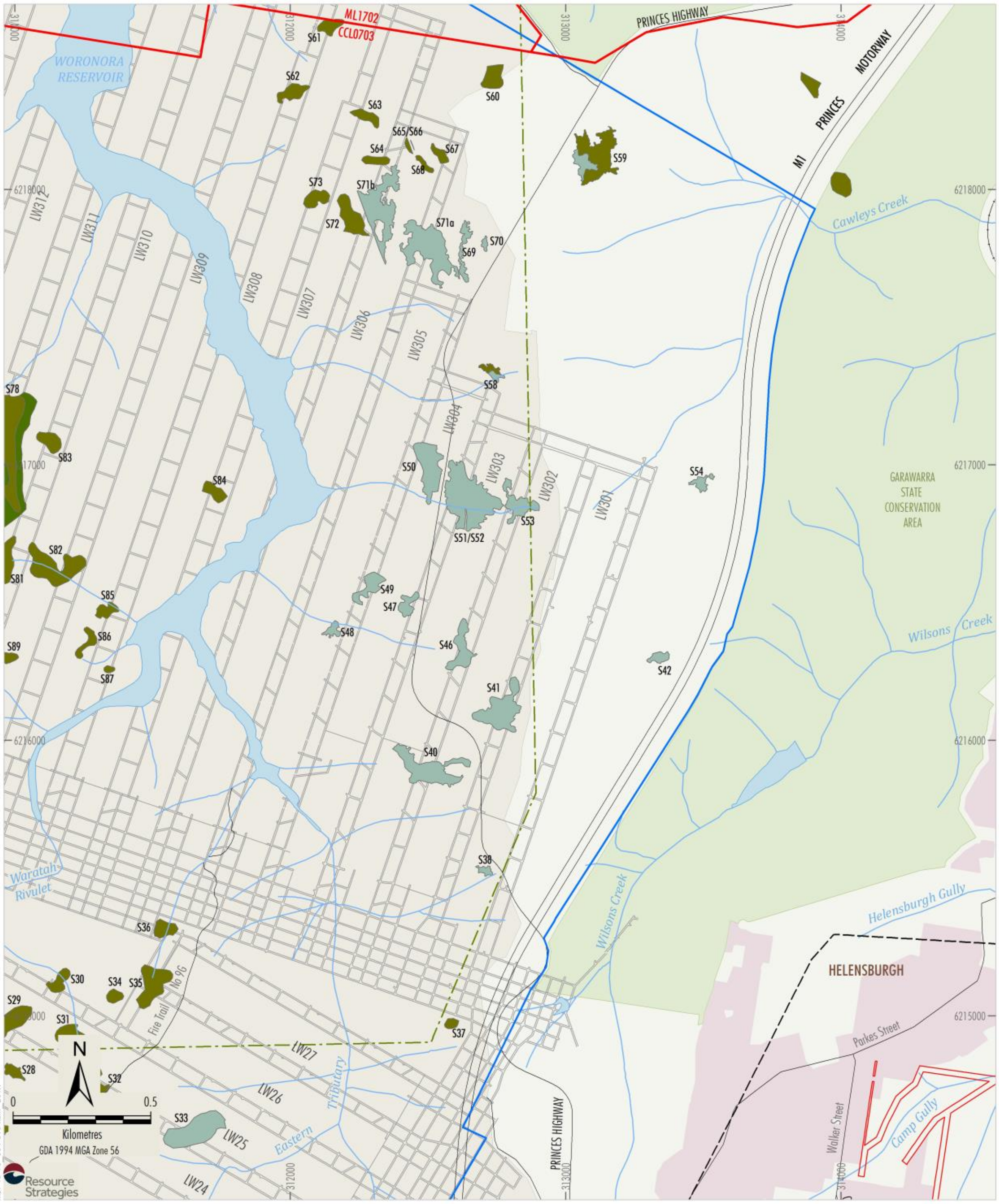
A total of 26 upland swamps were identified by Bangalay Botanical Surveys within 600 m of Longwalls 301-303 secondary extraction, namely, Swamps 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 69, 70 and 71 (Figure 1).

The field inspections by Eco Logical indicated that seven upland swamps identified by Bangalay Botanical Surveys (2008) (which was based on NPWS 2003 mapping) did not comprise upland swamp vegetation (i.e. they were identified as supporting non-swamp vegetation communities), namely, Swamps 39, 43/44/45, 55/56 and 57 (Figure 1) (Eco Logical 2016).

The boundaries of 19 upland swamps situated within 600 m of Longwalls 301-303 were revised as appropriate by Eco Logical, namely, Swamps 37, 38, 40, 41, 42, 46, 47, 48, 49, 50, 51, 52, 53, 54, 58, 69, 70 and 71 (Figure 1). The revised upland swamp and associated vegetation community mapping by Eco Logical (2016) of upland swamps within 600 m of Longwalls 301-303 is shown on Figure 2, and the revised vegetation community mapping for the Underground Mining Area and surrounds is shown on Figure 3.

All upland swamps within 600 m of Longwalls 301-303 secondary extraction were classified as Banksia Thicket, except for Swamps 58 and 59, which were mapped as a combination of Sedgeland-heath Complex and Banksia Thicket (Figure 2).

The Longwalls 301-303 revised upland swamp vegetation mapping is reported in Eco Logical (2016), included in Appendix 2 of the Longwalls 301-303 Biodiversity Management Plan.



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Woronora Notification Area
- Existing Underground Access Drive (Main Drift)

Map Unit	Vegetation Community
3a	Upland Swamp: Banksia Thicket
3b	Upland Swamps: Tea Tree Thicket
3c	Upland Swamp: Sedgeland-heath Complex
3d	Upland Swamp: Fringing Eucalypt Woodland

Note: Swamps 37, 38, 40, 41, 42, 46, 47, 48, 49, 50, 51/52, 53, 54, 58, 69, 70, 71a and 71b were re-mapped by Eco Logical (2016)

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

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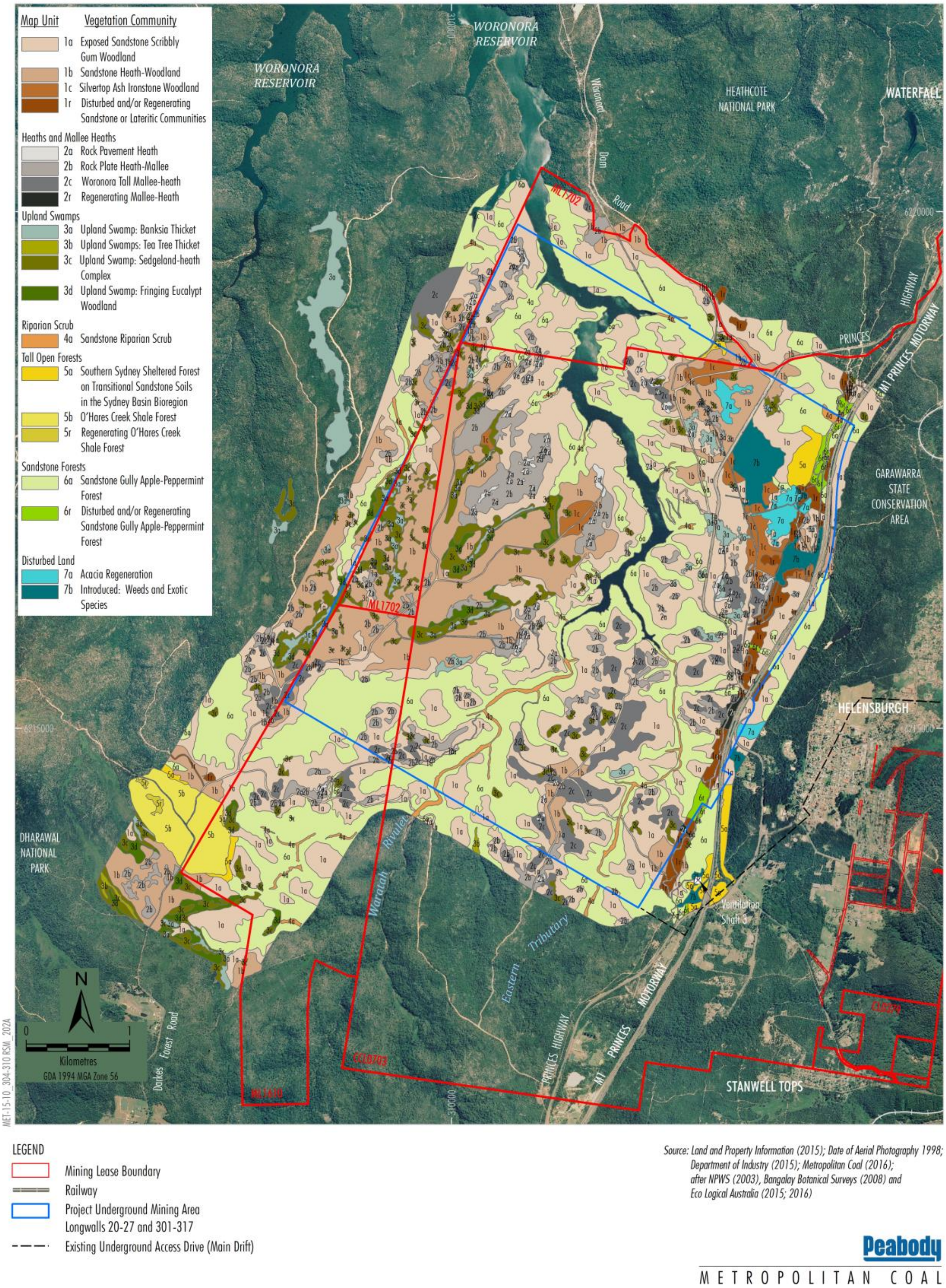
Upland Swamps over Longwalls 301 - 303 and Surrounds

Figure 2



Mapped Vegetation Communities Within the Project Underground Mining Area and Surrounds

Figure 3

4 Revised Upland Swamp Mapping for Longwalls 304-310

4.1 Background

A number of upland swamps were identified by Bangalay Botanical Surveys (2008) overlying or proximal to Longwalls 304-310. Excluding those upland swamps previously inspected and re-mapped by Eco Logical (2016) that are described in Section 3, these include Swamps 60, 61, 62, 63, 64, 65, 66, 67, 68, 72, 73, 81, 82, 83, 84, 85, 86, 87, 88, 89, 133 and 134 (Figure 1).

Of these, 21 swamps were identified by Bangalay Botanical Surveys (2008) as supporting Sedgeland-heath Complex, namely Swamps 60, 61, 62, 63, 64, 65, 66, 67, 68, 72, 73, 81, 82, 83, 84, 85, 86, 87, 88, 89 and 133 (Figure 1). Swamp 134 was identified by Bangalay Botanical Surveys (2008) as having a combination of Sedgeland-heath Complex and Banksia Thicket (Figure 1).

4.2 Methods

4.2.1 Revised Mapping Methodology

Field inspections of upland swamps overlying or proximal to Longwalls 304-310 to the east of the Woronora Reservoir (excluding those upland swamps previously inspected and re-mapped for Longwalls 301-303 described in Section 3) were undertaken by two ecologists, Elizabeth Norris and Brian Towle, on the 4th and 14th of July 2016 and the 19th of August 2016. Specifically, field surveys were conducted of Swamps 60, 61, 62, 63, 64, 65, 66, 67, 68, 72, 73, 133 and 134.

Field inspections of upland swamps overlying or proximal to Longwalls 304-310 to the west of the Woronora Reservoir were undertaken by two ecologists, Elizabeth Norris and Suzanne Eacott, on the 17th, 18th and 26th of July 2017. Specifically, field surveys were conducted of Swamps 81, 82, 83, 84, 85, 86, 87, 88 and 89.

At each upland swamp mapped by Bangalay Botanical Surveys (2008), the extent of the mapped polygon was traversed to confirm the presence of previously mapped vegetation communities, and to confirm the swamp vegetation community boundaries/extent.

The *NSW Native Vegetation Interim Type Standard* (Sivertsen 2009) requires patches of vegetation to be mapped if the dimensions of the representative polygon on a map sheet are 2 mm x 2 mm or greater (i.e. at a map scale of 1:25,000, patches of vegetation equal to or greater than 0.25 ha). Notwithstanding, the revised swamp vegetation mapping boundaries (including those swamps less than 0.25 ha in area) are shown on Figures 4 and 5 to document the changes to the previous Bangalay Botanical Surveys (2008) vegetation mapping. It is considered that these small areas comprising vegetation characteristic of the upland swamp vegetation communities doubtfully represent an ‘upland swamp’.

For each area confirmed as comprising upland swamp vegetation, a description of the vegetation was recorded, including the different stratum present, the dominant species and an estimation of percent foliage cover for each stratum. These descriptions formed the basis for assigning vegetation communities described by NPWS (2003) and Bangalay Botanical Surveys (2008). Final delineation of vegetation community boundaries was undertaken by interpretation of aerial photographs. Patterns identified on aerial photographs were considered with the field observations to finalise vegetation community boundaries.

4.2.2 Presence of Indicator Species

The presence of indicator species that are monitored as part of the current Longwalls 20-22, 23-27 and 301-303 vegetation monitoring programs was noted within each swamp overlying or proximal to Longwalls 304-310, and a rapid assessment of the number of individuals of each indicator species was made.

5 Results

5.1 Swamp Geomorphology

Three swamp types have been identified as occurring over the Metropolitan Coal Project underground mining area, as follows (Metropolitan Coal 2018):

- Headwater swamps: These are the largest swamp type. They occupy broad, shallow, trough-shaped valleys, usually on first order watercourses at the head of valleys on broad plateaux. They sit on a relatively impermeable, low gradient sandstone base with dispersed seepage flows that encourage the growth of hygrophilic vegetation that in turn traps sediment, thereby increasing the water holding capacity. These swamps usually terminate at points where the watercourse suddenly steepens or drops away at a ‘terminal step’. Terminal steps often occur at constrictions in the landscape where two ridges converge, causing a narrowing of the swamp and a concentration of water flows into a central channel.
- In-valley swamps: In-valley swamps are uncommon and occur on relatively flat sections of more deeply incised second and third order watercourses. Some are thought to develop behind obstructions in the watercourse, such as fallen rocks or log jams that result in a slowing of the water flow and deposition of sediments. Flat Rock Swamp is considered to represent a ‘classic’ in-valley swamp. Because of their relatively large catchment areas these swamps tend to be wetter than many headwater and valley side swamps.
- Valley side swamps: Valley side swamps occur on steeper terrain than headwater swamps and are sustained by small horizontal aquifers that seep from the sandstone strata and flow over unbroken outcropping rock masses. These ‘swamps’ have shallow soils because the gradient usually limits sediment accumulation. They tend to terminate either on a horizontal step in the bedrock, or where broken rock, scree or deeper soil occurs at the base of the outcropping rock.

All of the swamps overlying or proximal to Longwalls 304-310 were identified as ‘valley side swamps’. The highly dissected landscape with narrow ridges does not contain broad plateaux capable of supporting the larger ‘headwater swamps’. All of the swamps identified during the field inspections are located on the mid to upper portions of the slope and do not occur in association with an incised second or third order watercourse compared to in-valley swamps.

5.2 Upland Swamp Vegetation Communities

The field inspections of mapped upland swamps overlying or proximal to Longwalls 304-310 confirmed the presence of vegetation characteristic of upland swamps at the majority of upland swamps mapped by Bangalay Botanical Surveys (2008). However, the boundaries identified by Bangalay Botanical Surveys (2008) did not accurately reflect the boundaries of each upland swamp observed in the field and from current aerial photography (NearMap 2017). The revised swamp boundaries are shown on Figure 4, Figure 5 and in Attachment A.

Table 1 details the revised upland swamp vegetation revised by Eco Logical. Of the 22 swamps mapped by Bangalay Botanical Surveys, Eco Logical mapped:

- 15 swamps (Swamps 61, 62, 63, 64, 65/66, 67, 68a, 68b, 72, 81, 82, 83, 88, and 89) as Banksia Thicket.
- One swamp (Swamp 60) as Sedgeland-heath Complex.
- One swamp (Swamp 73) as a combination of Banksia Thicket and Tea Tree Thicket.
- Two swamps (Swamps 84 and 86) as a combination of Banksia Thicket and Sandstone Gully Apple-Peppermint Forest.
- One swamp (Swamp 134) as a combination of Sedgeland-heath Complex and Banksia Thicket.
- Two swamps (Swamps 85 and 87) as non-swamp vegetation.

Swamps 65 and 66 were identified as being a single swamp which has been dissected by a fire trail, and are herein referred to as a single swamp (Swamp 65/66) (Figure 4).

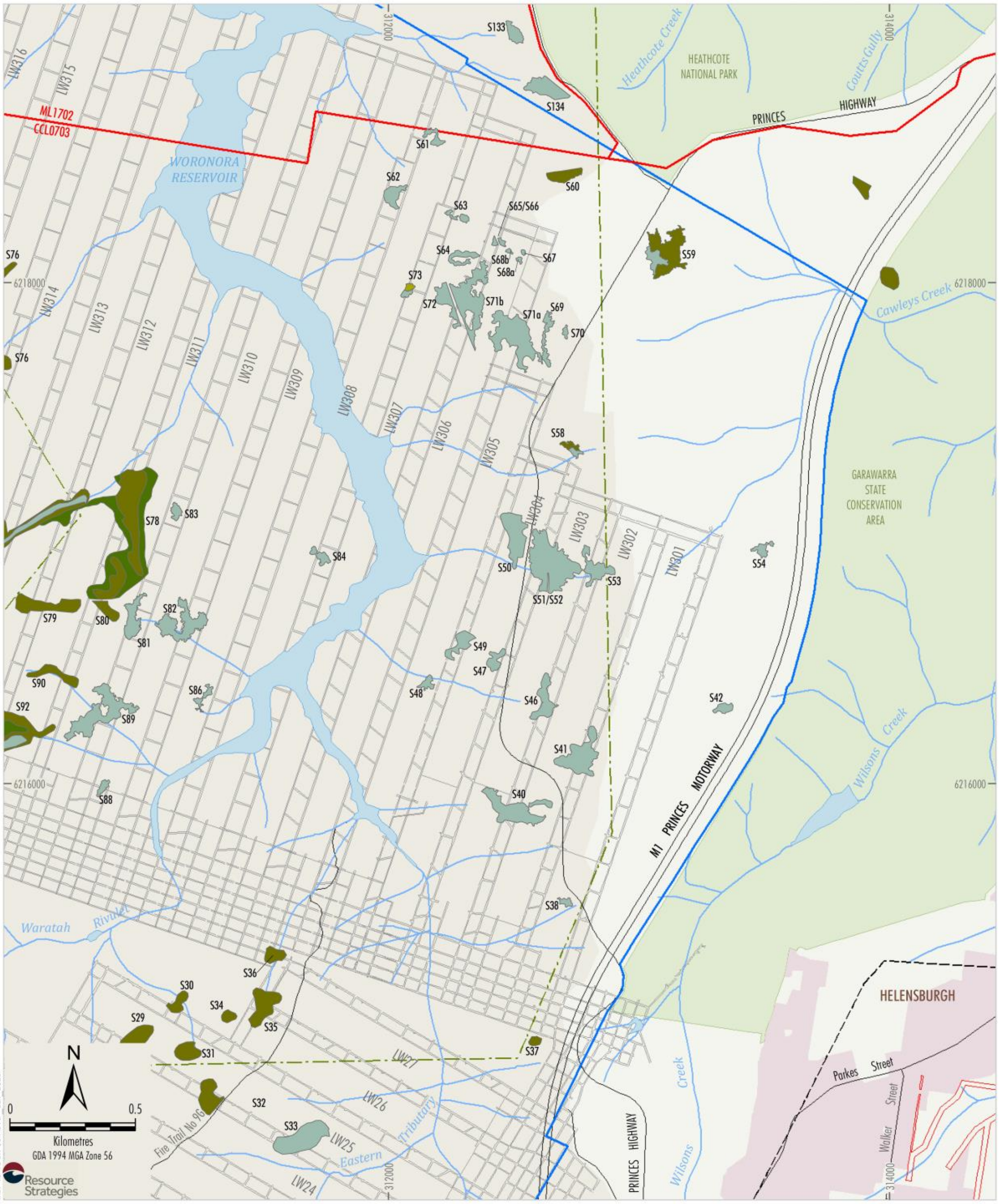
Swamp 68, as mapped by Bangalay Botanical Surveys (2008) (Figure 1), was found to include two small discrete areas comprising vegetation characteristics of the Banksia Thicket vegetation community, separated by an area of Sandstone Heath-Woodland (vegetation community 1b, Figure 5), re-mapped as Swamps 68a and 68b (Figure 4). Small-scale illustrations of the revised swamp vegetation boundaries are shown in Attachment A. As described above, it is considered that these small areas comprising vegetation characteristic of the upland swamp vegetation communities doubtfully represent an ‘upland swamp’.

Swamps 84 and 86 are considered to be marginal upland swamps in that they contain non-swamp vegetation more consistent with sandstone woodland. Swamps 84 and 86 are located on steeper east to south-east facing slopes to the west of the Woronora Reservoir where the vegetation observed is a combination of swamp vegetation and Sandstone Gully Apple-Peppermint Forest (vegetation community 6a, Figure 5), containing a dense mid-layer of *Banksia ericifolia* subsp. *ericifolia*, and with patches of more open canopy present. Numerous sandstone ledges commonly occur on these steeper slopes, enhancing more dense understorey growth through maintaining higher soil moisture. Terminal rocky steps are not present. It is noted that Swamp 84 is marginally greater than 0.25 ha (0.256 ha), while Swamp 86 is less than 0.25 ha (0.209 ha).

Table 1: Upland Swamp Vegetation Communities Mapped by Bangalay Botanical Surveys and Revised by Eco Logical Australia

Swamp	Vegetation Community (Bangalay Botanical Surveys 2008)	Swamp	Vegetation Community (Eco Logical)
60	Sedgeland-heath Complex	60	Sedgeland-heath Complex
61	Sedgeland-heath Complex	61	Banksia Thicket
62	Sedgeland-heath Complex	62	Banksia Thicket
63	Sedgeland-heath Complex	63	Banksia Thicket
64	Sedgeland-heath Complex	64	Banksia Thicket
65	Sedgeland-heath Complex	65/66	Banksia Thicket
66	Sedgeland-heath Complex		
67	Sedgeland-heath Complex	67	Banksia Thicket
68	Sedgeland-heath Complex	68a	Banksia Thicket
		68b	Banksia Thicket
72	Sedgeland-heath Complex	72	Banksia Thicket
73	Sedgeland-heath Complex	73	Banksia Thicket/Tea Tree Thicket
81	Sedgeland-heath Complex	81	Banksia Thicket
82	Sedgeland-heath Complex	82	Banksia Thicket
83	Sedgeland-heath Complex	83	Banksia Thicket
84	Sedgeland-heath Complex	84	Banksia Thicket/Sandstone Gully Apple-Peppermint Forest*
85	Sedgeland-heath Complex	85	Sandstone Gully Apple-Peppermint Forest
86	Sedgeland-heath Complex	86	Banksia Thicket/Sandstone Gully Apple-Peppermint Forest*
87	Sedgeland-heath Complex	87	Sandstone Gully Apple-Peppermint Forest
88	Sedgeland-heath Complex	88	Banksia Thicket
89	Sedgeland-heath Complex	89	Banksia Thicket
133	Sedgeland-heath Complex	133	Banksia Thicket
134	Sedgeland-heath Complex/Banksia Thicket	134	Sedgeland-heath Complex/Banksia Thicket

* Swamps 84 and 86 are considered to be marginal upland swamps in that they contain non-swamp vegetation more consistent with sandstone woodland.



LEGEND

- Mining Lease Boundary
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- 3d - Upland Swamp: Fringing Eucalypt Woodland

Note:

1. *Swamps 37, 38, 40, 41, 42, 46, 47, 48, 49, 50, 51/52, 53, 54, 58, 69, 70, 71a and 71b were re-mapped by Eco Logical (2016).*
2. *The NSW Native Vegetation Interim Type Standard 2009 requires patches of vegetation to be mapped if the dimensions of the representative polygon on a map sheet are 2 mm x 2 mm or greater (i.e. 0.25 hectares or greater at a scale of 1:25,000). Eco Logical Australia conducted field inspections of upland swamp vegetation previously mapped by Bangalay Botanical Surveys (2008) overlying or proximal to Longwalls 301-310 to confirm the upland swamp vegetation communities present and to confirm or update the swamp vegetation boundaries.*
   It is noted that the revised boundaries of a number of upland swamps (Swamps 37, 38, 42, 48, 54, 58, 61, 63, 65/66, 67, 68a, 68b, 70, 73, 83, 86 and 88) are less than 0.25 hectares in area and consistent with NSW vegetation mapping guidelines are not required to be mapped. Notwithstanding, the revised swamp vegetation mapping boundaries (including those swamps less than 0.25 hectares in area) are shown on this figure to document the changes to previous vegetation mapping.

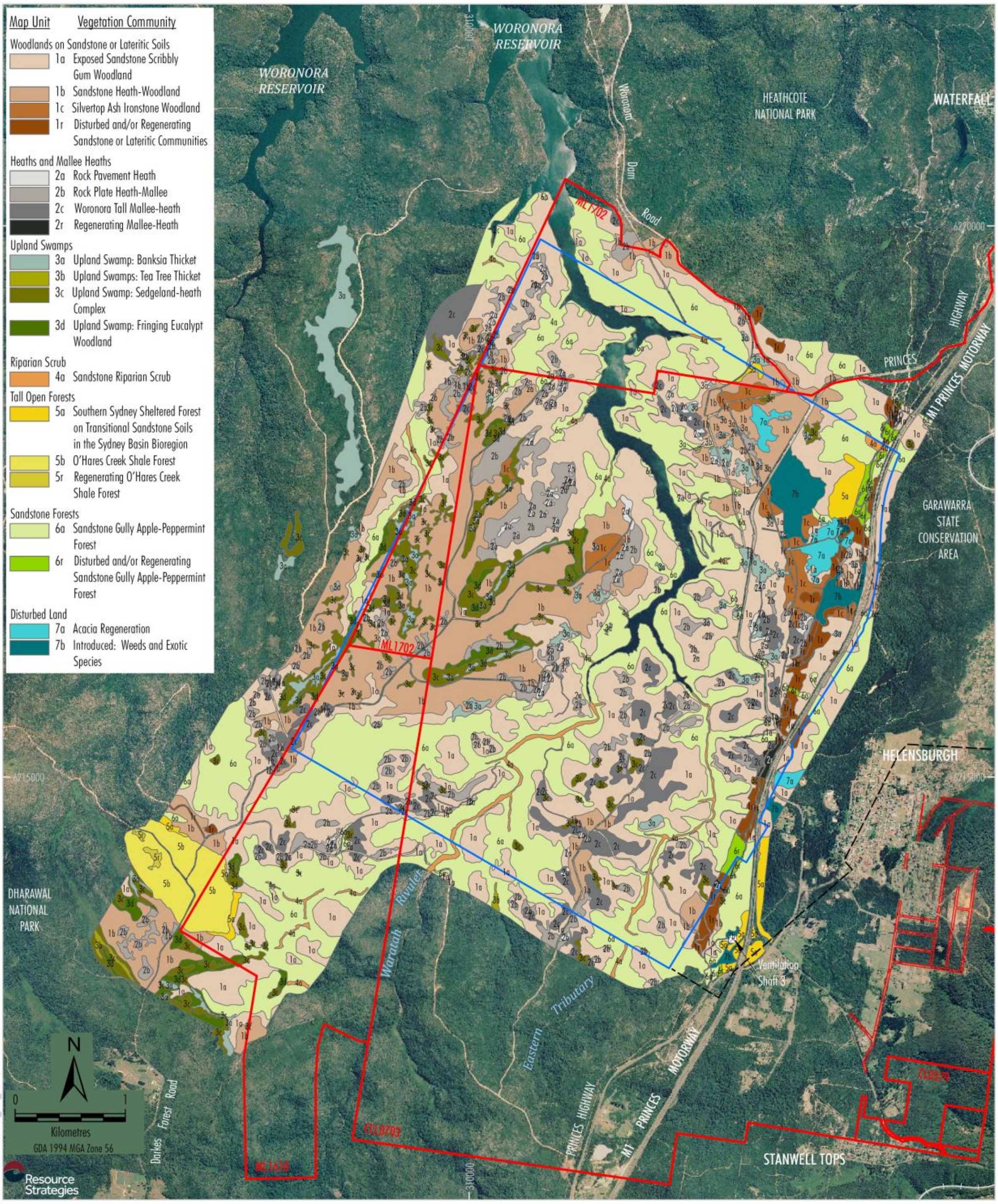
Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2018); after NPWS (2003), Bangalay Botanical Surveys (2008), Eco Logical Australia (2015; 2016; 2018)

Peabody

METROPOLITAN COAL

Upland Swamps over Longwalls 304-310 and Surrounds

Figure 4



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Existing Underground Access Drive (Main Drift)

The NSW Native Vegetation Interim Type Standard 2009 requires patches of vegetation to be mapped if the dimensions of the representative polygon on a map sheet are 2 mm x 2 mm or greater (i.e. 0.25 hectares or greater at a scale of 1:25,000). Eco Logical Australia conducted field inspections of upland swamp vegetation previously mapped by Bangalay Botanical Surveys (2008) overlying or proximal to Longwalls 301-310 to confirm the upland swamp vegetation communities present and to confirm or update the swamp vegetation boundaries.

It is noted that the revised boundaries of a number of upland swamps (Swamps 37, 38, 42, 48, 54, 58, 61, 63, 65/66, 67, 68a, 68b, 70, 73, 83, 86 and 88) are less than 0.25 hectares in area and consistent with NSW vegetation mapping guidelines are not required to be mapped. Notwithstanding, the revised swamp vegetation mapping boundaries (including those swamps less than 0.25 hectares in area) are shown on this figure to document the changes to previous vegetation mapping.

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2018); after NPWS (2003), Bangalay Botanical Surveys (2008) and Eco Logical Australia (2015; 2016; 2018)

Peabody

METROPOLITAN COAL

Mapped Vegetation Communities Within the Project Underground Mining Area and Surrounds

Figure 5

Swamps 85 and 87 included in the Bangalay Botanical Surveys (2008) mapping (Figure 1) were comprised of non-swamp vegetation (i.e. they did not comprise vegetation characteristic of the upland swamp vegetation communities). Swamp 85 occurs on a steep east to south-east facing slope to the west of the Woronora Reservoir where the vegetation observed was Sandstone Gully Apple-Peppermint Forest (vegetation community 6a, Figure 5). Similar to Swamps 84 and 86, numerous sandstone ledges commonly occur on these steeper slopes, enhancing more dense understorey growth through maintaining higher soil moisture. Swamp 87 is located along a drainage line and also comprises Sandstone Gully Apple-Peppermint Forest (Figure 5).

The area of each upland swamp overlying or proximal to Longwalls 304-310 inspected by Eco logical is provided in Table 2. Of these swamps, ten upland swamps have an area of 0.25 ha or greater, and ten upland swamps have an area of less than 0.25 ha.

Table 2: Area of each re-mapped Upland Swamp Overlying or Proximal to Longwalls 304-310

Swamp	Area (ha)
S60	0.520
S61	0.237
S62	0.463
S63	0.170
S64	0.363
S65/66	0.112
S67	0.030
S68a	0.043
S68b	0.034
S72	0.606
S73	0.182
S81	0.728
S82	1.437
S83	0.202
S84	0.256
S86	0.209
S88	0.164
S89	1.982
S133	0.362
S134	0.891

Note: Highlighted swamps are less than 0.25 ha in area.

The *NSW Native Vegetation Interim Type Standard* (Sivertsen 2009) requires patches of vegetation to be mapped if the dimensions of the representative polygon on a map sheet are 2 mm x 2 mm or greater (i.e. at a map scale of 1:25,000, patches of vegetation equal to or greater than 0.25 ha). It is noted that the revised boundaries of a number of the upland swamps (Swamps 61, 63, 65/66, 67, 68a, 68b, 73, 83, 86 and 88) are less than 0.25 ha in area and consistent with NSW vegetation mapping guidelines are not required to be mapped. Notwithstanding, the revised swamp vegetation mapping boundaries (including those swamps less than 0.25 ha in area) are shown on Figures 4 and 5 to document the changes to the previous Bangalay Botanical Surveys (2008) vegetation mapping. It is considered that these small areas comprising vegetation characteristic of the upland swamp vegetation communities doubtfully represent an 'upland swamp'.

5.3 Fire History of Upland Swamps Overlying or Proximal to Longwalls 304-310

The field surveys conducted by Bangalay Botanical Surveys (2008) for upland swamps overlying or proximal to Longwalls 304-310 were undertaken between late 2006 and early 2008, five to six years post the fire of December 2001 and January 2002 respectively, and approximately 12-20 years post the fires in 1986-1987 and 1993-1994, all which extensively burnt the catchments of Woronora, O'Hares, Nepean and Avon.

The field surveys conducted by Eco Logical for upland swamps overlying or proximal to Longwalls 304-310 were undertaken in July/August 2016 for swamps to the east of the Woronora Reservoir, and in July 2017 for swamps to the west of the Woronora Reservoir. The inspections to the east and west of the Woronora Reservoir were conducted approximately 14-15 years post the fire of December 2001 and January 2002 respectively. The field surveys undertaken for this report were also undertaken at least 22 years after the fires in 1986-1987 and 1993-1994 described above.

Much of the upland swamp vegetation mapped as Banksia Thicket in this report likely had more affinity to the Sedgeland-heath Complex vegetation community in the years immediately following the fires in 2001/2002, as mapped by Bangalay Botanical Surveys in 2008. For example, Keith & Myerscough (1993) observed that the boundaries delineating Banksia Thicket may shift after fire, and speculated that fires influence the relative occurrence of upland swamp communities that occur in drier habitats, including Banksia Thicket, Restioid Heath & Sedgeland.

Profiles for each of the upland swamps overlying or proximal to Longwalls 304-310, including the vegetation 'communities' present, their updated boundaries, photos and key characteristics are provided in Attachment A. The revised vegetation community mapping (as a result of the revised boundaries and vegetation community classifications for upland swamps overlying or proximal to Longwalls 304-310) by Eco Logical is shown on Figure 5.

In October 2016 (and subsequent to the field inspections described in this report), Swamps 64, 65/66, 67, 68a and 68b, were subject to WaterNSW hazard reduction burns[1]. As a result, the swamps which comprised 'Banksia Thicket' may now represent 'Sedgeland-heath Complex' vegetation.

[1] It is noted that Swamps 69, 70, 71a and 71b that were previously re-mapped (Eco Logical, 2016) were also subject to the WaterNSW hazard reduction burns.

5.4 Presence of Indicator Species

Counts of *Epacris obtusifolia*, *Pultenaea aristata* and *Sprengelia incarnata* were conducted within each upland swamp. Within upland swamps overlying or proximal to Longwalls 304-310 to the east of the Woronora Reservoir (Swamps 60, 61, 62, 63, 64, 65/66, 67, 68a, 68b, 72, 73, 133 and 134) *Epacris obtusifolia* was widespread and common, while *Pultenaea aristata* and *Sprengelia incarnata* were comparatively infrequent (Table 3).

Within upland swamps overlying or proximal to Longwalls 304-310 to the west of the Woronora Reservoir (Swamps 81, 82, 83, 84, 86, 88 and 89), *Epacris obtusifolia* and *Pultenaea aristata* were widespread, however the individual numbers were low in many instances, whilst *Sprengelia incarnata* was comparatively infrequent (Table 3).

Pultenaea aristata was located in nine upland swamps overlying or proximal to Longwalls 304-310 (namely, Swamps 62, 64, 72, 81, 82, 84, 86, 88 and 89), however was only present in sufficient numbers for potential future monitoring in Swamps 81, 82 and 86 (Table 3).

Sprengelia incarnata, which typically occupies wetter areas with deeper soils within the Banksia Thicket vegetation community was observed within 12 upland swamps overlying or proximal to Longwalls 304-310 (Swamps 60, 62, 64, 65/66, 70, 72, 81, 82, 83, 89, 133 and 134), but was only present in sufficient numbers to allow for monitoring at three of these swamps (Swamps 60, 62 and 134) (Table 3).

Epacris obtusifolia was recorded in 13 upland swamps overlying or proximal to Longwalls 304-310 (Swamps 61, 62, 63, 64, 65/66, 72, 81, 82, 83, 88, 89, 133 and 134) and was present in sufficient numbers for potential future monitoring in all of these swamps, with the exception of Swamps 88 and 89. *Epacris obtusifolia* was also recorded in the marginal upland swamp, Swamp 86, but few were recorded (Table 3).

Ten individuals of *Banksia robur* (a Tea Tree Thicket vegetation community indicator species) were recorded in Swamp 73.

The results of the indicator species field inspections are provided in Table 3.

Table 3: Summary of Indicator Species Field Inspection Results

Swamp	Area (ha)	Number of Individuals Recorded		
		Pultenaea aristata	***Sprengelia incarnata***	***Epacris obtusifolia***
S60	0.520	NR	>20	NR
S61	0.237	NR	NR	>20
S62	0.463	~6	>20	>20
S63	0.170	NR	NR	>20
S64	0.363	15	4	>20
S65/66	0.112	NR	15	>20
S67	0.030	NR	NR	NR
S68a	0.043	NR	NR	NR
S68b	0.034	NR	NR	NR
S72	0.606	8	3	>20
S73	0.182	NR	NR	NR
S81	0.728	>20	11	>20
S82	1.437	>20	4	>20
S83	0.202	NR	15	>20
S84[#]	0.256	<20	NR	NR
S86[#]	0.209	>20	NR	3
S88	0.164	6	NR	11
S89	1.982	18	8	14
S133	0.362	NR	~10	>20
S134	0.891	NR	>20	>20

NR Not recorded.

[#] Swamps 84 and 86, which were mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008), are marginal swamps, comprised of a combination of Banksia Thicket and Sandstone Gully Apple-Peppermint Forest vegetation communities.

6 References

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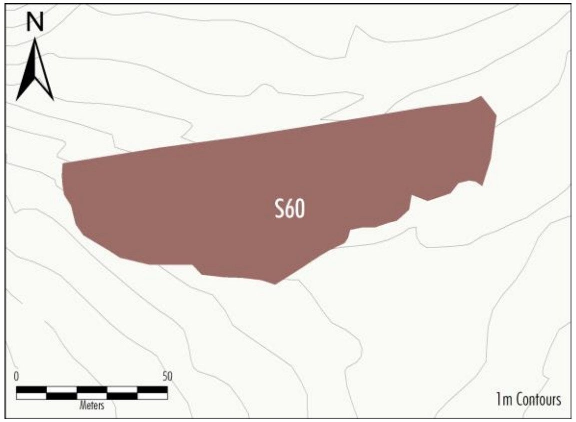
Sivertsen, D 2009. *Native Vegetation Interim Type Standard*, Department of Environment, Climate Change and Water NSW, Sydney.

Attachment A - Upland Swamp Vegetation Mapping

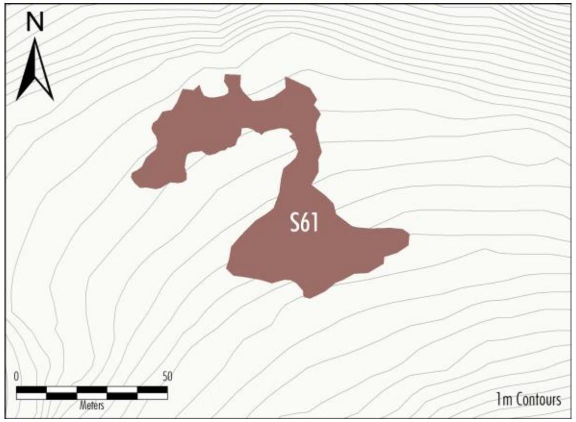
Swamp 60

- Swamp 60 is a valley side swamp.
- Swamp 60 was previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) and field inspections confirmed the presence of this community across the entire revised extent of this swamp.
- Evidence of recent fire disturbance was observed at the time of inspection (July 2016), following hazard reductions burns undertaken in this area during the last three years.
- This swamp is approximately 0.520 ha in area.
- This swamp is generally characterised as having a variable, low and open canopy (*Eucalyptus haemastoma, Corymbia gummifera* and *Leptospermum trinervium*) with a moderately dense, low shrub layer (*Banksia oblongifolia* and *Lambertia formosa*) and dense understorey dominated by sedges (*Leptocarpus tenax, Cyathochaeta diandra, Schoenus brevifolius* and *Schoenus paludosus* with *Patersonia sericea* and *Xanthorrhoea resinosa* also common).
- No terminal step or seepage was observed within this swamp, although soils were saturated at the time of inspection.

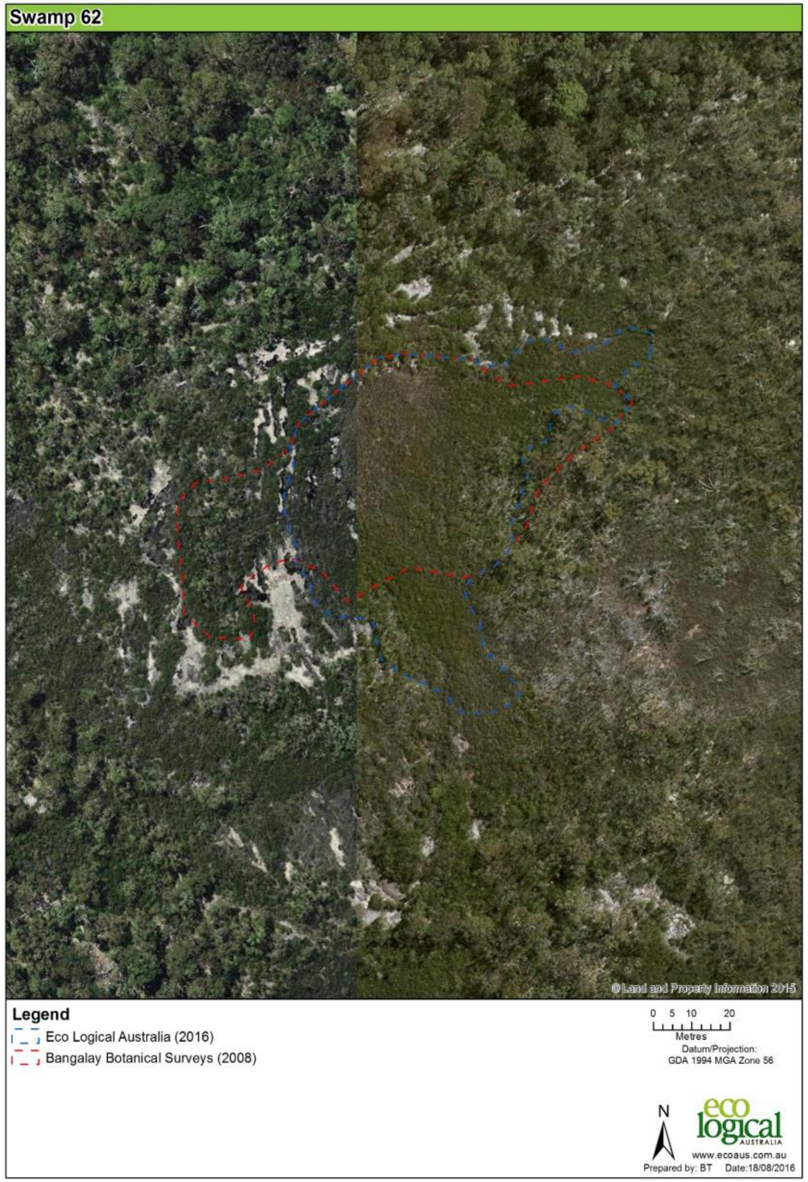


Swamp 61

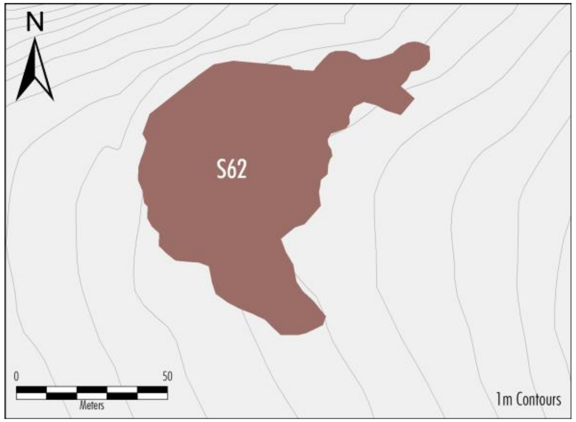
- Swamp 61 is a valley side swamp.
- Swamp 61 was previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) though field inspections confirmed the presence of Banksia Thicket vegetation community across the entire revised extent of this swamp.
- This swamp is approximately 0.237 ha in area.
- This swamp is characterised as having a tall dense shrub layer (*Banksia ericifolia* subsp. *ericifolia* and *Leptospermum squarrosum* up to 4 m in height) over a comparatively sparse understorey dominated by sedges (*Lepidosperma neesii, Leptocarpus tenax, Empodisma minus* and *Schoenus brevifolius*).
- A very small area of outcropping sandstone is present at the lower end of this swamp, although this did not represent a ‘terminal step’ as Banksia Thicket Vegetation continued downslope of this outcrop.
- No seepage was observed across the small area of outcropping sandstone at the time of inspection (July 2016).



Swamp 62

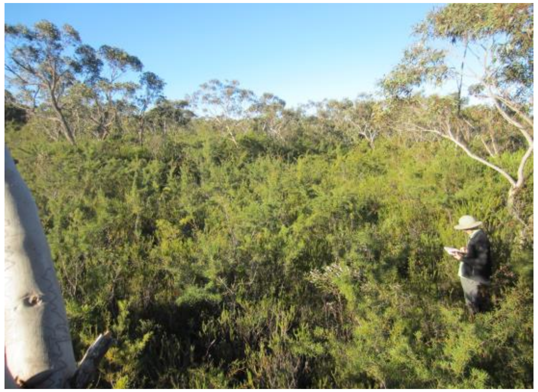


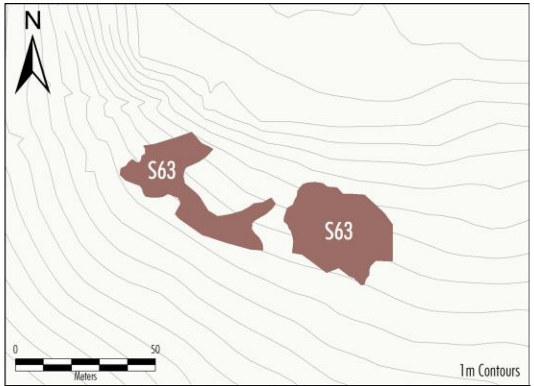
- Swamp 62 is a valley side swamp approximately 0.463 ha in area.
- Swamp 62 was previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) though field inspections confirmed the presence of Banksia Thicket vegetation community across the entire revised extent of this swamp.
- This swamp is characterised as having a dense shrub layer (*Banksia ericifolia subsp. ericifolia, Leptospermum squarrosum* and *Epacris microphylla* up to 2 m in height) over a comparatively sparse understorey dominated by sedges (*Leptocarpus tenax, Chordifex fastigiatus, Lepidosperma filiforme and Schoenus brevifolius*).
- A terminal step of outcropping sandstone was present across the lower end of this swamp, and seepage and standing water was observed across this terminal step.

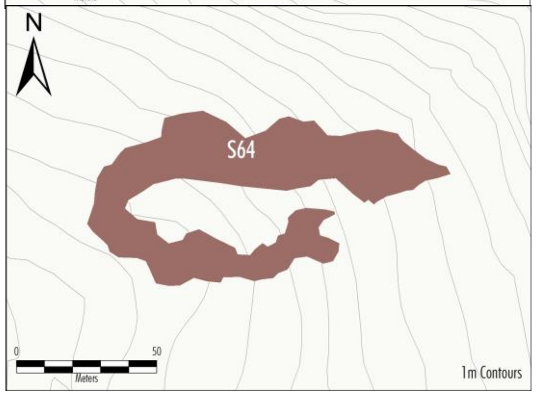


Swamps 63 and 64

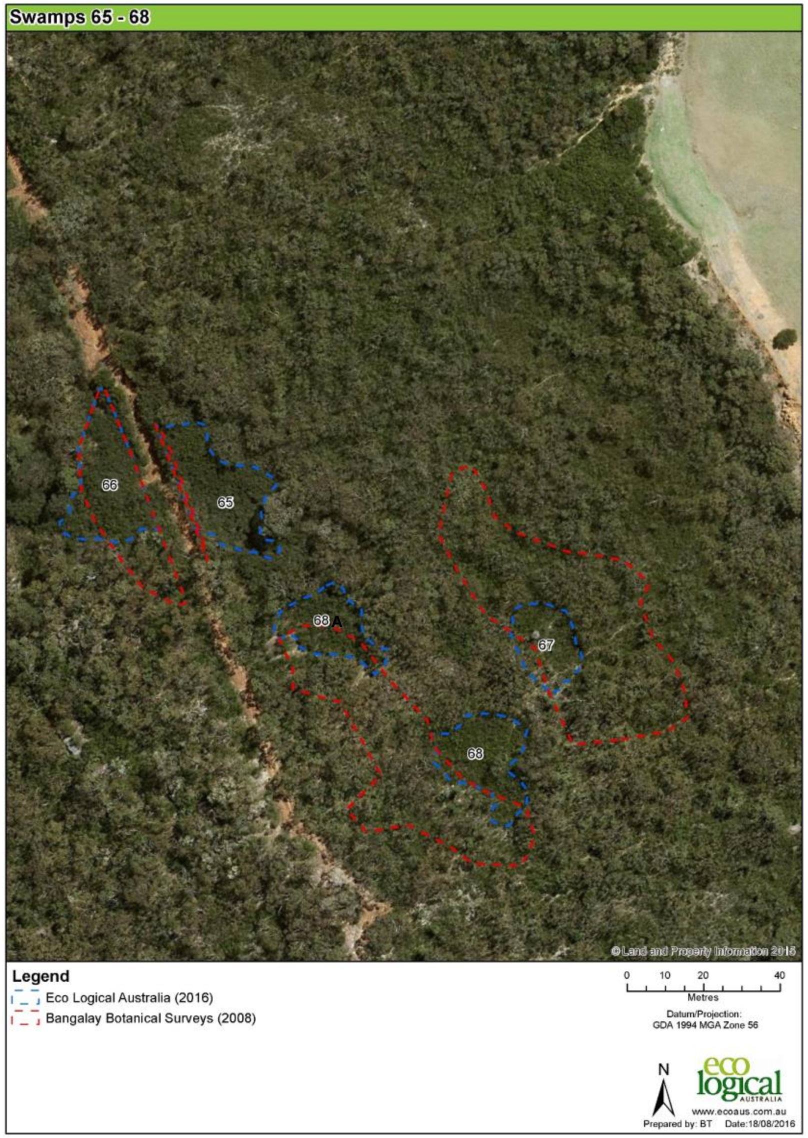
- Swamps 63 and 64 are valley side swamps, approximately 0.17 ha and 0.363 ha in area, respectively.
- These swamps were both previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) though field inspections confirmed the presence of Banksia Thicket vegetation community across the entire revised extents of these swamps.
- These swamps are all characterised as supporting tall dense shrub layers dominated by *Banksia ericifolia* subsp. *ericifolia, Leptospermum squarrosum* and *Hakea teretifolia* over a sedge dominated ground layers (*Lepidosperma neesii, Empodisma minus, Lepyrodia scariosa, Cyathochaeta diandra* and *Ptilothrix deusta*).
- No terminal step was observed for either of these two swamps and no seepage was recorded at the time of inspections (July 2016).
- A large trench is present adjacent to Fire Trail 9I which is located to the west of Swamp 64. There appears to have been some alteration to the local hydrology of Swamp 64 caused by this deep trench intercepting water flows.



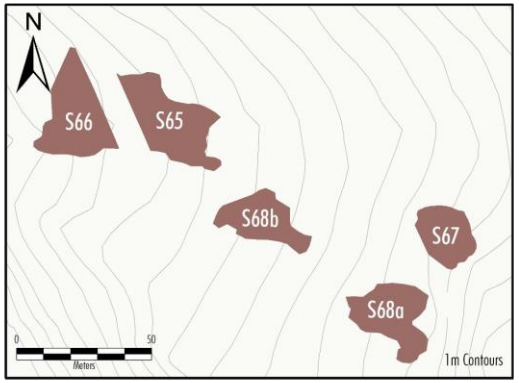




Swamps 65 - 68

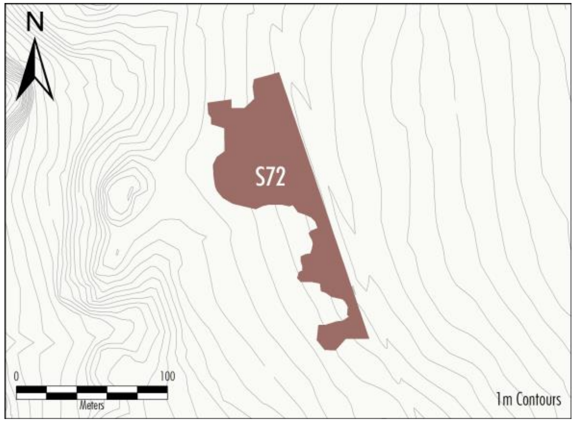


- Swamps 65 to 68 are all valley side swamps, approximately 0.055 ha, 0.057 ha, 0.030 ha and 0.077 ha in area, respectively.
- These swamps were all previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) although field inspections confirmed the presence of Banksia Thicket vegetation community across the entire revised extents of these swamps.
- These swamps are all characterised as supporting tall dense shrub layers dominated by *Banksia ericifolia* subsp. *ericifolia, Leptospermum squarrosum* and *Hakea teretifolia* over a sedge dominated ground layer.
- These swamps form a mosaic with adjacent woodland and heath vegetation types. No terminal steps were observed for any of Swamps 65 to 68.
- Field inspections revised the boundaries of all of these swamps including a much-increased extent of Swamp 65 which was identified as being part of a single swamp with Swamp 66, separated by a cleared track. Additionally, the extents of Swamps 67 and 68 were much reduced with Swamp 68 being identified as two discrete areas of Banksia Thicket vegetation (68a and 68b).



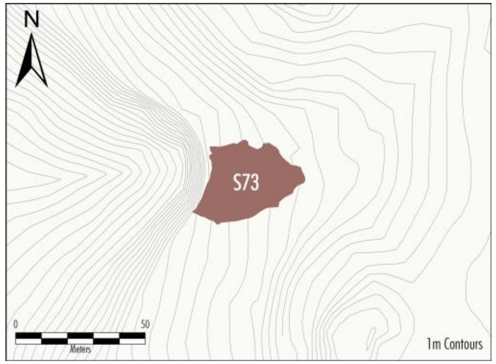
Swamp 72

- Swamp 72 is a valley side swamp approximately 0.606 ha in area.
- This swamp was previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) though field inspections confirmed the presence of Banksia Thicket vegetation community across the entire revised extent of this swamp.
- This swamp is characterised as having a dense shrub layer (*Banksia ericifolia subsp. ericifolia* and *Hakea teretifolia* generally up to 2 m in height) over an understorey dominated by sedges (*Chordifex fastigiatus* and *Lepyrodia scariosa*).
- Extensive areas of sandstone outcropping are present at the downslope limit of this swamp forming a terminal step, with seepage from the swamp observed across this area. The extensive sandstone outcropping supported the 'Rock Pavement Heath' vegetation community.
- Impacted by track creation and water infrastructure along roadside.

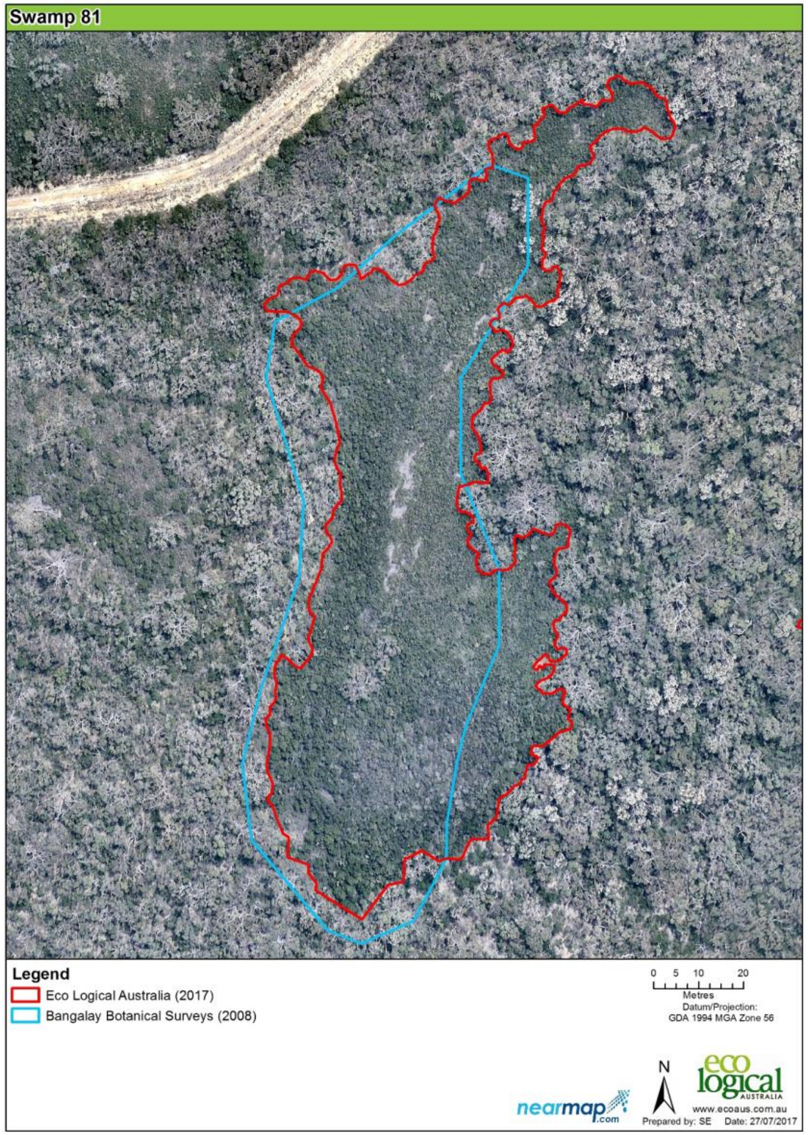


Swamp 73

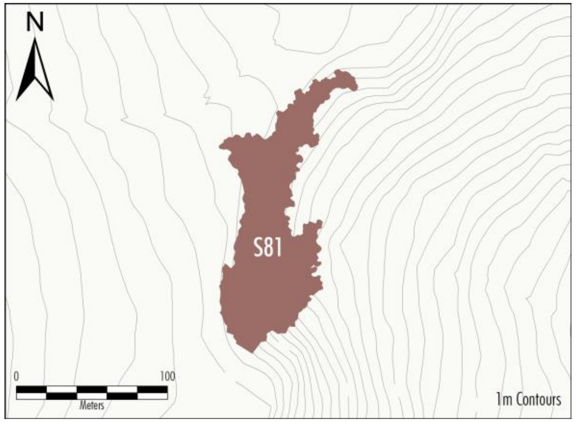
- Swamp 73 is a valley side swamp approximately 0.182 ha in area.
- This swamp was previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) though field inspections confirmed the presence of Banksia Thicket and Tea Tree Thicket vegetation communities within the revised extent of this swamp.
- The northern portion of this swamp occurs in association with a poorly defined drainage line and supports Tea Tree Thicket vegetation with a moderately dense shrub layer (*Banksia robur, Persoonia pinifolia* and *Hakea teretifolia*) over an understorey dominated by the fern *Gleichenia microphylla*. The southern portion of this swamp is located away from the drainage line and supports Banksia Thicket vegetation with a tall dense shrub layer (*Banksia ericifolia* subsp. *ericifolia*, *Leptospermum squarrosum* and *Hakea teretifolia*) over and understorey dominated by sedges.
- A small to moderate cliff line forms the terminal step of this swamp. Abundant seepage was present at the time of inspection, creating a waterfall over the terminal step.



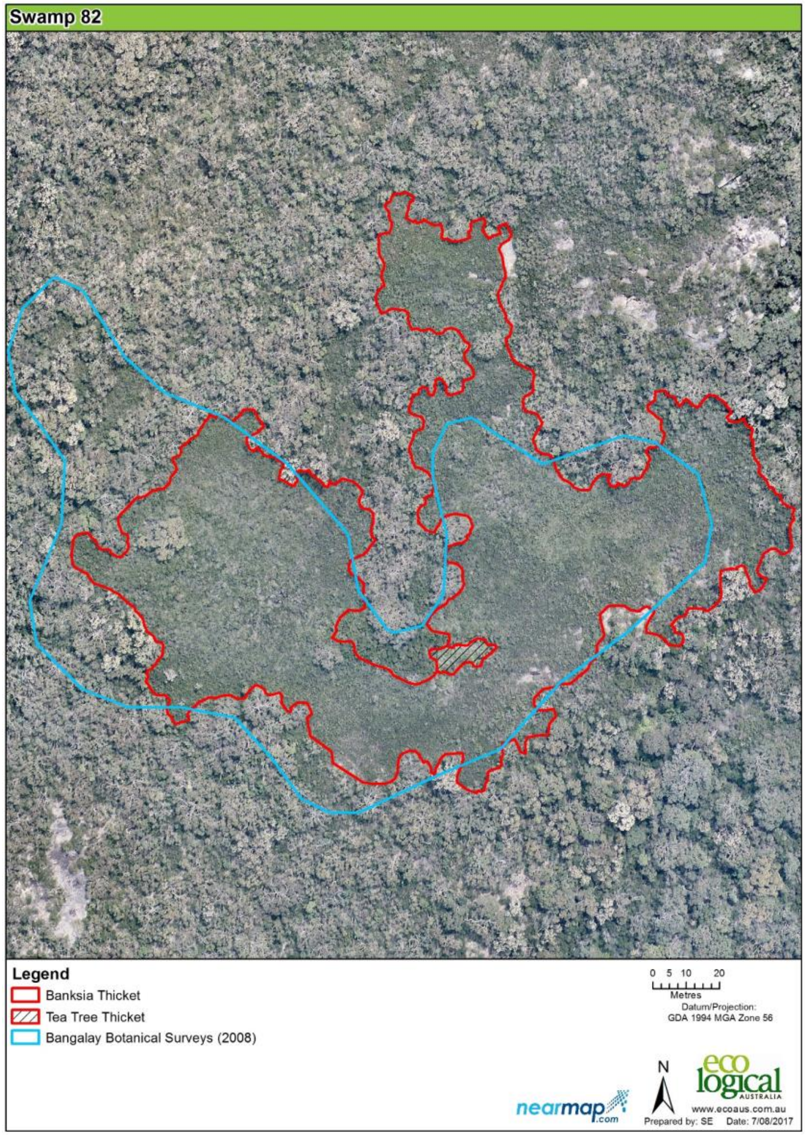
Swamp 81



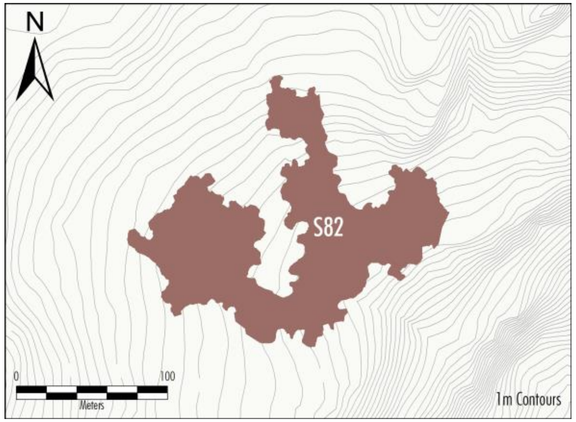
- Swamp 81 is a valley side swamp approximately 0.728 ha in area.
- This swamp was previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) though field inspections confirmed the presence of Banksia Thicket vegetation community across the entire revised extent of this swamp.
- Fire history: burnt 1986-1987 and 1993-1994.
- This swamp is characterised as having a tall dense shrub layer (*Banksia ericifolia* subsp. *ericifolia* and *Leptospermum squarrosum* 2-3 m in height) over an understorey dominated by sedges (*Chordifex fastigiatus, Lepidosperma filiforme* and *L. neesii*).
- No terminal step was observed but an extensive mid-swamp step is present, with abundant seepage present.



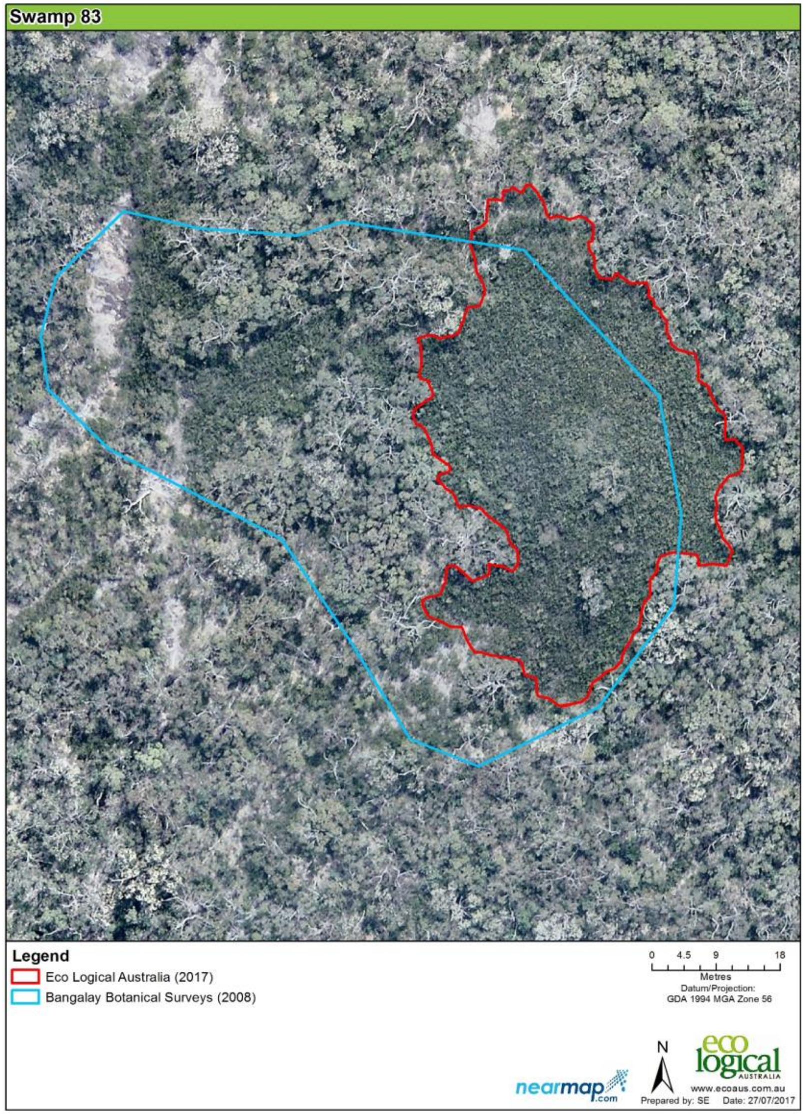
Swamp 82



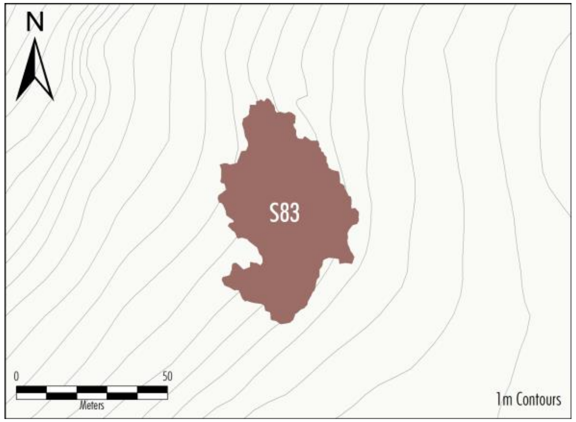
- Swamp 82 is a valley side swamp approximately 1.437 ha in area.
- This swamp was previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) though field inspections confirmed the presence of Banksia Thicket vegetation community across the entire revised extent of this swamp.
- Some vegetation characteristic of Tea Tree Thicket was found embedded within a very small area of this swamp, overlying the drainage line upslope of the terminal step.
- Fire history: burnt 1986-1987 and 1993-1994.
- This swamp is characterised as having a tall dense shrub layer (*Banksia ericifolia* subsp. *ericifolia, Hakea teretifolia* and *Leptospermum squarrosum* up to 5 m in height) over a comparatively sparse understorey dominated by sedges (*Chordifex fastigiatus, Lepidosperma neesii, L filiforme, Empodisma minus* and *Schoenus brevifolius*).
- An intermittent area of outcropping sandstone/terminal step is present at the lower end of this swamp, below which a woodland community was present.
- A drainage line is present within the swamp, which flows out across part of the terminal step.



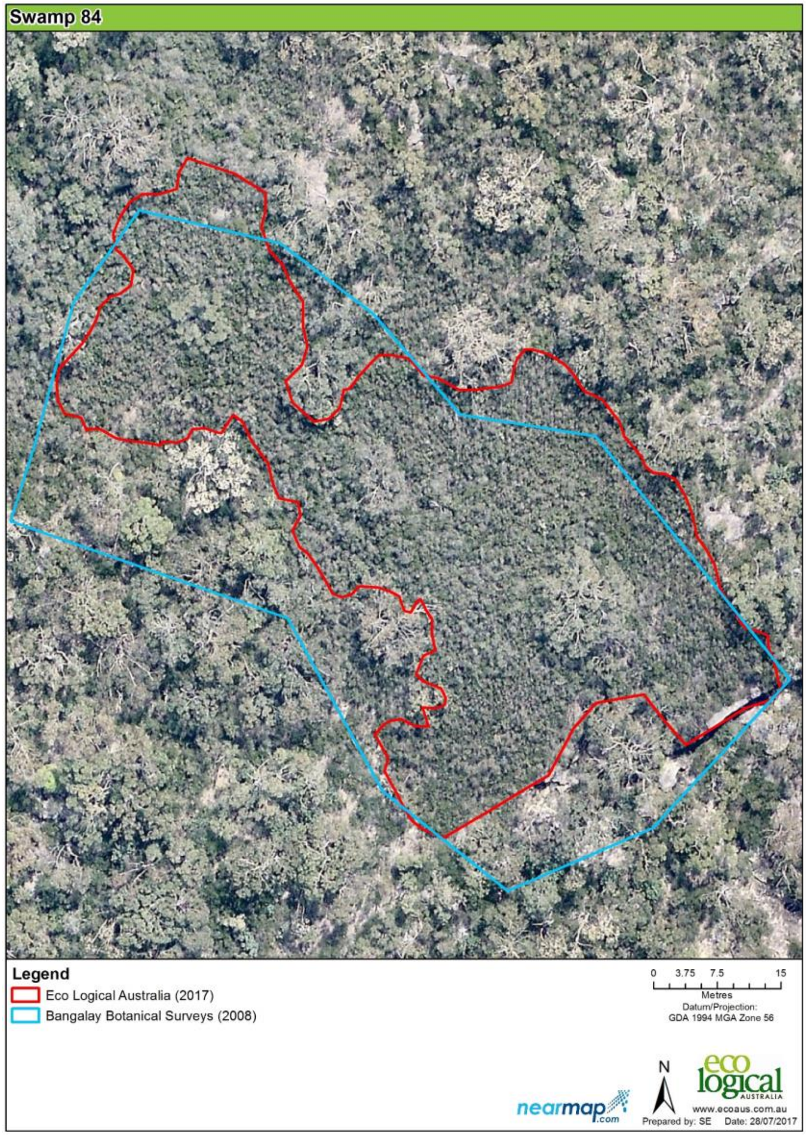
Swamp 83



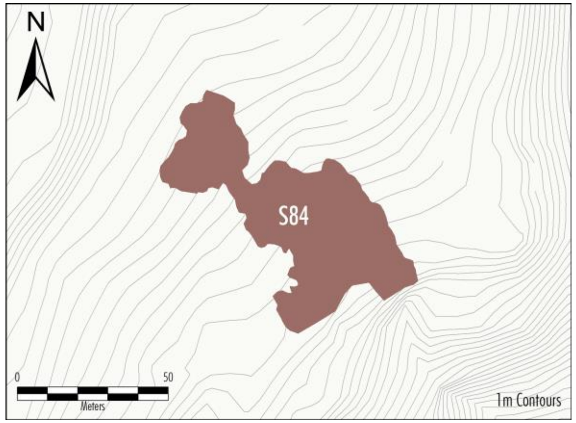
- Swamp 83 is a valley side swamp 0.202 ha in area.
- This swamp was previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) though field inspections confirmed the presence of Banksia Thicket vegetation community across the entire revised extent of this swamp.
- Fire history: burnt 1986-1987.
- This swamp is characterised as having a dense shrub layer (Banksia ericifolia subsp. ericifolia*, Leptospermum squarrosum, Baeckea imbricata* and scattered *Hakea teretifolia* up to 2.5 m in height) over a sparse understorey dominated by sedges (*Chordifex fastigiatus, Lepidosperma neesii and Schoenus brevifolius*). *Bauera microphylla* is also common. Some woodland species are present including *Eucalyptus* sp., *Leptospermum trinervium* and *Allocasuarina distyla*
- No terminal step of outcropping sandstone was observed, however outcropping sandstone was present within the swamp.



Swamp 84



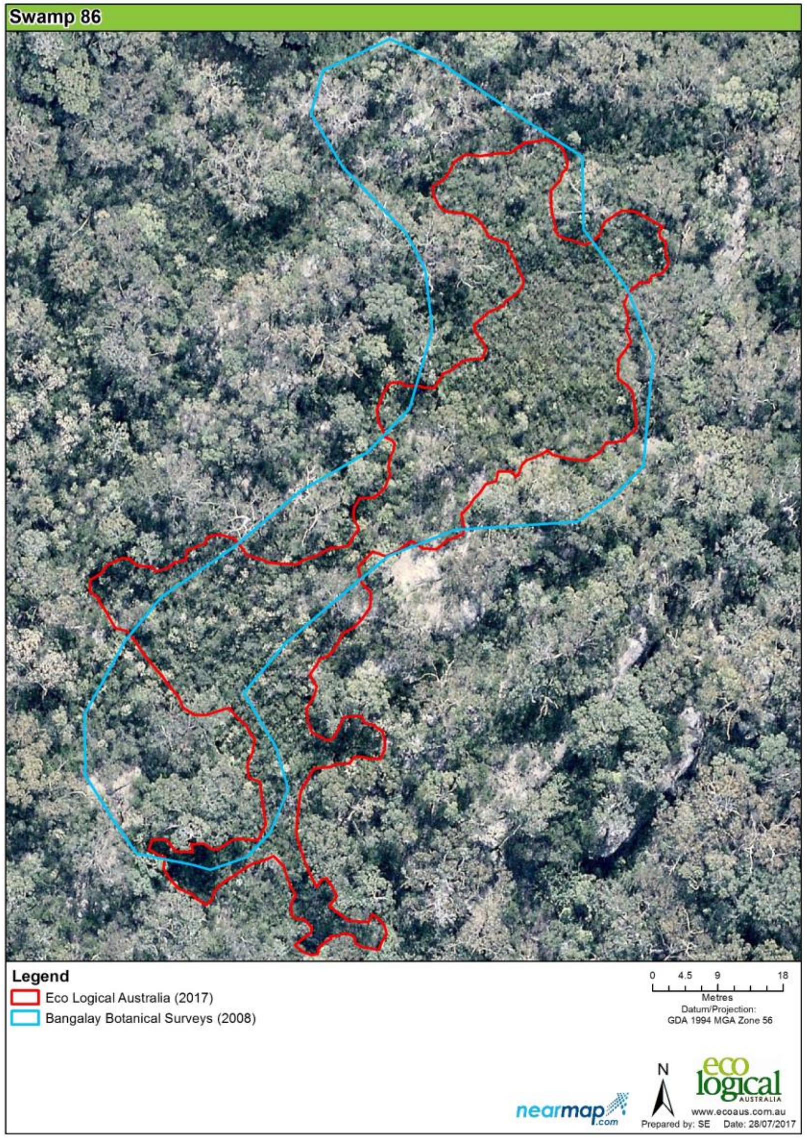
- Swamp 84 is a valley side swamp 0.256 ha in area.
- This swamp was previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008); though field inspections confirmed the presence of Banksia Thicket vegetation community across the entire revised extent of this swamp. The boundaries of this swamp are not well defined and woodland species are interspersed within this community.
- Fire history: unknown, greater than 30 years.
- This swamp is characterised by canopy species of *Angophora costata*, *Eucalyptus piperita*, *Corymbia gummifera* and *E. luehmanniana*, and shrub species including *Allocasuarina distyla*, *Persoonia pinifolia*, *Isopogon anethifolius*, *Grevillea diffusa*, *G. sphacelata* and *Boronia ledifolia*.
- Sandstone outcrops are present and a drainage line is located downslope of this area.



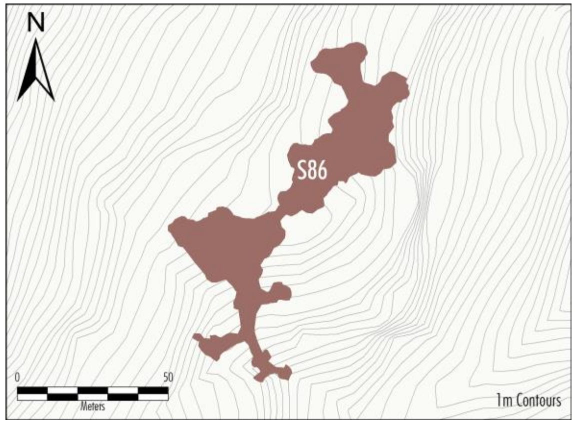
Swamp 85

- Swamp 85 mapped by Bangalay Botanical Surveys (2008) is located on a steep south-east facing slope.
- This swamp was previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) however from aerial photography and field inspection it is considered that this area is more akin to Sandstone Gully Apple-Peppermint Forest as described by Bangalay Botanical Surveys (2008).
- Fire history: unknown, greater than 30 years.
- Area: not mapped.
- The vegetation is characterised by a canopy dominated by Angophora costata, with an understorey comprising the shrubs *Banksia ericifolia* subsp. *ericifolia*, *B. marginata*, *B. serrata*, *Woollsia pungens*, *Grevillea diffusa* and *Persoonia pinifolia*, and a ground layer of sedges and grasses including *Lepyrodia scariosa* and *Entolasia stricta*.
- Swamp boundaries have not been mapped in this instance as it is not a swamp. Rather, the vegetation is comprised of Sandstone Gully Apple-Peppermint Forest.

Swamp 86



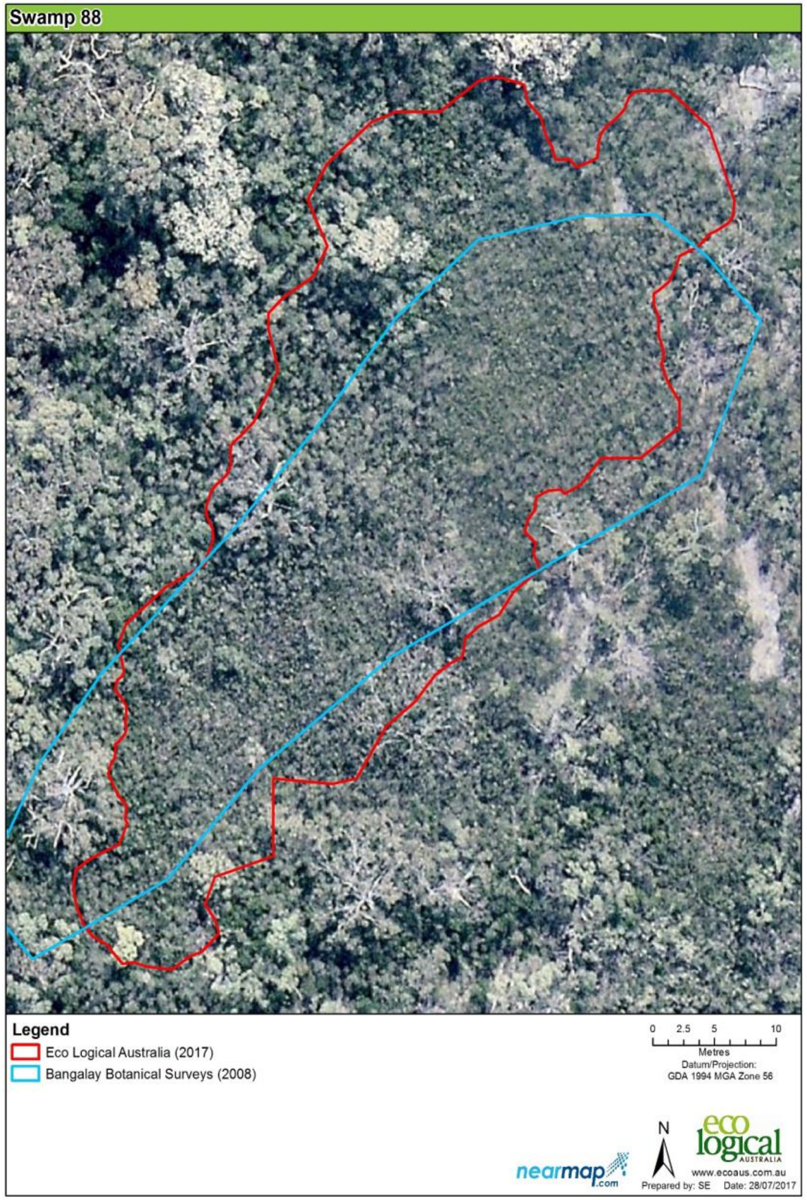
- Swamp 86 is a valley side swamp 0.209 ha in area.
- This swamp was previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) though field inspections confirmed the presence of Banksia Thicket vegetation community across the entire revised extent of this swamp. The boundaries of this swamp are not well defined and woodland species of the Apple-Peppermint Gully Forest are interspersed within this community.
- Fire history: unknown, greater than 30 years.
- This swamp is characterised by the presence of scattered canopy trees of *Angophora costata* and *Eucalyptus piperita* over a dense shrub layer of *Banksia ericifolia* subsp. *ericifolia*, *Leptospermum squarrosum* and *Hakea teretifolia* up to 5 m in height. Other shrub species include *Banksia serrata, Logania albiflora, Hakea dactyloides* and *Leptospermum trinervium.* The understorey is dominated by smaller shrubs and sedges (*Hibbertia riparia* and *Lepyrodia scariosa, Lepidosperma filiforme* and *L. neesii*).
- No terminal step was observed.



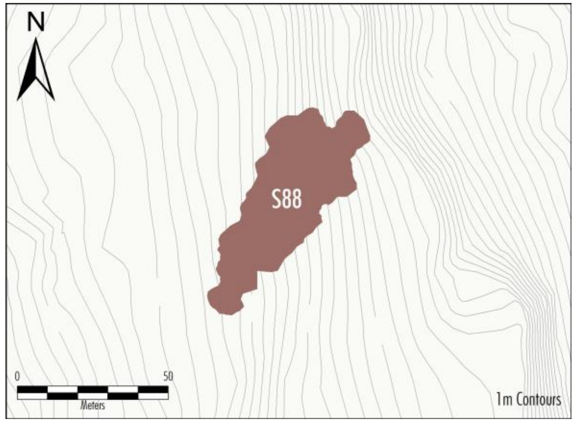
Swamp 87

- This swamp was previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) though aerial photography and field inspections confirmed that this swamp is a good example of the Sandstone Gully Apple-Peppermint Forest located in a valley containing a drainage line.
- Fire history: unknown, greater than 30 years.
- Area: not mapped
- The vegetation is characterised by a canopy dominated by *Angophora costata* and *Eucalyptus piperita* over a shrub layer dominated by *Banksia ericifolia* subsp. *ericifolia, Doryanthes excelsa, Ceratopetalum gummiferum* and *Banksia serrata.*
- A terminal step was not observed.
- Swamp boundaries have not been mapped in this instance as it is not a swamp. Rather, the vegetation is comprised of Sandstone Gully Apple-Peppermint Forest.

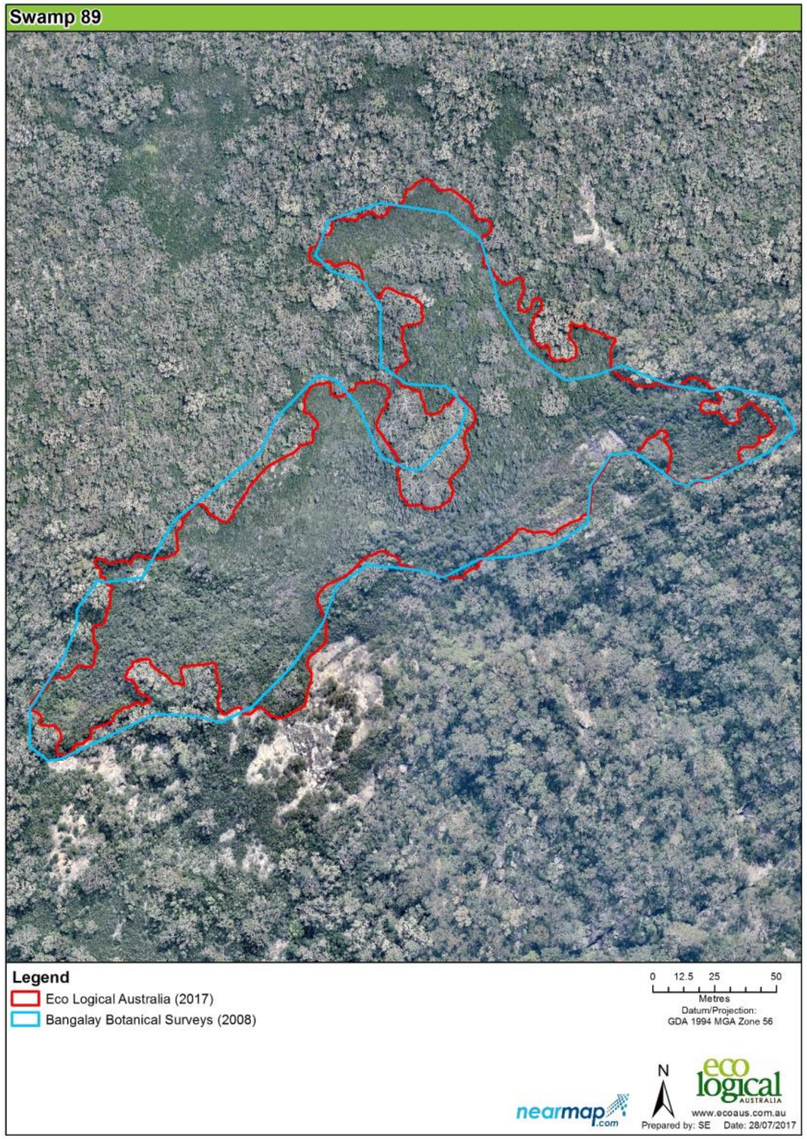
Swamp 88



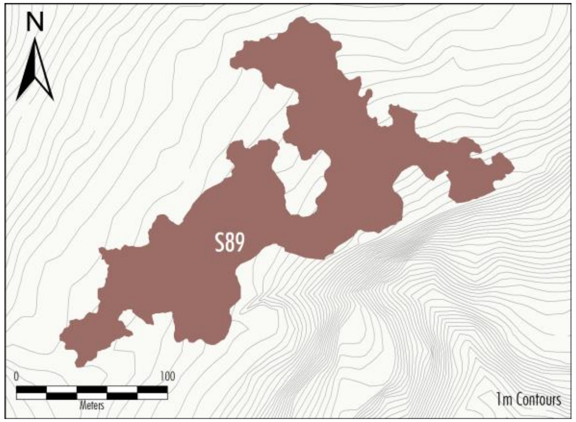
- Swamp 88 is a valley side swamp 0.164 ha in area.
- This swamp was previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) though field inspections confirmed the presence of Banksia Thicket vegetation community across the entire revised extent of this swamp.
- Fire history: burnt 1993-1994.
- This swamp is characterised as having a tall dense shrub layer of *Banksia ericifolia* subsp*. ericifolia, Leptospermum squarrosum* and scattered *Hakea teretifolia* up to 4.5 m in height over a comparatively dense understorey dominated by sedges (*Empodisma minus, Chordifex dimorphus* and *Leptocarpus tenax*).
- A low sandstone step is present midway through the swamp.



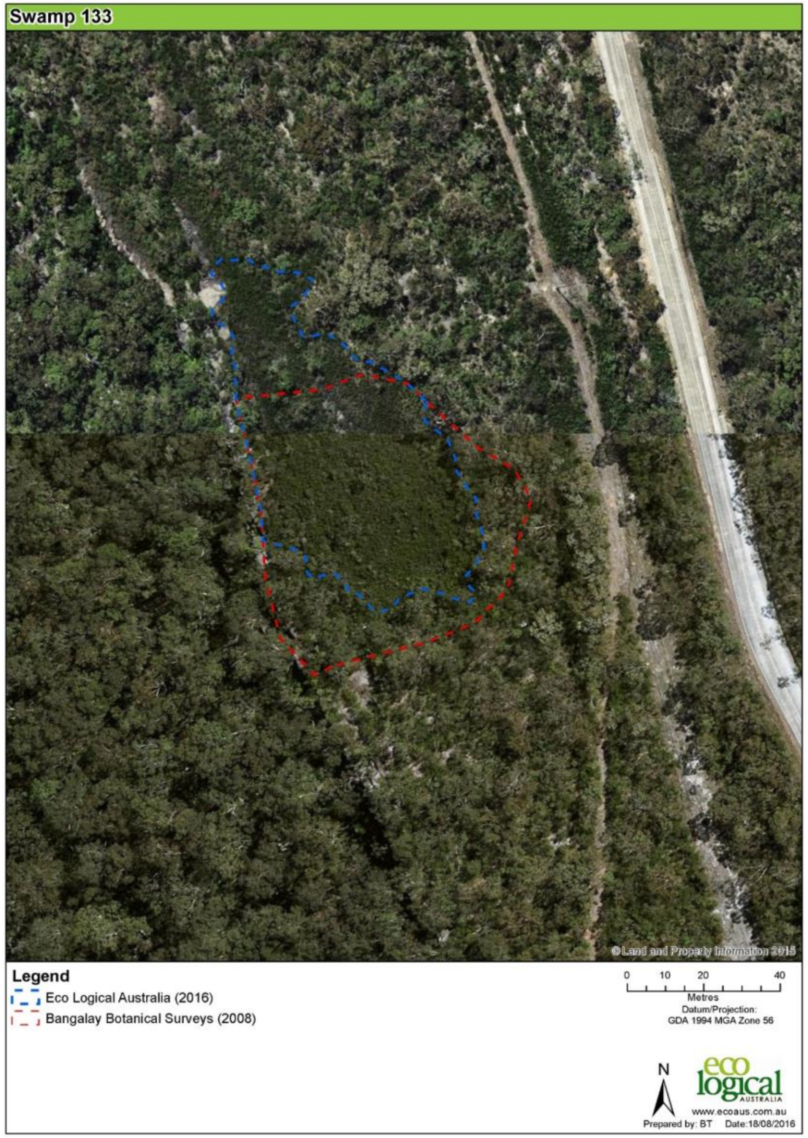
Swamp 89



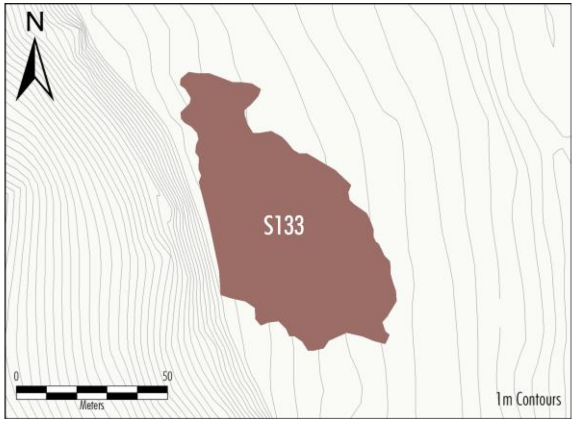
- Swamp 89 is a valley side swamp 1.983 ha in area.
- This swamp was previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) though field inspections confirmed the presence of Banksia Thicket vegetation community across the entire revised extent of this swamp.
- Fire history: burnt 1993-1994.
- This swamp is characterised as having a tall dense shrub layer (*Banksia ericifolia* subsp. *ericifolia, Leptospermum squarrosum* and *Hakea teretifolia* up to 5 m in height) over an understorey dominated by sedges (*Lepidosperma neesii, Empodisma minus* and *Cyathochaeta diandra*). *Bauera microphylla* is also common. Emergent trees are present in low densities and include *Eucalyptus racemosa* and *Corymbia gummifera.*
- An extensive area of sandstone outcropping is present along the south-eastern edge of this swamp where seepage and water flow exiting from the swamp was observed.



Swamp 133

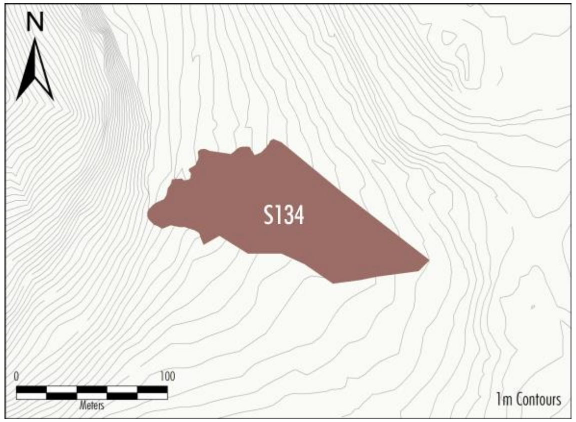


- Swamp 133 is a valley side swamp 0.362 ha in area.
- This swamp was previously mapped as Sedgeland-heath Complex by Bangalay Botanical Surveys (2008) though field inspections confirmed the presence of Banksia Thicket vegetation community across the entire revised extent of this swamp.
- This swamp is characterised as having a tall dense shrub layer (*Banksia ericifolia* subsp. *ericifolia, Hakea teretifolia* and *Leptospermum squarrosum* up to 4 m in height) over a comparatively sparse understorey dominated by sedges (*Lepyrodia scariosa* and *Leptocarpus tenax*). Emergent trees are present in low densities across this swamp including *Eucalyptus racemosa* with *Angophora costata* and *Eucalyptus piperita* occurring on the downslope margin of the swamp.
- A low sandstone cliff line represents the terminal step of this swamp, with seepage commonly observed across the terminal step.



Swamp 134

- Swamp 134 is a valley side 0.891 ha in area.
- This swamp was previously mapped as a combination of Sedgeland-heath Complex and Banksia Thicket by Bangalay Botanical Surveys (2008) though field inspections identified that Banksia Thicket vegetation occurred across the entire revised extent of this swamp.
- This swamp is characterised as having a tall dense shrub layer (*Banksia ericifolia subsp. ericifolia, Hakea teretifolia* and *Leptospermum juniperinum* up to 5 m in height) over an understorey dominated by sedges (*Empodisma minus*, *Lepyrodia scariosa* and *Leptocarpus tenax*). Emergent trees are present in low densities across the swamp including *Eucalyptus racemosa, Angophora costata* and *Eucalyptus piperita*.
- A terminal step comprising a small area of sandstone outcropping is present within this swamp, and seepage was not observed over the step at the time of inspection. The remains of an old vehicular track (which extends across the western edge of this swamp) and an associated table drain are present appearing to have diverted surface flows away from the terminal step.



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HEAD OFFICE
Suite 2, Level 3
668-672 Old Princes Highway
Sutherland NSW 2232
T 02 8536 8600
F 02 9542 5622

CANBERRA
Level 2
11 London Circuit
Canberra ACT 2601
T 02 6103 0145
F 02 9542 5622

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35 Orlando Street
Coffs Harbour Jetty NSW 2450
T 02 6651 5484
F 02 6651 6890

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Suite 1 & 2
49 Ord Street
West Perth WA 6005
T 08 9227 1070
F 02 9542 5622

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16/56 Marina Boulevard
Cullen Bay NT 0820
T 08 8989 5601
F 08 8941 1220

SYDNEY
Suite 1, Level 1
101 Sussex Street
Sydney NSW 2000
T 02 8536 8650
F 02 9542 5622

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19 Bolton Street
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T 02 4910 0125
F 02 9542 5622

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T 02 8081 2685
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F 02 9542 5622

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Mudgee NSW 2850
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F 02 6372 9230

GOSFORD
Suite 5, Baker One
1-5 Baker Street
Gosford NSW 2250
T 02 4302 1221
F 02 9542 5622

1300 646 131
www.ecoaus.com.au

APPENDIX 3

VISUAL INSPECTION AND PHOTOGRAPHIC SURVEY OF STREAMS IN THE VICINITY OF LONGWALLS 304-310

Visual Inspection and Photographic Survey of Streams in the Vicinity of Longwalls 304 to 310

1.0 INTRODUCTION

A visual inspection and photographic survey of streams in the vicinity of Longwalls 304-310 was conducted by Hydro Engineering and Consulting Pty Ltd (HEC) in April 2018 to characterise and document the baseline conditions and prominent features in surface water streams overlying or in the vicinity of Longwalls 304-310 and, on the basis of the field inspections, consider surface water flow, pool water level or surface water quality monitoring.

HEC undertook a similar inspection and photographic survey of streams in the 301 to 303 area in July 2015 during preparation of the Longwalls 301-303 Water Management Plan. This exercise for Longwalls 304-310 expands on the previous HEC (2016)[1] stream survey.

2.0 DESKTOP REVIEW

An east-west divide runs approximately north to south to the east of the Longwalls 304-310 study area, dividing drainages which flow into the Eastern Tributary and the Woronora Reservoir (on the western side) from areas which flow into Wilsons Creek and Cawleys Creek (on the eastern side) (Figure 1).

One metre contours were used to refine the mapping available from the Department of Lands in the vicinity of Longwalls 304-310. The one metre contour mapping generated by Geo-Spectrum (Australia) Pty Ltd[2] was the most detailed mapping available and provided greater accuracy in terms of stream location, alignment and stream network for the field survey. Sixteen streams overlying or in close proximity to Longwalls 304-310 were identified using the one metre contours, as shown on Figure 1 (streams A, B, C, D, E, F, H, I, J, K, L, P, Q, R, S and T).

[1] Hydro Engineering & Consulting (2016). *Visual Inspection and Photographic Survey of Streams in the Vicinity of Longwalls 301 to 303*.

[2] Geo-Spectrum (Australia) Pty Limited (2007). *Orthophotomap (1:7,500) of Helensburgh Coal Metropolitan Colliery*. October 2007 from 1:20,000 Scale. Aerial photography from 27 August 2007. Ground survey by Monaghan Surveyors Pty Ltd.

The locations of stream lines shown in this report (Figure 1) have been adjusted from the locations shown in HEC (2016) so as to be more closely aligned to the valley floor and to reflect the actual stream bed alignment as observed during the reconnaissance surveys. The differences reflect the limitations of mapping produced from aerial photography of densely forested canopy and the difficulties of identifying the location of small first order streams in the underlying complex sandstone morphology.

The main streams that were inspected are shown as solid blue lines in Figure 1. Where tributaries to the streams have been observed, their alignments have been interpreted based on the 1 metre contours and are shown as dashed blue lines on Figure 1.

Streams A, B, C, H, I, J, K and L were considered and inspected as part of HEC's 2015 survey (Table 1).

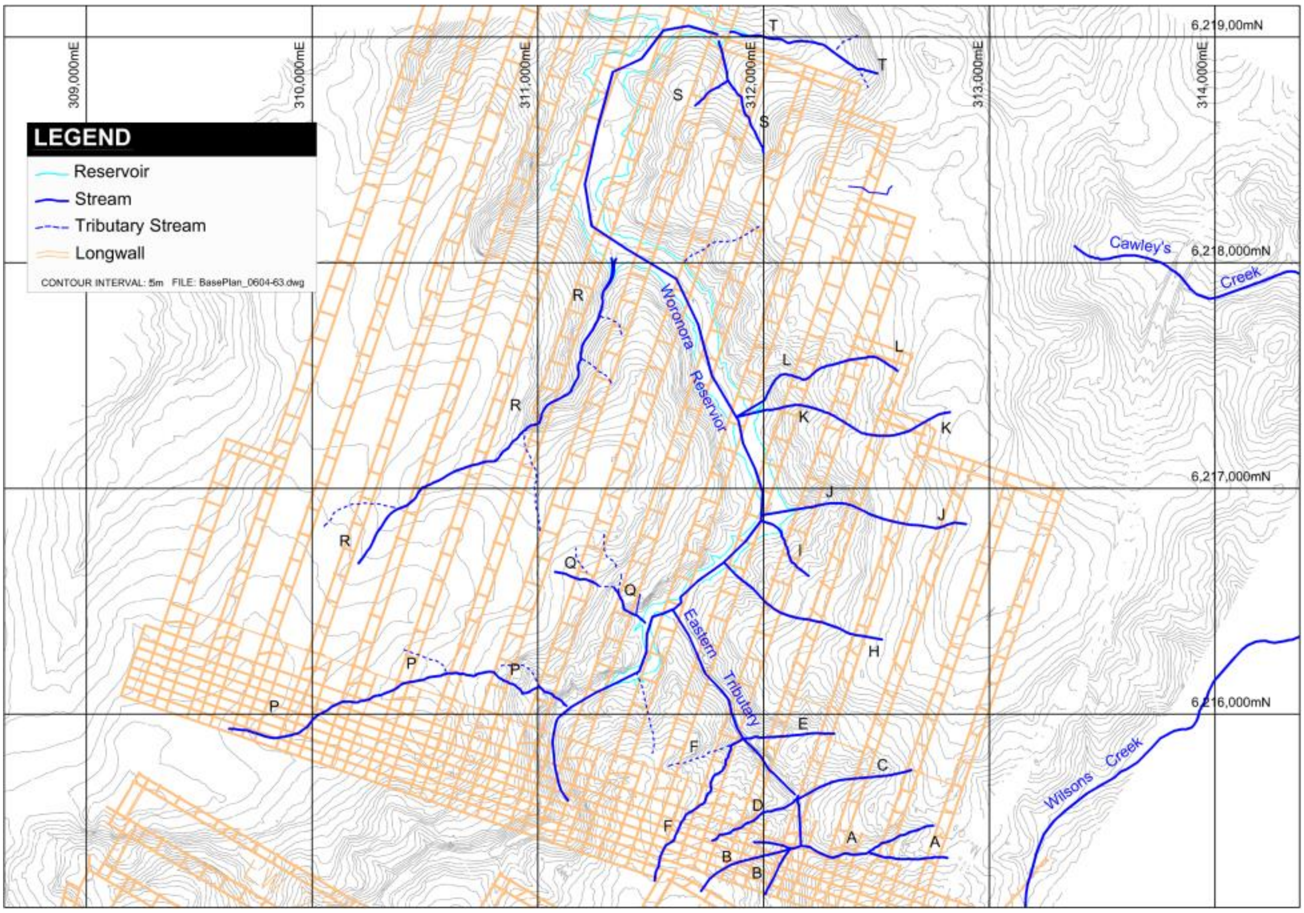


Figure 1 Streams Overlying or Near to Proposed Longwalls 304 to 310[3]

3 Streams J and L shown in Figure 1 were referred to as Streams I and K, respectively, in an earlier draft of the Longwalls 301-303 reconnaissance report. Streamflow monitoring stations have been installed on these streams as a component of the Woronora Reservoir Impact Strategy.

Details of the streams overlying or near to Longwalls 304-310 are summarised in Table 1 below.

Table 1 Stream Reconnaissance Summary

Stream Label	Stream Order*	Comments
A	2	Previously inspected (HEC, 2016)
B	2	Previously inspected (HEC, 2016)
C	1	Previously inspected (HEC, 2016)
D	1	Inspected April 2018
E	1	Previously inspected (HEC, 2016)
F	2	Inspected April 2018
H	1	Previously inspected (HEC, 2016)
I	1	Previously inspected (HEC, 2016)
J	1	Previously inspected (HEC, 2016)
K	1	Previously inspected (HEC, 2016)
L	1	Previously inspected (HEC, 2016)
P	2	Inspected April 2018
Q	2	Inspected April 2018
R	2	Inspected April 2018
S	2	Inspected April 2018
T	2	Inspected April 2018

2.0 FIELD CONDITIONS

The stream reconnaissance was conducted between the 9th and 13th of April 2018. The weather was fine during the course of the reconnaissance. The period leading up to the reconnaissance had relatively low rainfall (refer Figure 2). January and early February experienced unusually low rainfall with only minor falls being recorded through to late February. Two moderate rainfall events on the 20th and 26th of February (44 and 47.5 mm respectively) were recorded at Metropolitan Coal's pluviometer PV7. Following these events there was no significant rainfall recorded until the 21st of March when a total of 96.5 mm was recorded between the 21st and 23rd of March. There was no significant rainfall recorded between the 23rd of March and the reconnaissance survey – indicated by the red lines on Figure 2. Flow in the surface catchments would therefore have been in recession from the 21st to the 23rd March rainfall event.

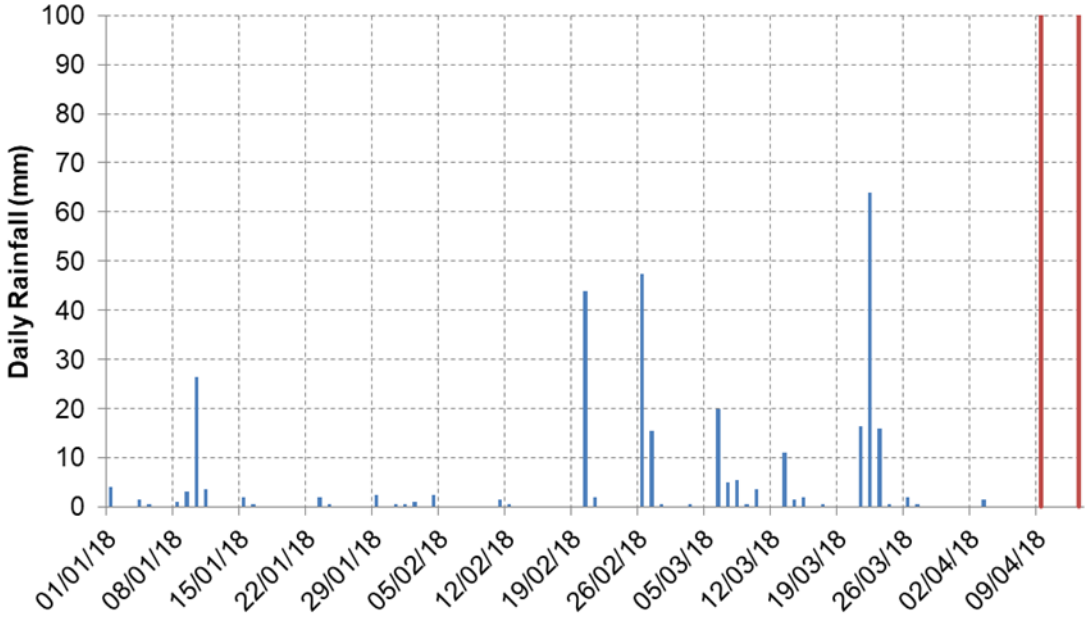


Figure 2 Rainfall Recorded at PV7 January to April 2018

Groundwater-fed baseflow in streams responds to dominant wetting (aquifer recharging) and drying (aquifer discharging) cycles. These cycles are typically evident in rainfall residual plots which can be correlated to periods when aquifers are predominantly recharging when groundwater levels are rising; and periods when aquifers are discharging and groundwater levels are declining. Figure 3 shows the rainfall residual for the period 1st January 2000 to 31st April 2018 derived from the rainfall record from the Bureau of Meteorology rain gauge at Darkes Forest – Station 68024. Periods where the residual rainfall curve is trending upward correspond to above average rainfall. Periods where the residual rainfall line decreases (slopes downward) reflect below average rainfall. The reconnaissance, shown by the vertical red line, was conducted during a pronounced drying period. The steep downward trend in the rainfall from mid-2017 indicates drying catchment conditions with declining groundwater outflows to streams (compared to the average) in the lead-up to the survey. The rainfall residual over this period is sloping unusually steeply downward for a prolonged period indicating likely low groundwater outflows to streams from groundwater sources.

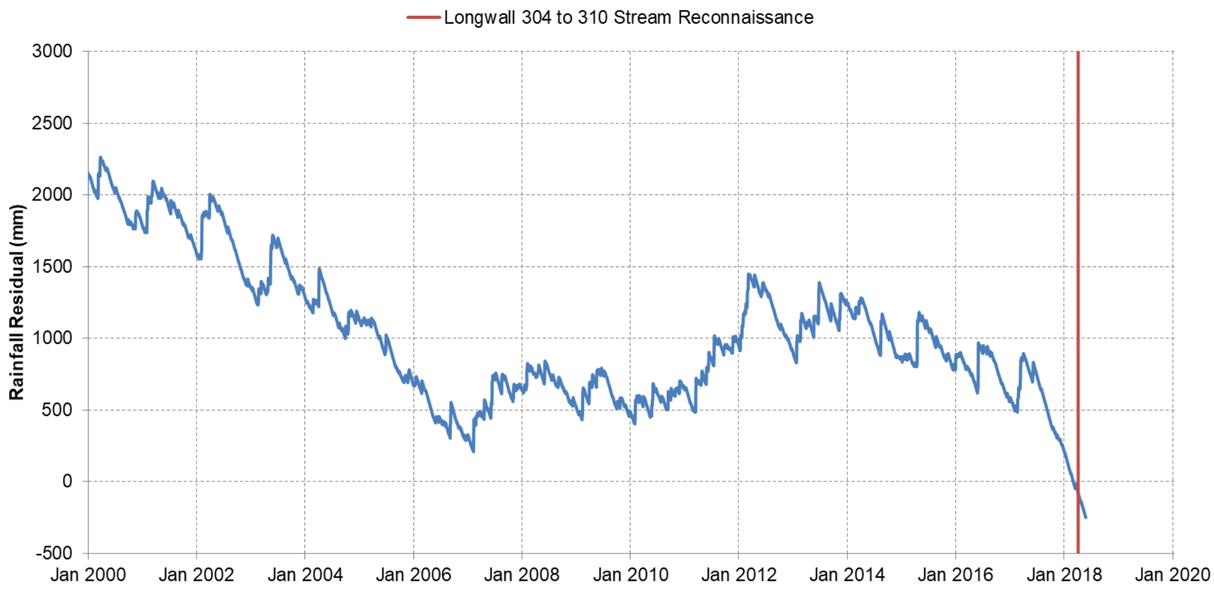


Figure 3 Darkes Forest Rainfall Residual Plot, January 2000 to May 2018

The water level in the Woronora Reservoir was about 5.4 m below the full supply level during the survey.

3.0 METHODOLOGY

Reconnaissance of the streams involved walking along the accessible length of the streams, mapping the geomorphic characteristics and features of the streams and compiling a photographic record. The observed features and mapping of each stream are shown and described in Section 4 and photographs of the features are provided in Attachment A.

Stream features have been mapped using the following alphabetic symbols:

(US) Upland swamp

(WF) Waterfall of at least 2 m near vertical drop.

(BC) Boulder cascade comprising a steep chute of boulders. Water would be highly aerated by rapid flow over and through spaces between the boulders.

(BF) Boulder field comprising an extended section of boulders with low flows passing through the interstices between the boulders and which acts to control upstream water level

(RS) Rock shelf comprising a hard and relatively smooth rock outcrop often containing shallow depression(s).

(RC) Rock cascade a steep chute of predominately cobbles and gravel sized bed sediment.

(P_s) Small pool between 1 m and 3 m long and less than 0.3 m deep. These features would likely be transient but persist for some time following cessation of flow.

(P_m) Medium sized pool larger than a small pool and typically 3 m to 5 m long and around 0.5 m deep. The largest pool observed was estimated to be less than 5 m long and less than 1 m deep at its deepest. These pools would be expected to retain ponded water under most climatic conditions.

(P_l) Large pool longer than 5 m and greater than 0.5m deep.

4.0 RESULTS OF STREAM RECONNAISSANCE

4.1 Stream D

Stream D comprised a small first order stream which drained into Eastern Tributary (Figure 4) adjacent to the flow monitoring flume at Pool ETAU.

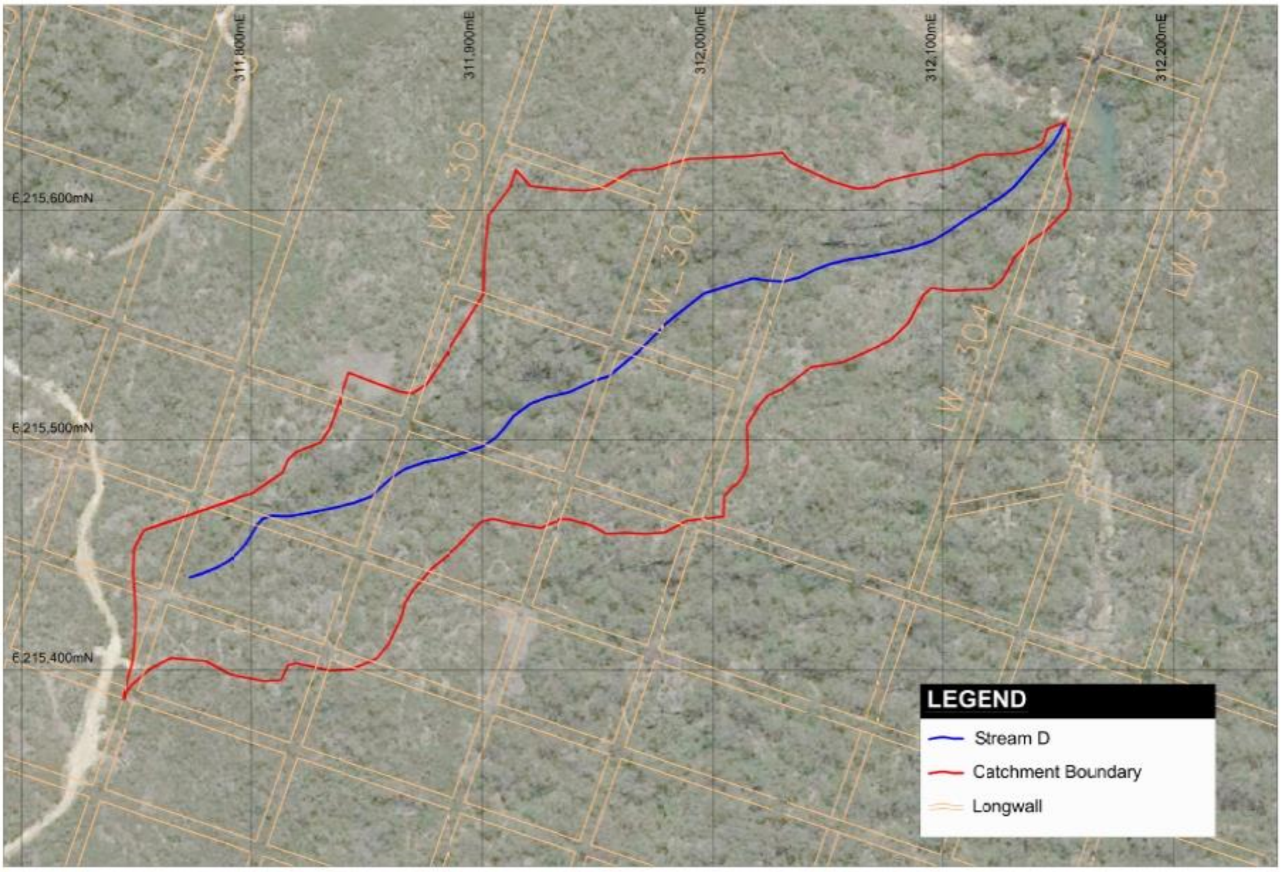


Figure 4 Stream D Catchment

There was no flow or significant water observed within the stream at the time of the reconnaissance. The upper sections comprised small localized and discontinuous drainage lines and depressions. The middle and lower sections of the stream comprised a steep incised channel with boulder cascades interspaced with rock shelves and shallow depressions – refer Figure 5. A summary of the catchment characteristics is provided in Table 2 below.

Table 2 Catchment Characteristics Stream D

Feature	Value
Stream order	1st
Catchment area (km^2)	0.04
Stream length (km)	0.45
Average gradient (%)	13.5

The observed features in Stream D are shown on Figure 5.

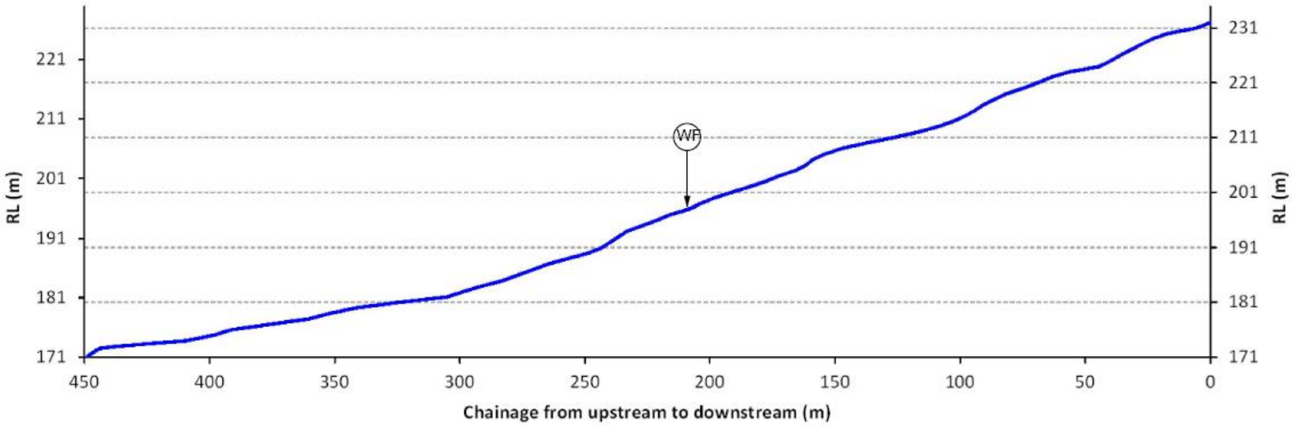


Figure 5 Features in Stream D

4.2 Stream F

Stream F is a longer stream which is joined by a one shorter stream near the inflow to the reservoir. The upper sections on the longer stream comprised a densely vegetated upland swamp – refer Figure 6 and 7. The only surface drainage features observed with in the swamp comprised discontinuous depressions in the topographic "low" points of the swamp. The swamp terminated at an extensive rock bar. There was a trickle of water overflow on one section of the rock bar. Moss and stain markings on the rock bar however suggested that larger overflows would have occurred frequently in the past.

The reach downstream of the swamp comprised a series of rock cascades, small waterfalls, instream pools, rock shelves and sections of straight incised channel. Small semi-continuous flow was observed along the downstream reach. The instream pools became larger and more dominant in the lower sections of the stream.

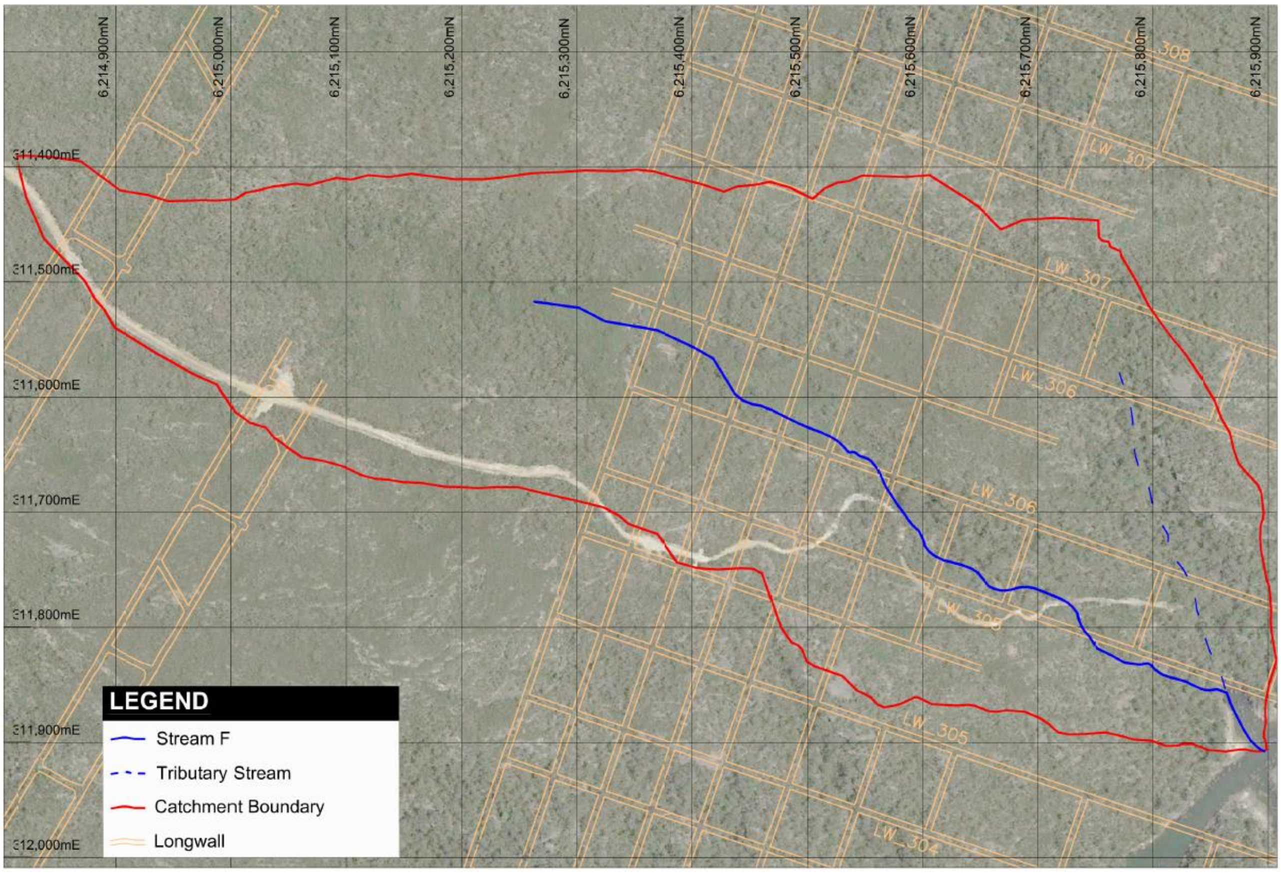


Figure 6 Stream F Catchment

The observed features in Stream F are shown in Figure 7.

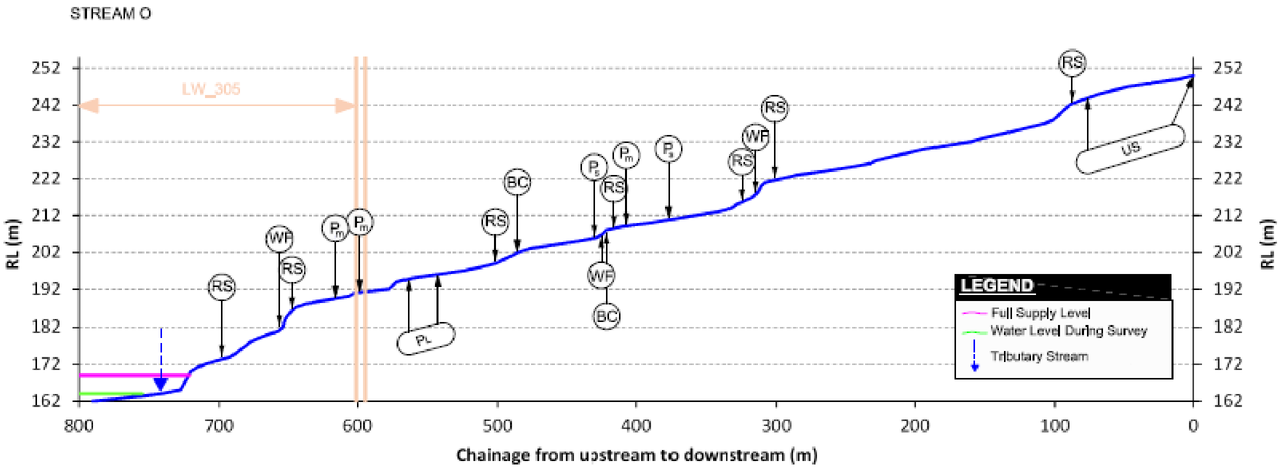


Figure 7 Features in Stream F

A summary of the catchment characteristics is provided in Table 3 below.

Table 3 Catchment Characteristics Stream F

Feature	Value
Stream order	2nd
Catchment area (km²)	0.324
Stream length (km)	0.80
Average gradient of upland swamp (%)	8.2
Average gradient downstream of swamp (%)	7.6

4.3 Stream P

Stream P comprised a long stream with shorter tributary streams which flowed into the stream near the reservoir – refer Figure 8. The upper sections of the main (longer) arm comprised a densely vegetated upland swamp. The only surface drainage features observed with in the swamp comprised discontinuous depressions in the topographic "low" points of the swamp. The swamp terminated at an extensive rock bar. There was no overflow evident on the rock bar. Desiccated moss and staining markings on the rock bar suggested that overflows would have occurred frequently in the past and that the swamp would contribute flow to downstream reaches.

The reach on the main arm downstream of the swamp comprised a series of rock and boulder cascades, small waterfalls, instream pools, rock shelves and sections of straight incised channel. Small semi-continuous flow[4] was observed along the downstream reach. The instream pools became larger and more dominant in the lower sections of the stream. The lower reach of shorter arm was also inspected. It comprised a series of dry boulder cascades and rock chutes – refer Figure 9.

4 Flow disappeared from view in the boulder cascades where it flowed along the base of the loose boulder field. Flow also disappeared from view in the sandy delta which had formed where the stream flowed into the reservoir.

Figure 8 Stream P Catchment

The observed features in Stream P are shown in Figure 9.

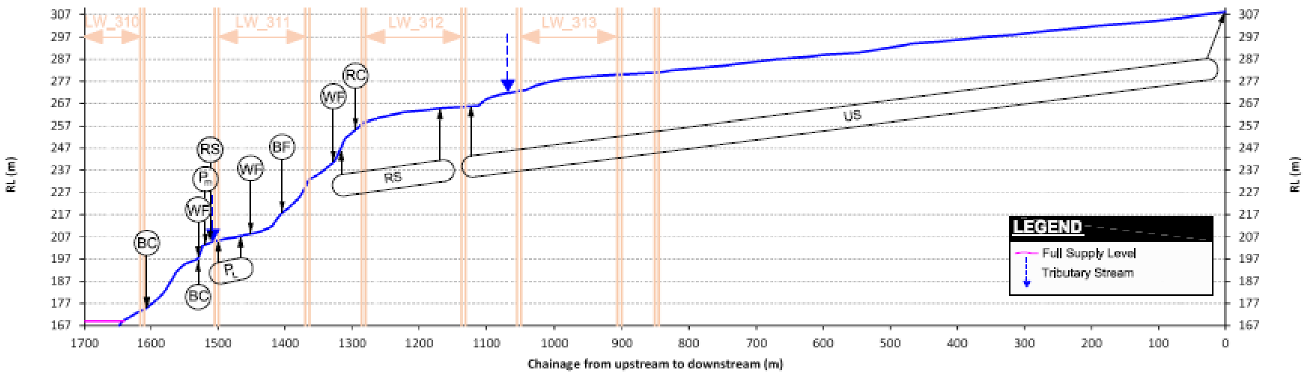


Figure 9 Features in Stream P

A summary of the catchment characteristics is provided in Table 4 below.

Table 4 Catchment Characteristics Stream P

Feature	Value
Stream order	2nd
Catchment area (km²)	0.864
Stream length main arm (km)	1.65
Stream length shorter arm (km)	1.62
Average gradient of upland swamp (%)	3.7
Average gradient downstream of swamp (%)	8.8

4.4 Stream Q

Stream Q comprised a small semi-continuous stream with small tributaries joining in three locations – refer Figure 10. The upper reaches comprised an ill-defined drainage path in a moderately steep gully. There was no water observed upstream of a significant waterfall which was partially obscured by dense vegetation. Access to the lower reaches of the stream was deemed too dangerous and completion of the planned reconnaissance of the lower sections of the creek was abandoned due to safety concern with very dense vegetation potentially obscuring steep drops.

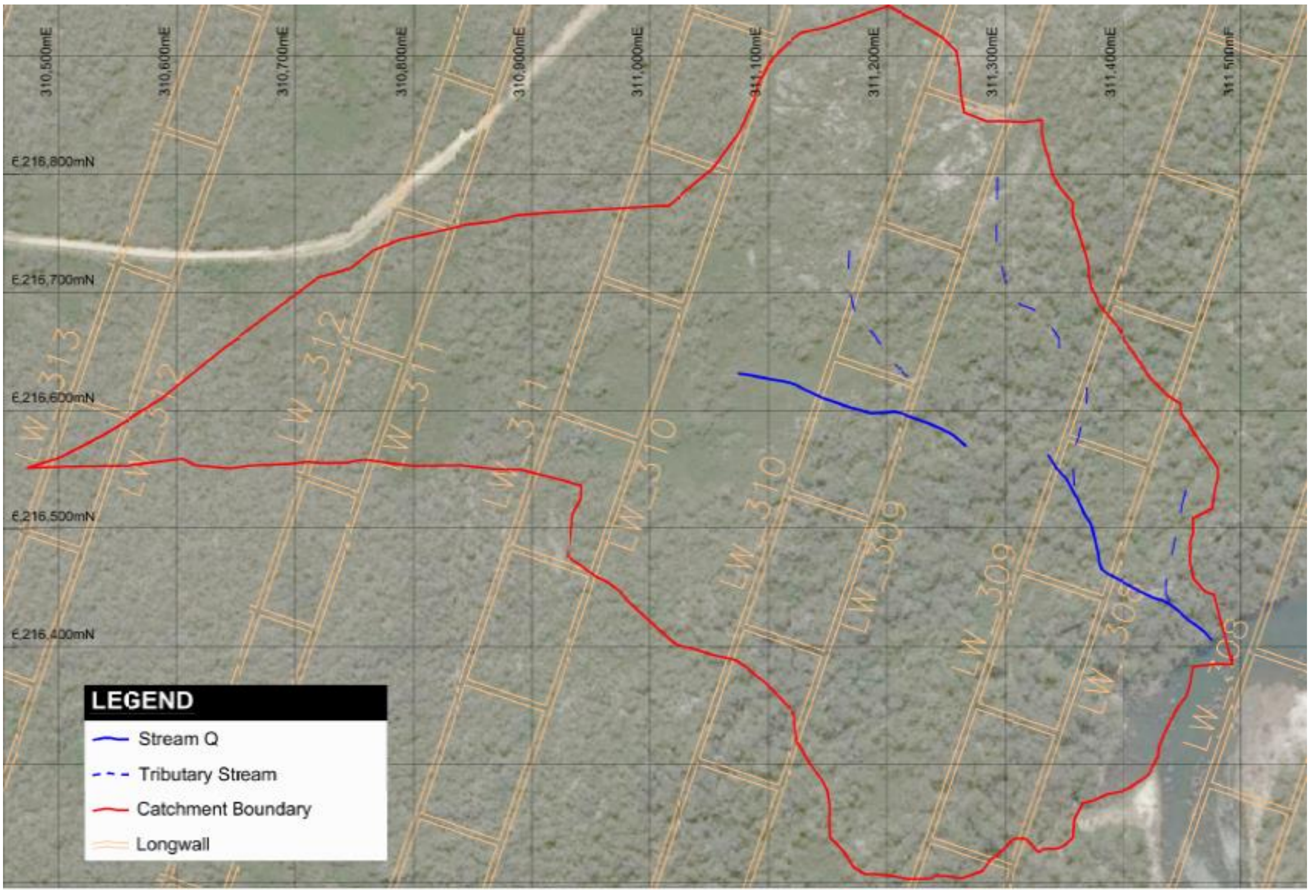


Figure 10 Stream Q Catchment

The observed features in Stream Q are shown in Figure 11.

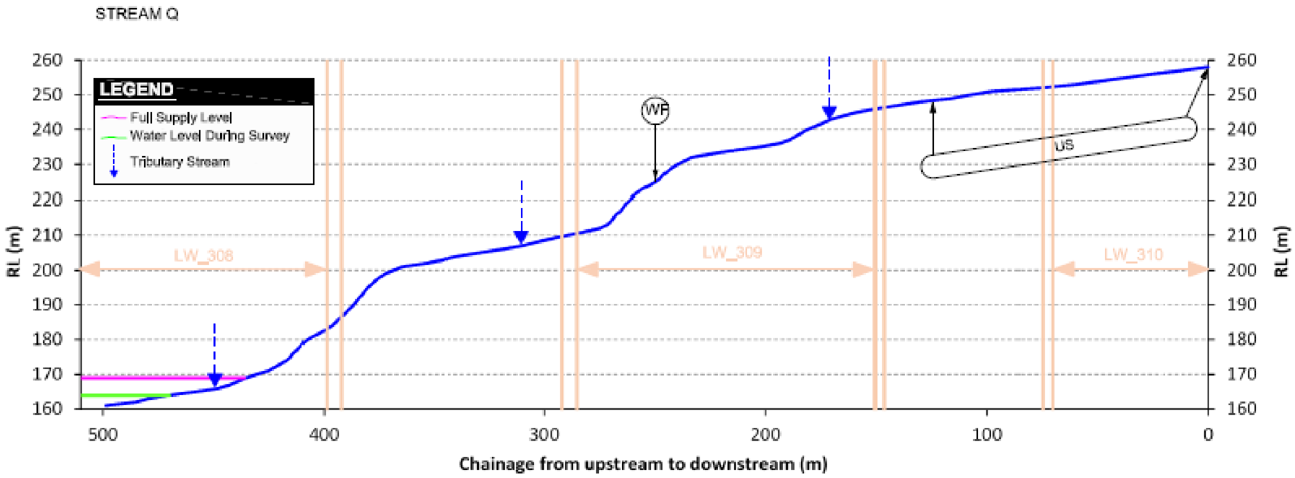


Figure 11 Stream Q Features

A summary of the catchment characteristics is provided in Table 5 below.

Table 5 Catchment Characteristics Stream Q

Feature	Value
Stream order	2nd
Catchment area (km²)	0.329
Stream length (km)	0.50
Average gradient (%)	19.1

4.5 Stream R

Stream R originates in an upland swamp and becomes a second order stream following inflow of a smaller stream line some 300m upstream of its outlet into the Woronora Reservoir – refer Figures 12 and 13.

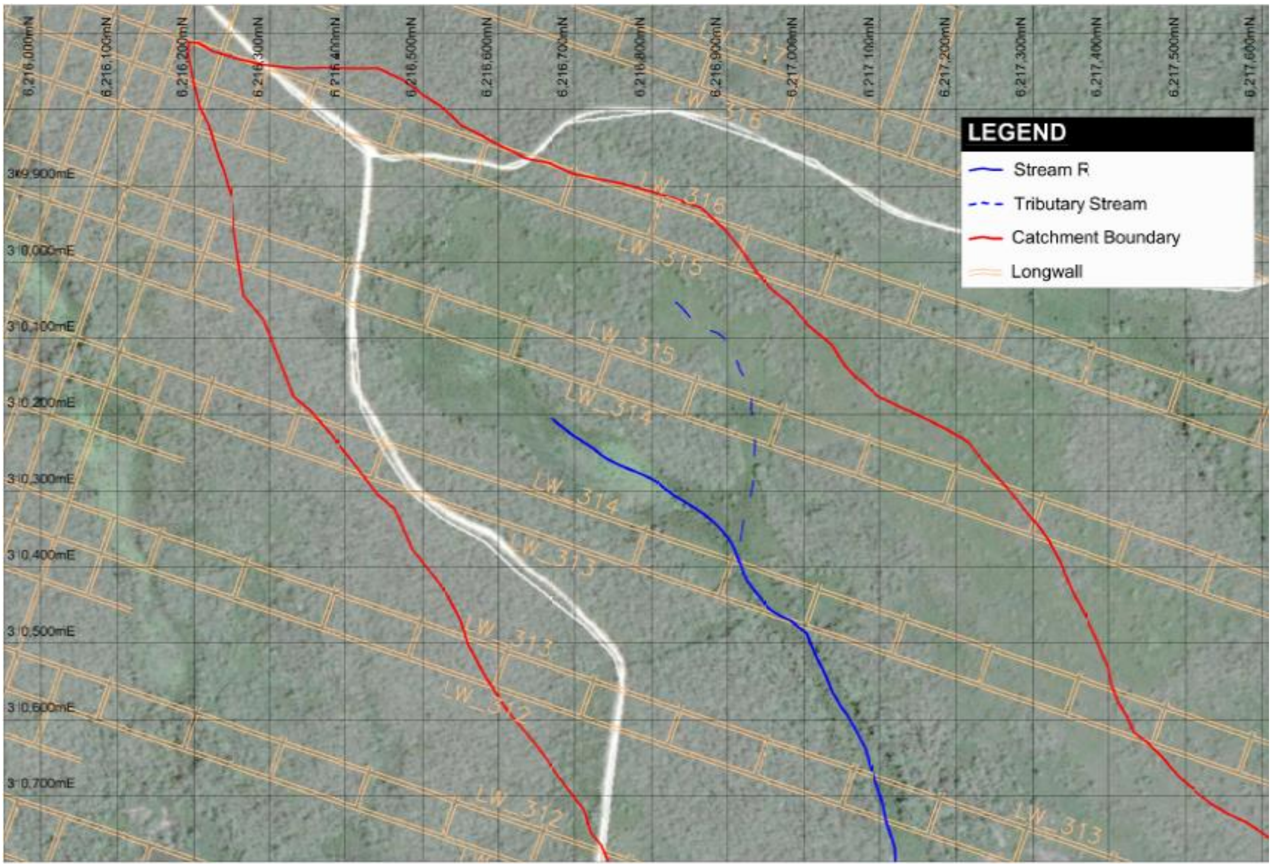


Figure 12 Stream R Upper Catchment

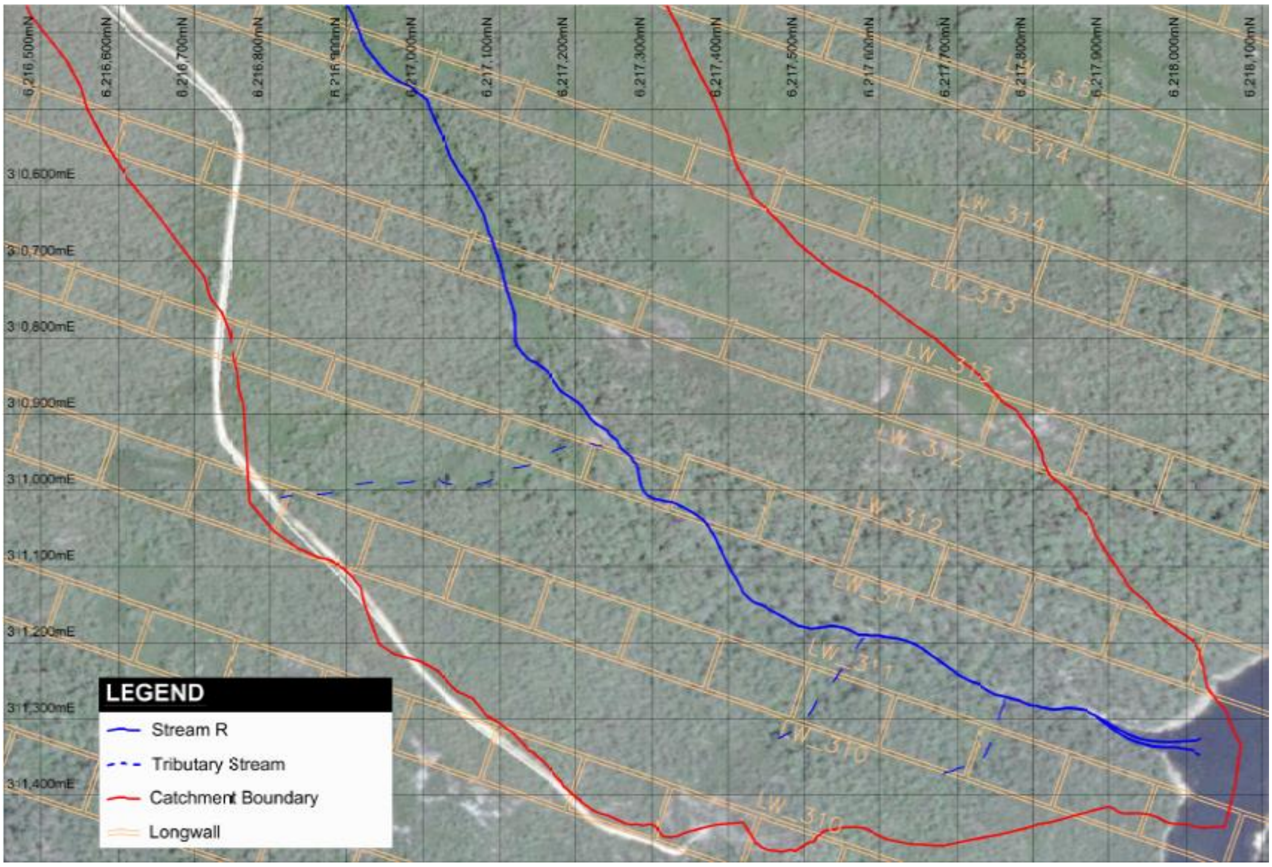


Figure 13 Stream R Lower Catchment

The upper reach comprised a large upland swamp. Swamp vegetation was very dense and inhibited access. The sections of the swamp accessed during the survey indicate it was similar to the swamps in the upstream reaches of Streams O and P with an ill-defined and discontinuous flow path. The swamp terminated at a large rock bar. There was no discernible flow over the rock bar however as with the other swamps it was apparent that there would be surface water flowing out of the swamp during wet periods. Downstream of the swamp the stream gradient changed with the stream morphology becoming more incised and comprising a series of rock and boulder cascades and waterfalls interspersed by pools and rock shelves. A continuous flow was observed in the lower reaches where relatively closely spaced pools become the dominant feature.

The tributary stream which flowed into the main arm some 250 m upstream of the outfall into Woronora Reservoir was dry. The largest pools downstream of this confluence were up to 25 m long which formed in depressions between low rock bars. The observed features in Stream R are shown in Figure 14.

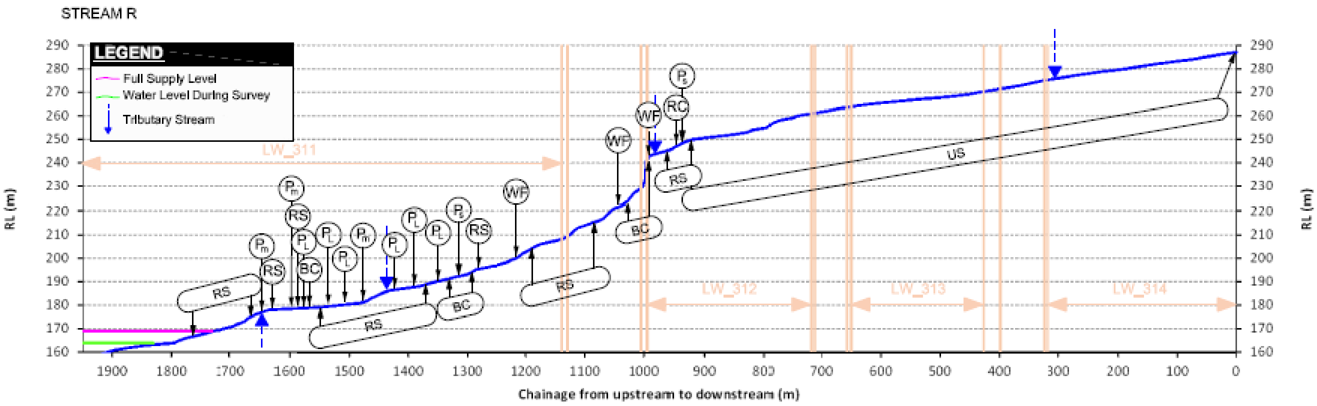


Figure 14 Stream R Features

A summary of the catchment characteristics is provided in Table 6 below.

Table 6 Catchment Characteristics Stream R

Feature	Value
Stream order	2nd
Catchment area (km²)	1.401
Stream length (km)	1.90
Average gradient (%)	6.7

4.6 Stream S

Stream S is joined by a small stream which flowed through a confined valley – refer Figure 15. The upper sections comprised a steep, gully form with ill-defined drainage channels and boulder cascades. Several pools were observed in the lower reaches with two medium pools near the confluence of the two arms of the stream. There was no significant flow observed and no visible flow at either the stream confluence or at the outflow to the Woronora Reservoir.

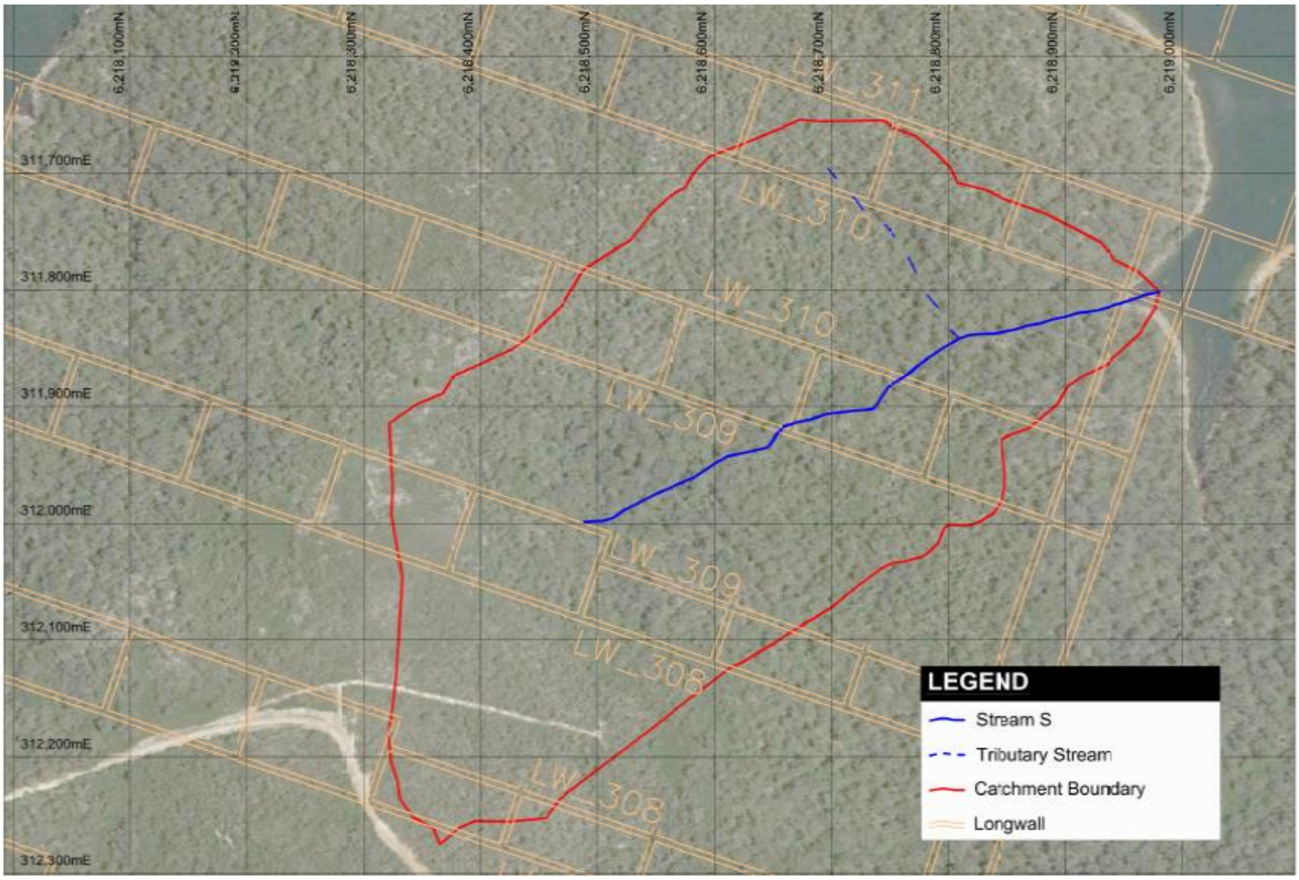


Figure 15 Stream S Catchment

The observed features in Stream S are shown in Figure 16.

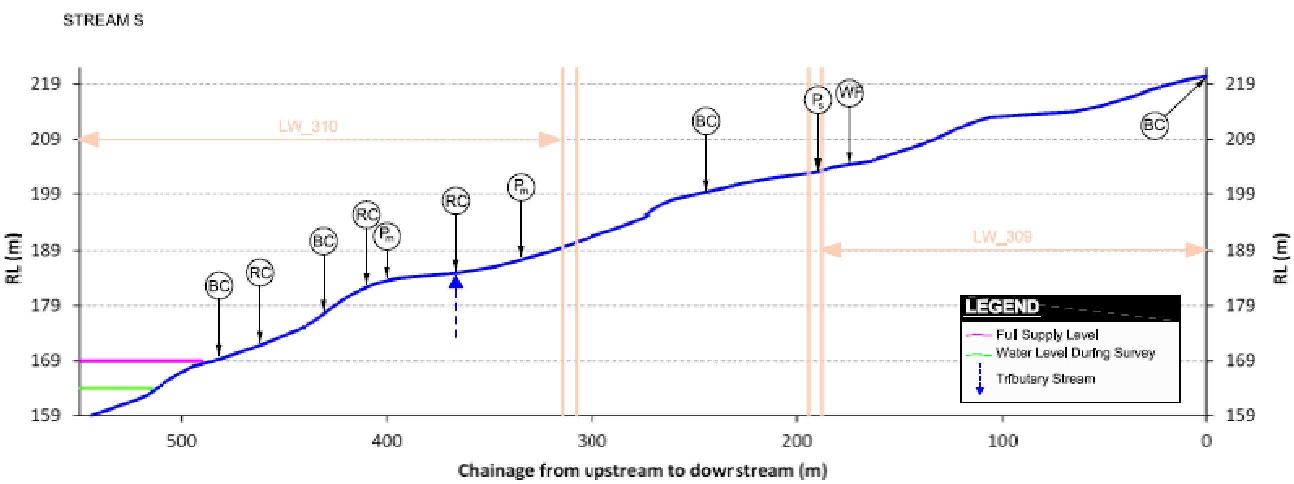


Figure 16 Stream S Features

A summary of the catchment characteristics is provided in Table 7 below.

Table 7 Catchment Characteristics Stream S

Feature	Value
Stream order	2nd
Catchment area (km²)	0.224
Stream length (km)	0.55
Average gradient (%)	11.3

4.7 Stream T

Stream T is a small second order stream – refer Figure 17. The stream morphology is similar to Stream S. There was a small continuous flow in the lower reaches of the stream which carried through to the Woronora Reservoir. The medium and larger pools mapped were larger than those observed in Stream S.

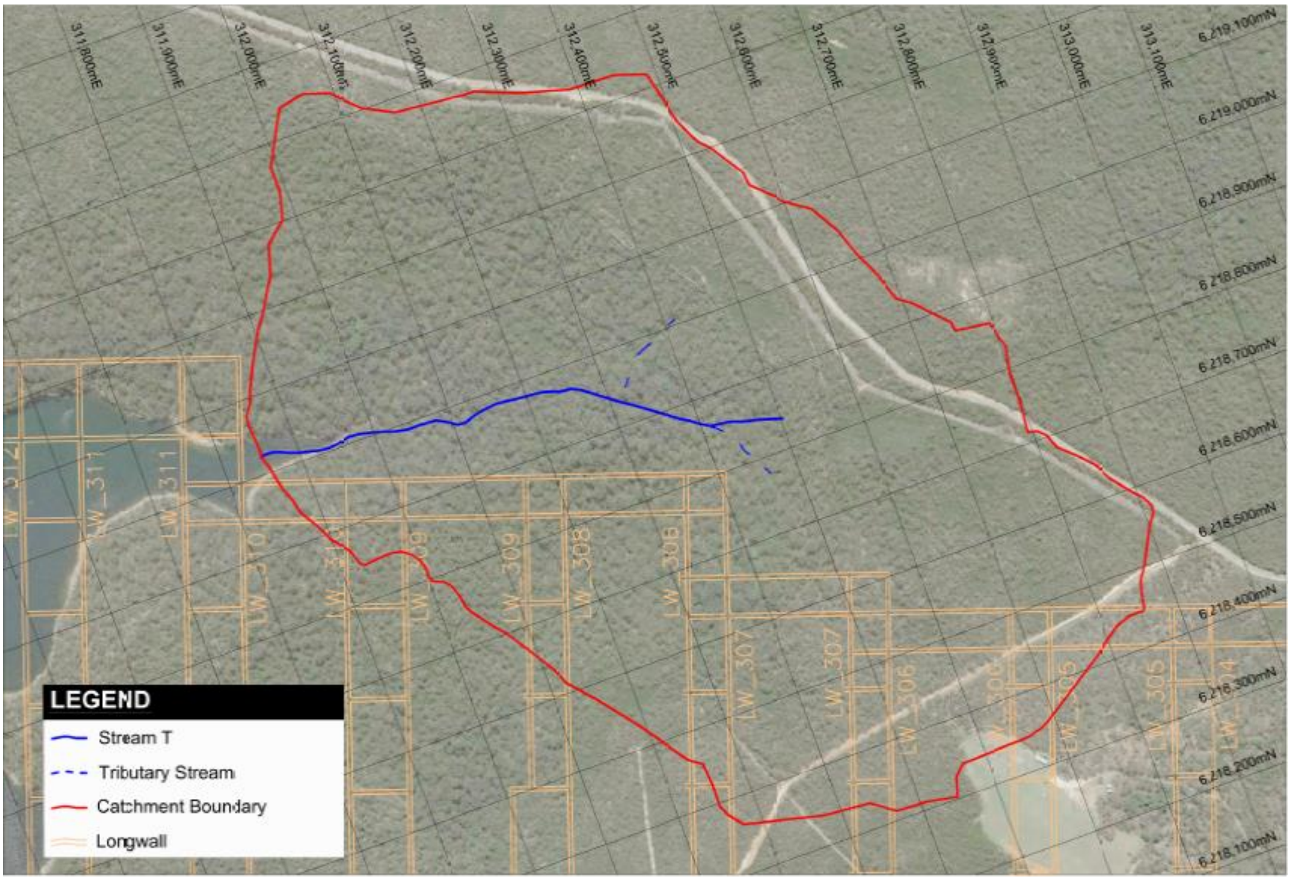


Figure 17 Stream T Catchment

The observed features in Stream T are shown in Figure 18.

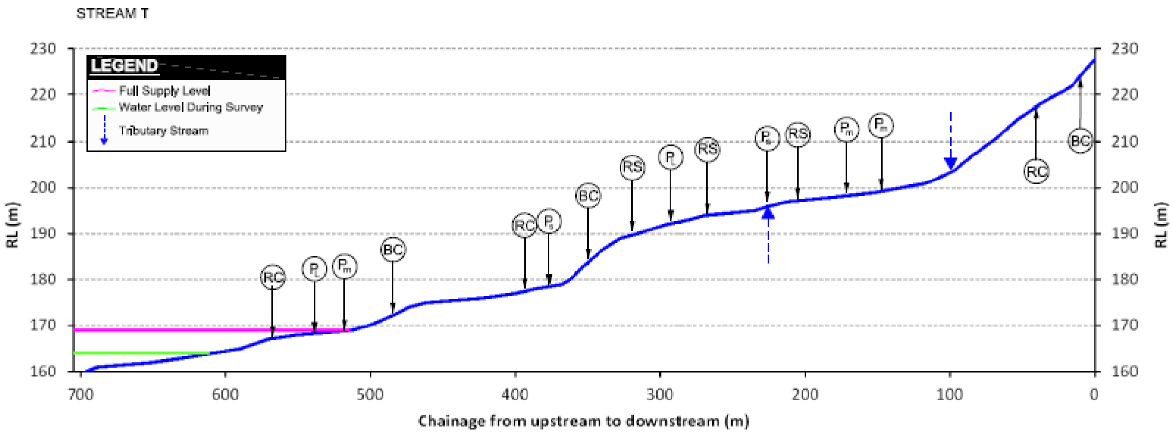


Figure 18 Stream T Features

A summary of the catchment characteristics is provided in Table 8 below.

Table 8 Catchment Characteristics Stream T

Feature	Value
Stream order	2nd
Catchment area (km²)	0.716
Stream length (km)	0.71
Average gradient (%)	9.8

5.0 RECOMMENDATIONS FOR MONITORING

The inspected streams are all small 1st and 2nd order streams. Based on observation of the effects of subsidence and non-conventional subsidence impacts on similar streams, including Forest Gully and Tributary B and D, it is expected that longwall mining will result in fracturing of bed rock and underflow and loss of function of some of what are currently a mixture of both intermittent and permanent pools.

It is recommended that, subject to access constraints, Metropolitan Coal investigate the potential to install:

- a pool water level meter in the large pool mapped on Stream P (Figure 9);
- a pool water level meter in two large pools in the lower reaches of Stream R (Figure 14);
- a small flow measuring flume immediately downstream of the upland swamp associated with Streams P (Figure 9) (no pool has been mapped at this location, however there may be potential to direct flow from the upland swamp toward a flume); and
- a small flow measuring flume in the vicinity of the first small pool mapped on Stream R to provide data on outflows from the swamp in the headwaters of this catchment (Figure 14).

Yours sincerely

Lindsay Gilbert
Principal Water Resources Engineer

ATTACHMENT A

Stream Reconnaissance Photographs

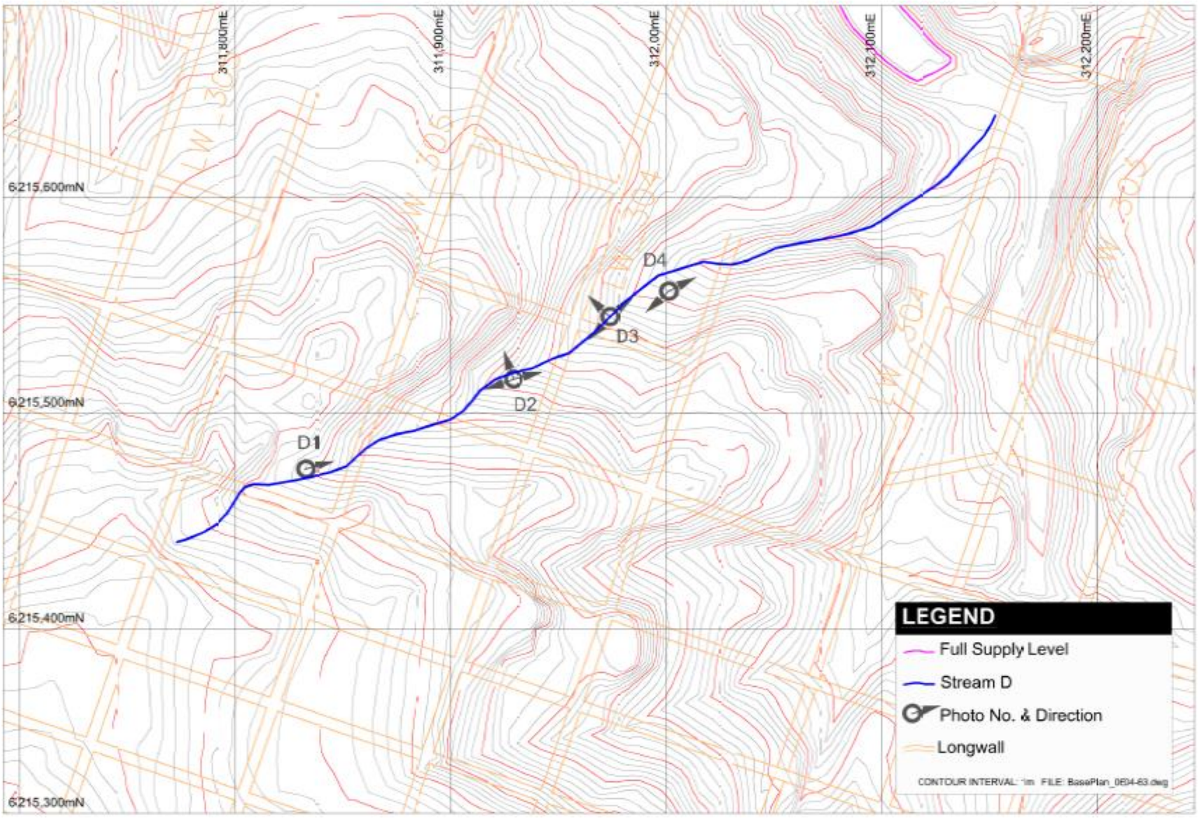


Photo D1 (Downstream)

Photo D2 (Downstream)

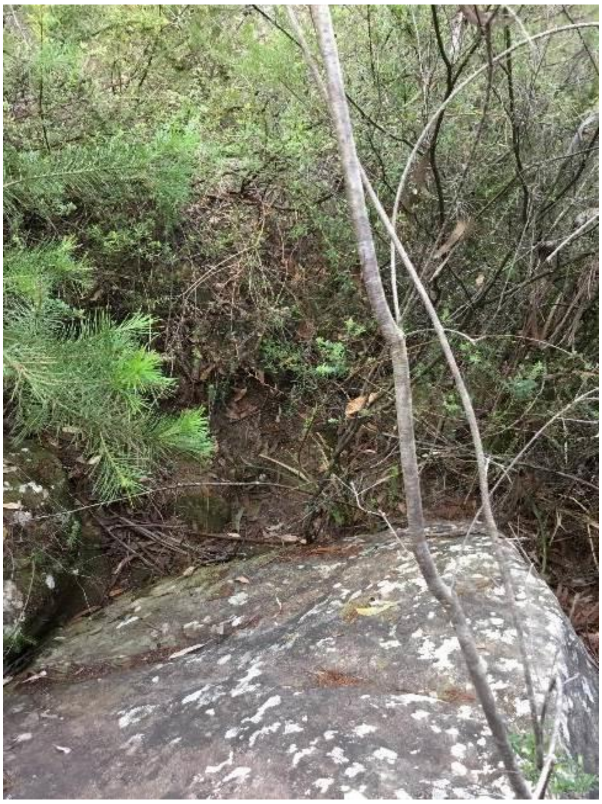


Photo D2 (Left Bank)

Photo D2 (Upstream)

Photo D3 (Downstream)

Photo D3 (Left Bank)

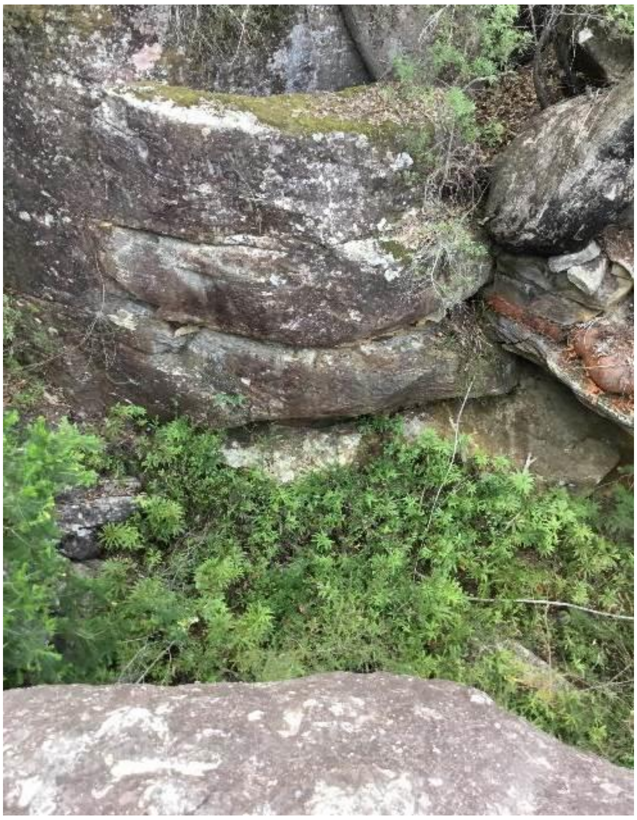


Photo D3 (Upstream)

Photo D4 (Downstream)

Photo D4 (Upstream)

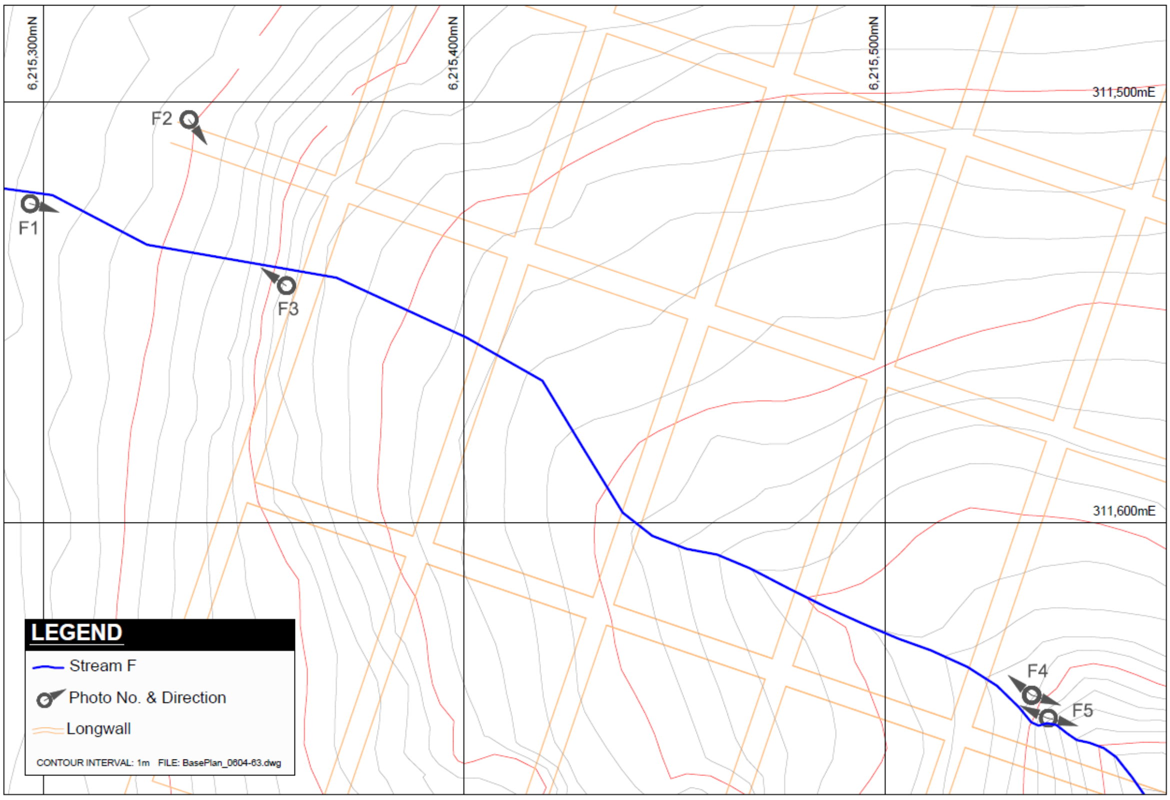


Photo F1 (Downstream)

Photo F2 (Downstream)

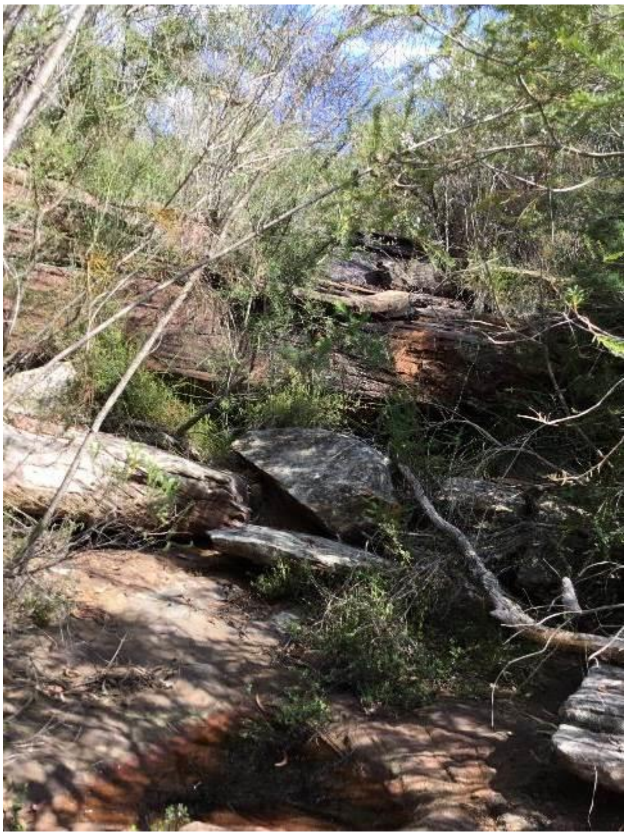
Photo F3 (Upstream)

Photo F4 (Downstream)

Photo F4 (Upstream)

Photo F5 (Downstream)

Photo F5 (Upstream)



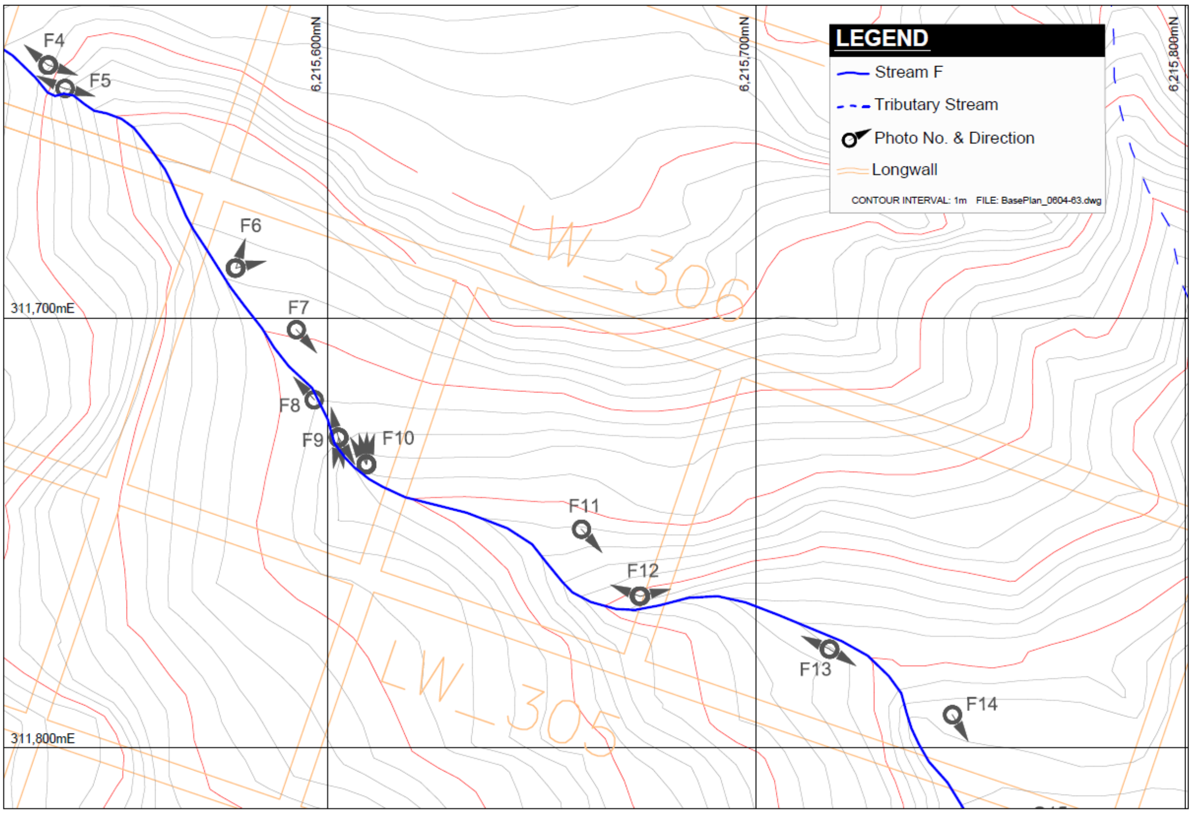


Photo F6 (Left Bank 1)

Photo F6 (Left Bank 2)

Photo F7 (Downstream)

Photo F8 (Upstream)

Photo F8 (Downstream 1)

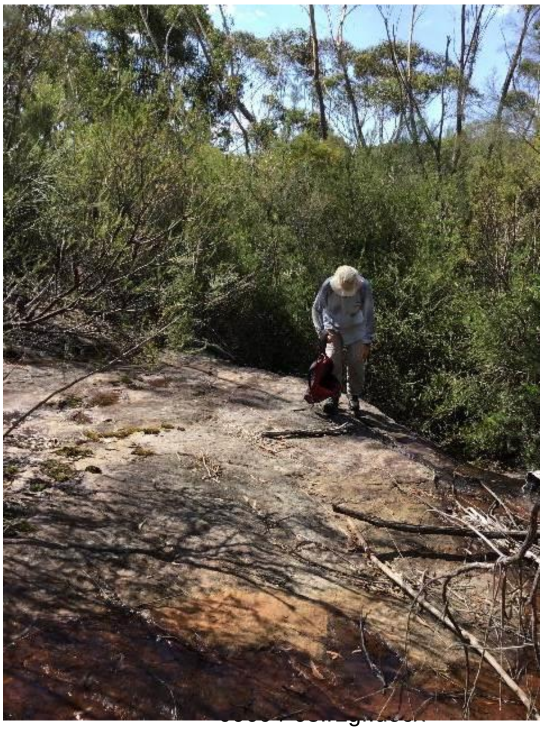


Photo F8 (Downstream 2)

Photo F8 (Downstream 3)

Photo F9 (Upstream 1)

Photo F9 (Upstream 2)

Photo F10 (Upstream 1)

Photo F10 (Upstream 2)

Photo F10 (Upstream 3)

Photo F10 (Upstream 4)

Photo F11 (Downstream)

Photo F12 (Downstream)

Photo F12 (Upstream)

Photo F13 (Downstream)

Photo F13 (Upstream)

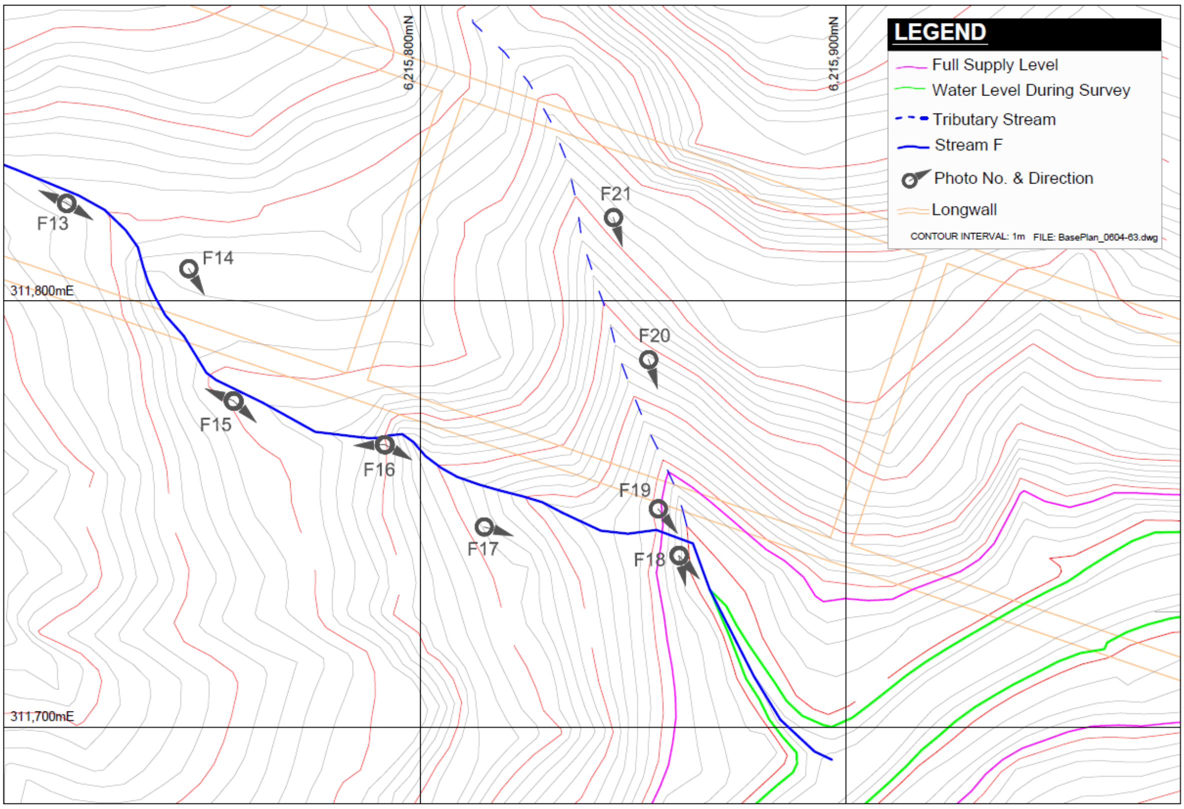


Photo F14 (Downstream)

Photo F15 (Downstream)

Photo F15 (Upstream)

Photo F16 (Downstream)

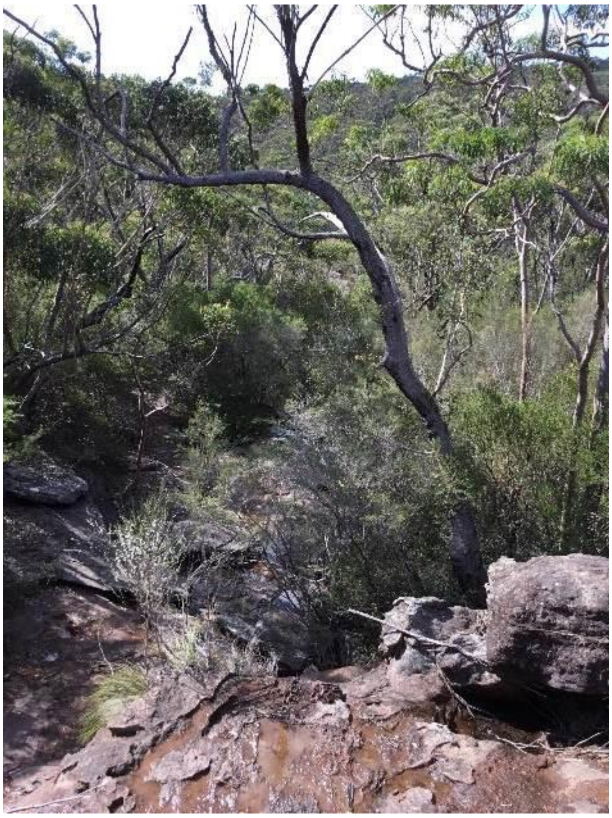


Photo F16 (Upstream)

Photo F17 (Downstream)

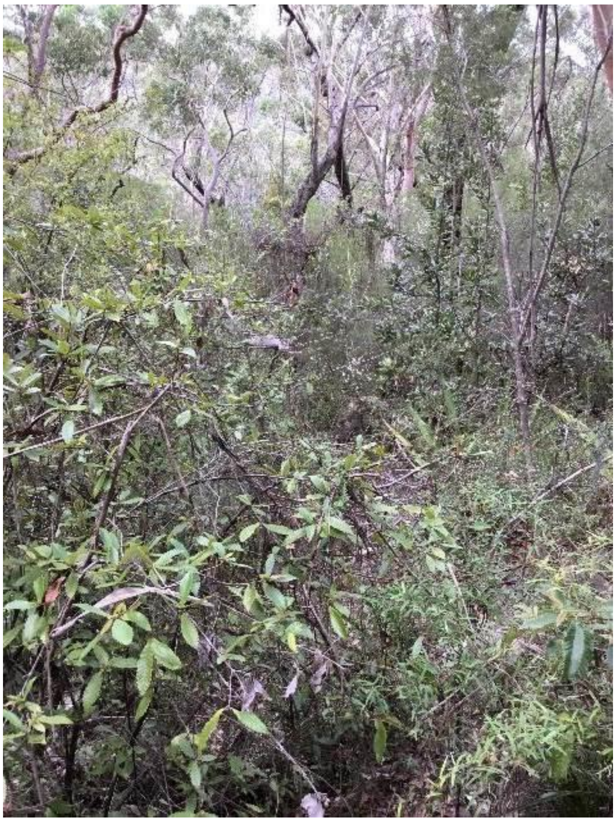
Photo F18 (Downstream 1)

Photo F18 (Downstream 2)

Photo F19 (Downstream)

Photo F20 (Downstream)

Photo F21 (Downstream)



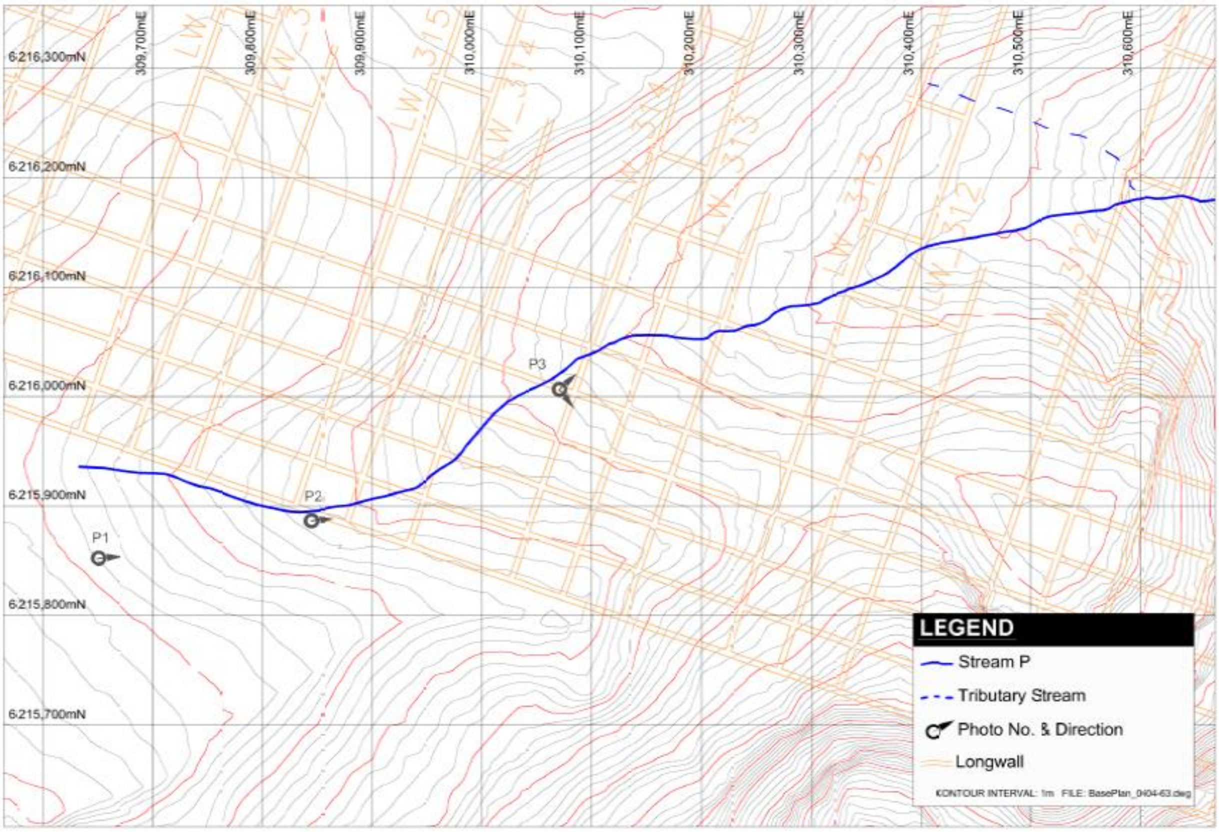


Photo P1 (Downstream)

Photo P2 (Downstream)

Photo P3 (Right Bank Bore)

Photo P3 (Downstream)

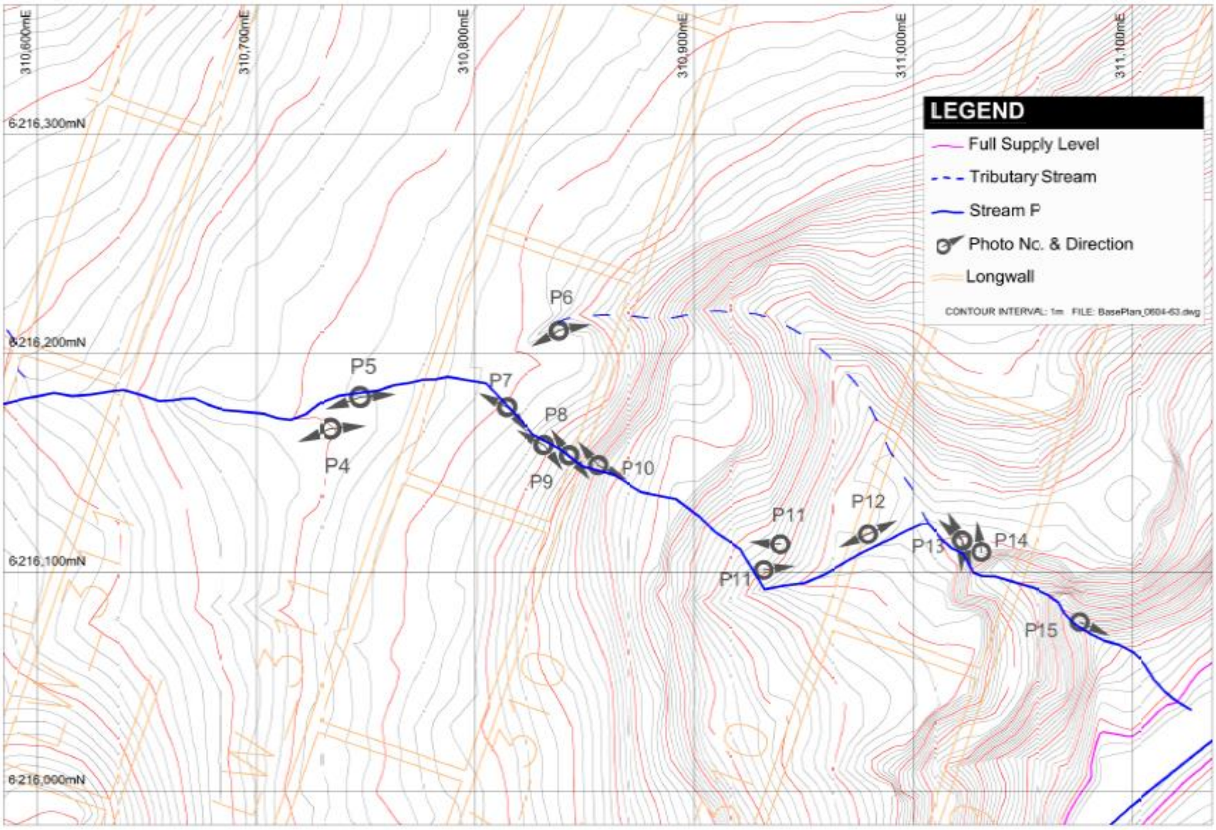


Photo P4 (Downstream)

Photo P4 (Upstream)

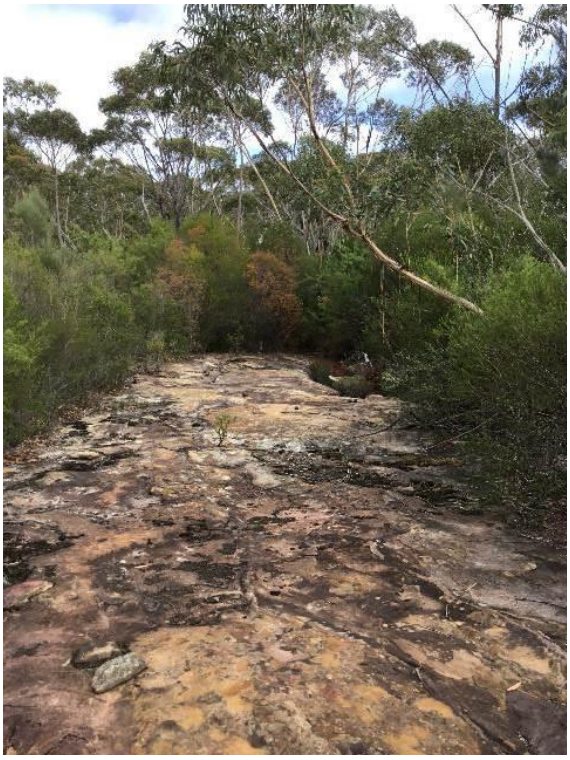


Photo P5 (Downstream)

Photo P5 (Upstream)

Photo P6 (Downstream)

Photo P6 (Upstream)

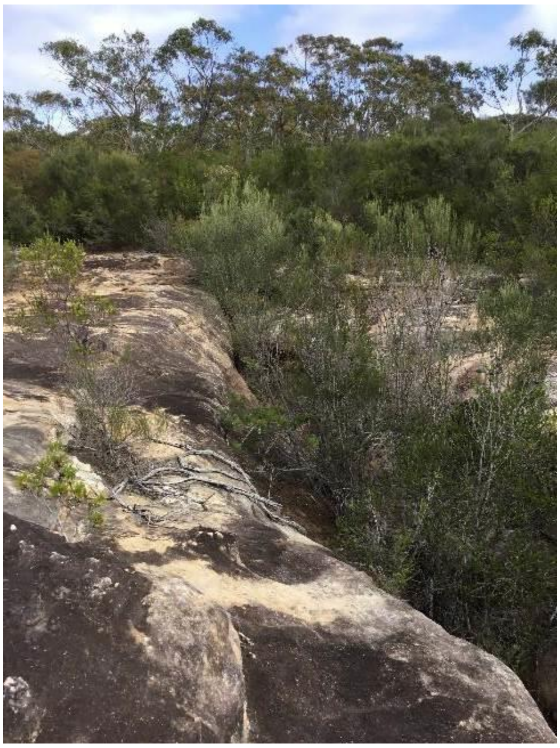


Photo P7 (Downstream)

Photo P7 (Upstream)

Photo P8 (Downstream)

Photo P8 (Upstream)

Photo P9 (Downstream)

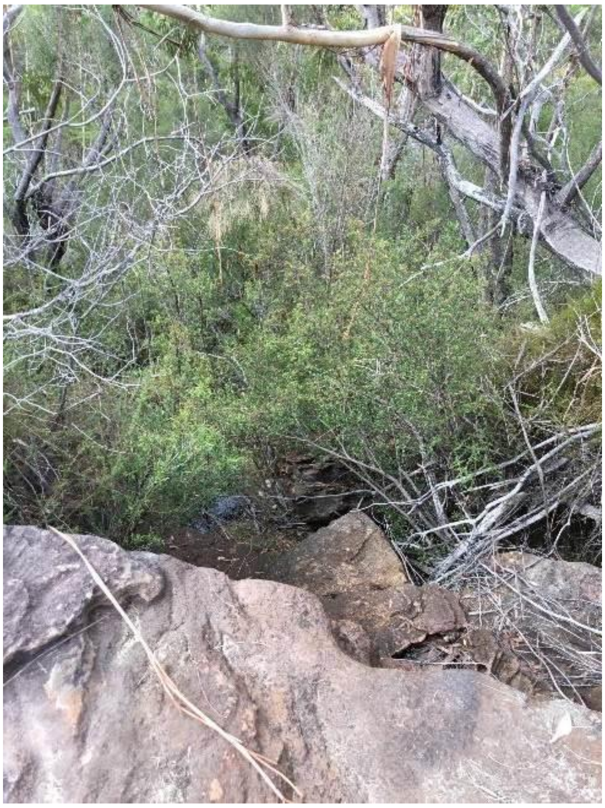


Photo P9 (Upstream)

Photo P10 (Downstream)

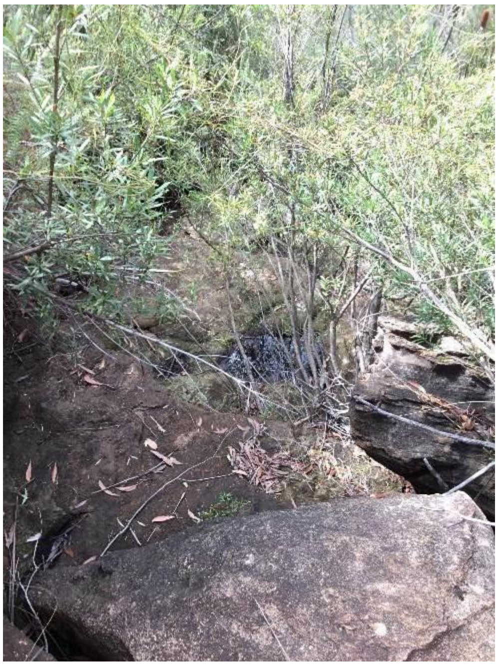


Photo P10 (Upstream)

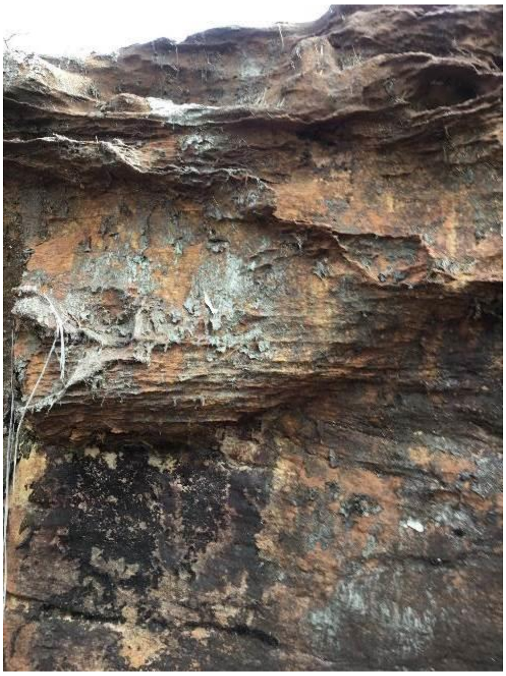


Photo P11 (Downstream)

Photo P11 (Upstream)

Photo P12 (Downstream)

Photo P12 (Upstream)

Photo P13 (Downstream 1)

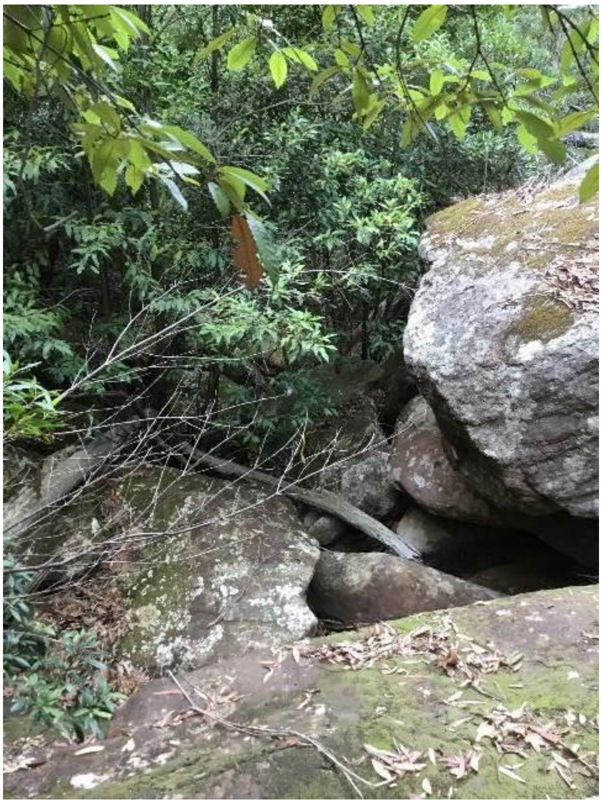
Photo P13 (Downstream 2)

Photo P13 (Upstream 1)

Photo P13 (Upstream 2)

Photo P14 (Upstream)

Photo P15 (Downstream)



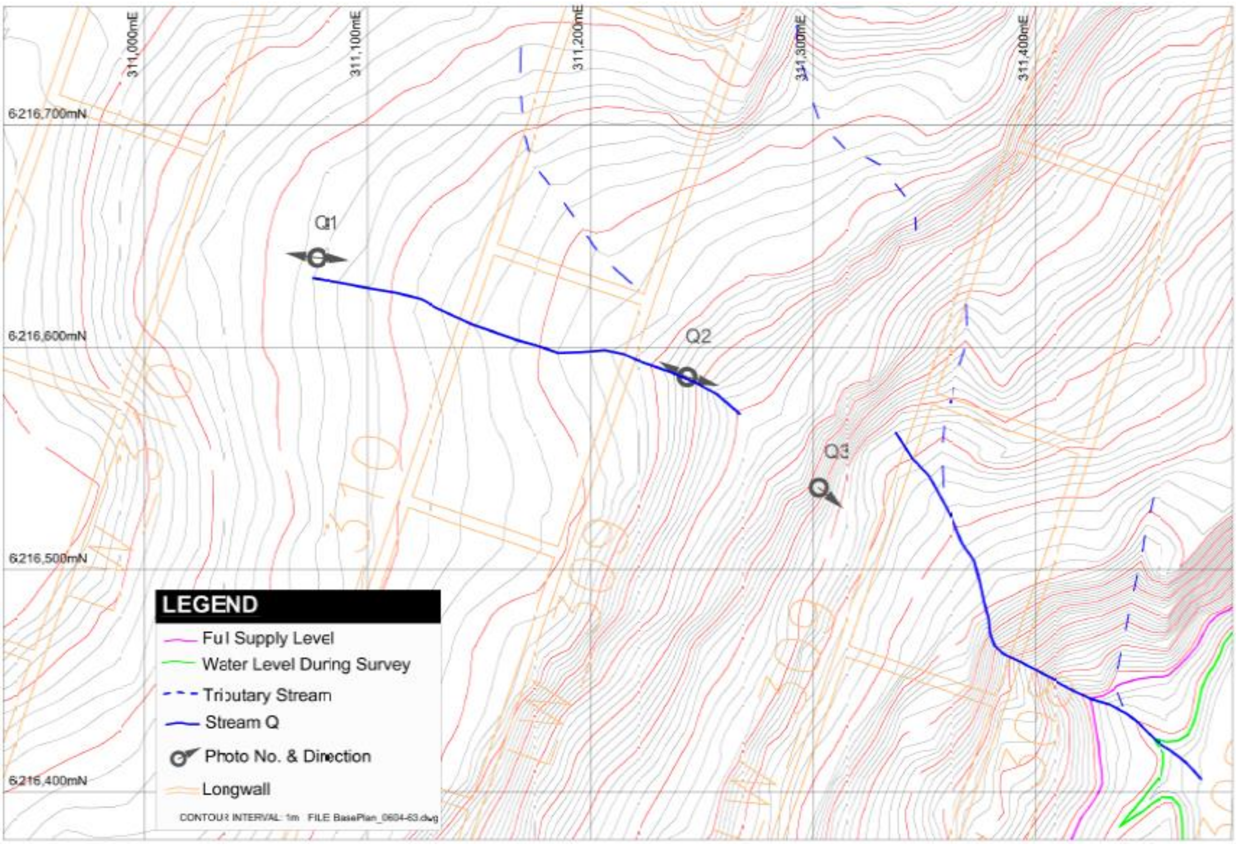


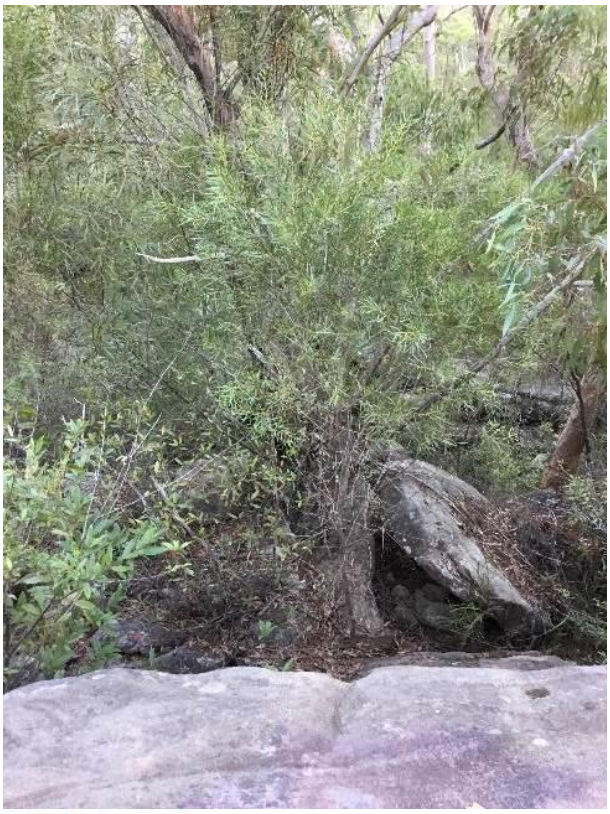
Photo Q1 (Downstream)

Photo Q1 (Upstream)

Photo Q2 (Downstream)

Photo Q2 (Upstream)

Photo Q3 (Downstream)



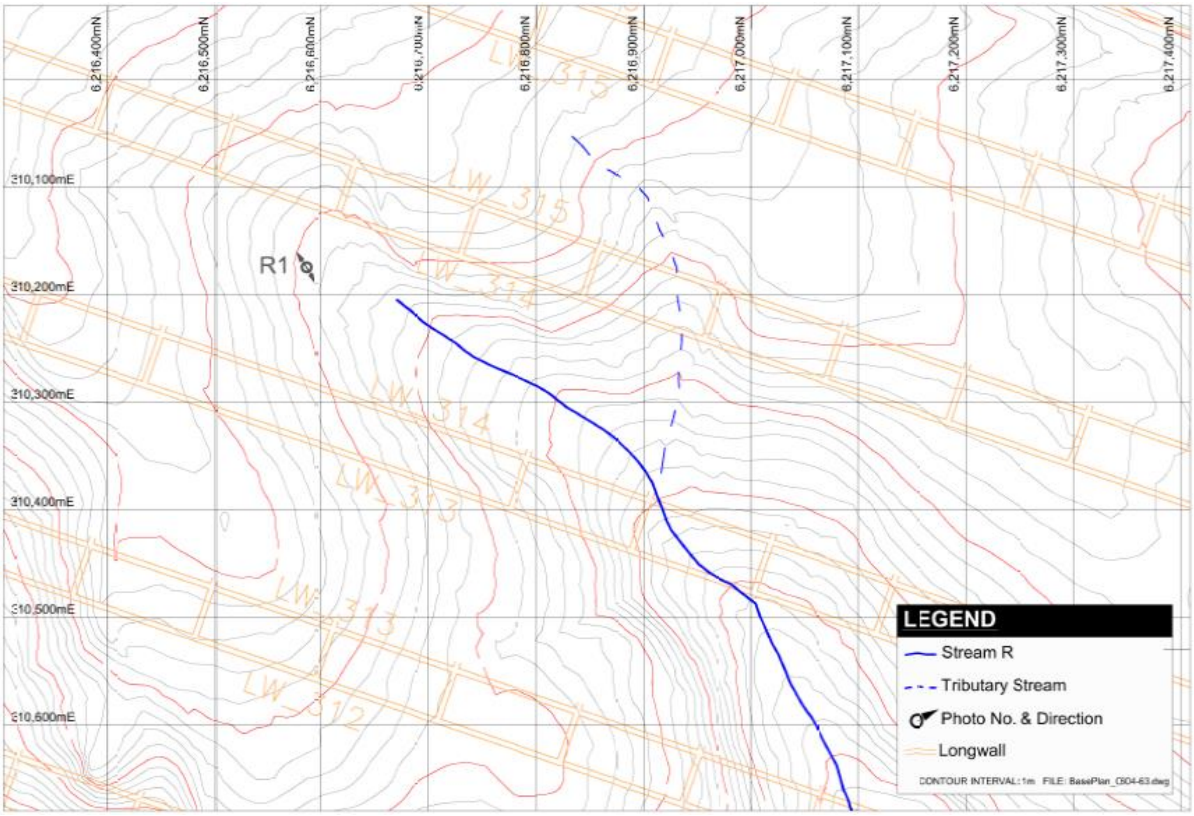


Photo R1 (Downstream)

Photo R1 (Upstream)

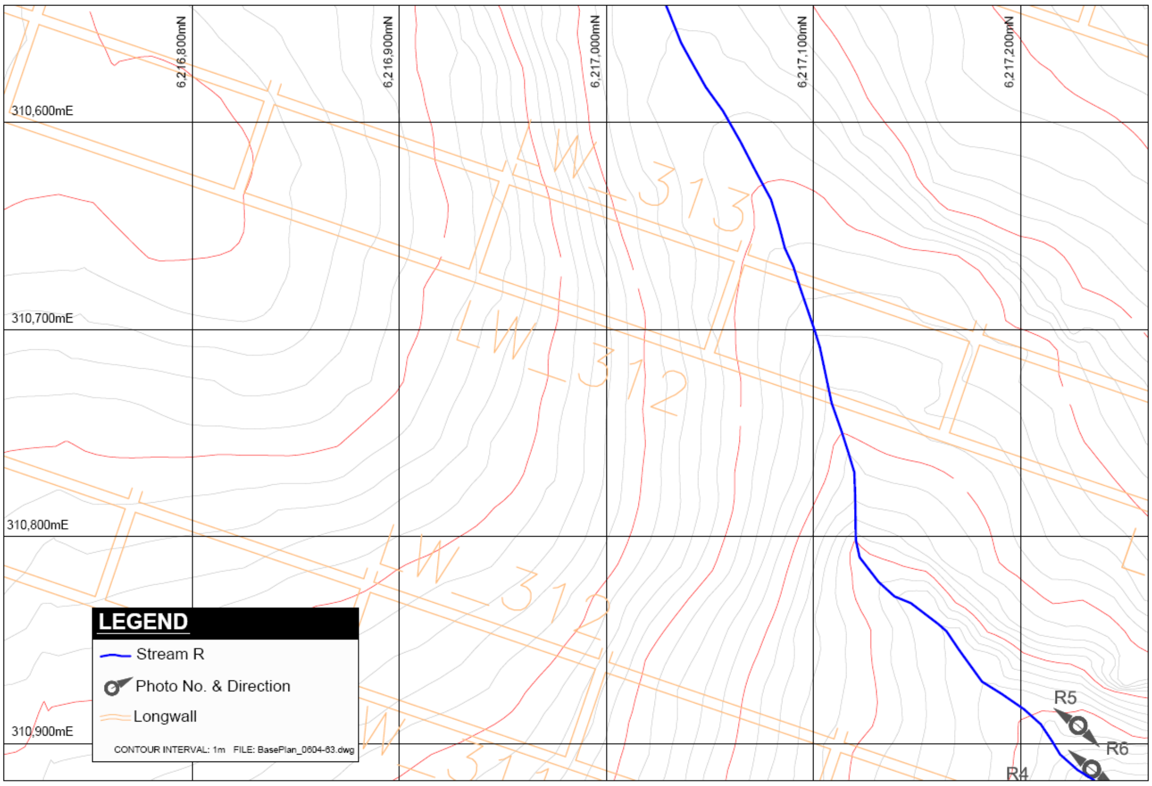


Photo R5 (Downstream)

Photo R5 (Upstream)

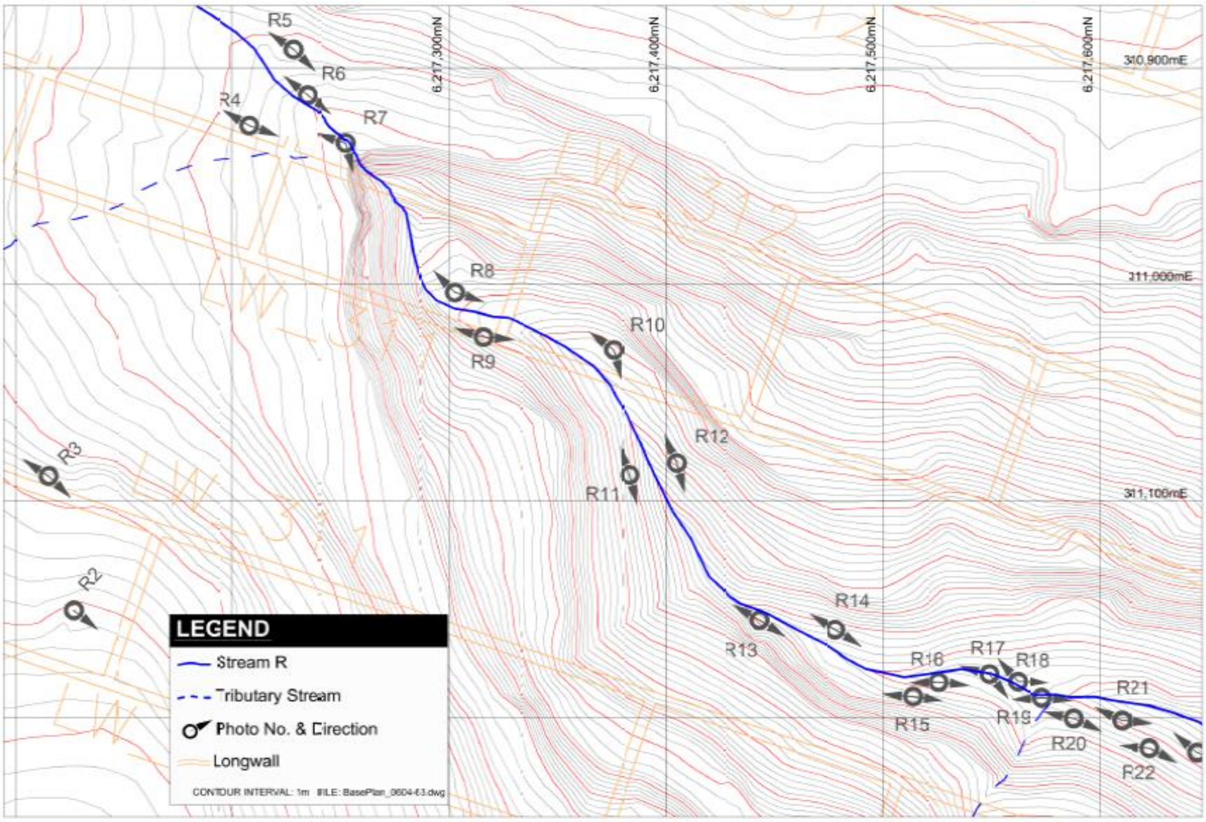


Photo R2 (Downstream)

Photo R3 (Downstream)

Photo R3 (Upstream)

Photo R4 (Downstream)

Photo R4 (Upstream)

Photo R6 (Downstream)

Photo R6 (Upstream)

Photo R7 (Downstream)

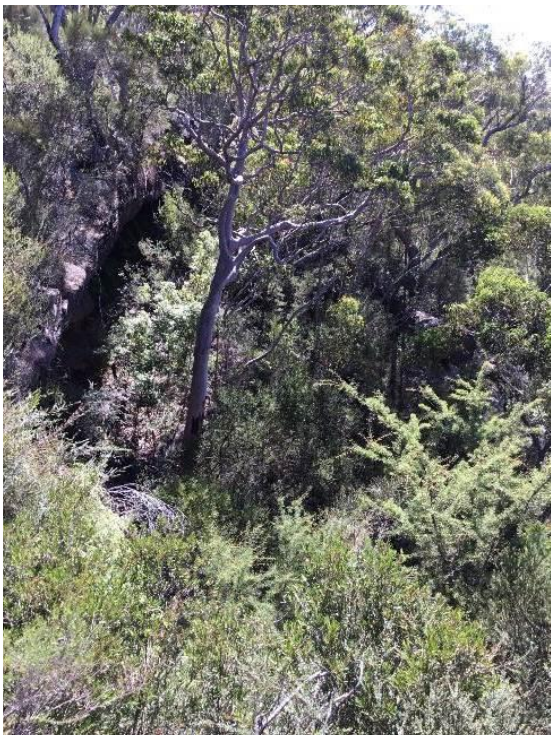


Photo R7 (Upstream)

Photo R8 (Downstream)

Photo R8 (Upstream)

Photo R9 (Downstream)

Photo R9 (Upstream)

Photo R10 (Downstream)

Photo R10 (Upstream)

Photo R11 (Downstream)

Photo R11 (Upstream)

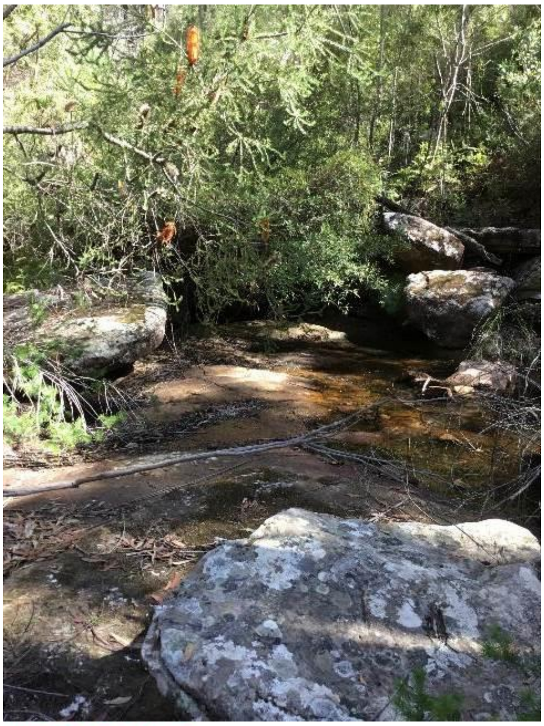


Photo R12 (Downstream)

Photo R12 (Upstream)

Photo R13 (Downstream)

Photo R13 (Upstream)

Photo R14 (Downstream)

Photo R14 (Upstream)

Photo R15 (Downstream)

Photo R15 (Upstream)

Photo R16 (Downstream)

Photo R16 (Upstream)

Photo R17 (Downstream)

Photo R17 (Upstream)

Photo R18 (Downstream)

Photo R18 (Upstream)

Photo R19 (Downstream)

Photo R19 (Upstream)

Photo R20 (Downstream)

Photo R20 (Upstream)

Photo R21 (Downstream)

Photo R21 (Upstream)

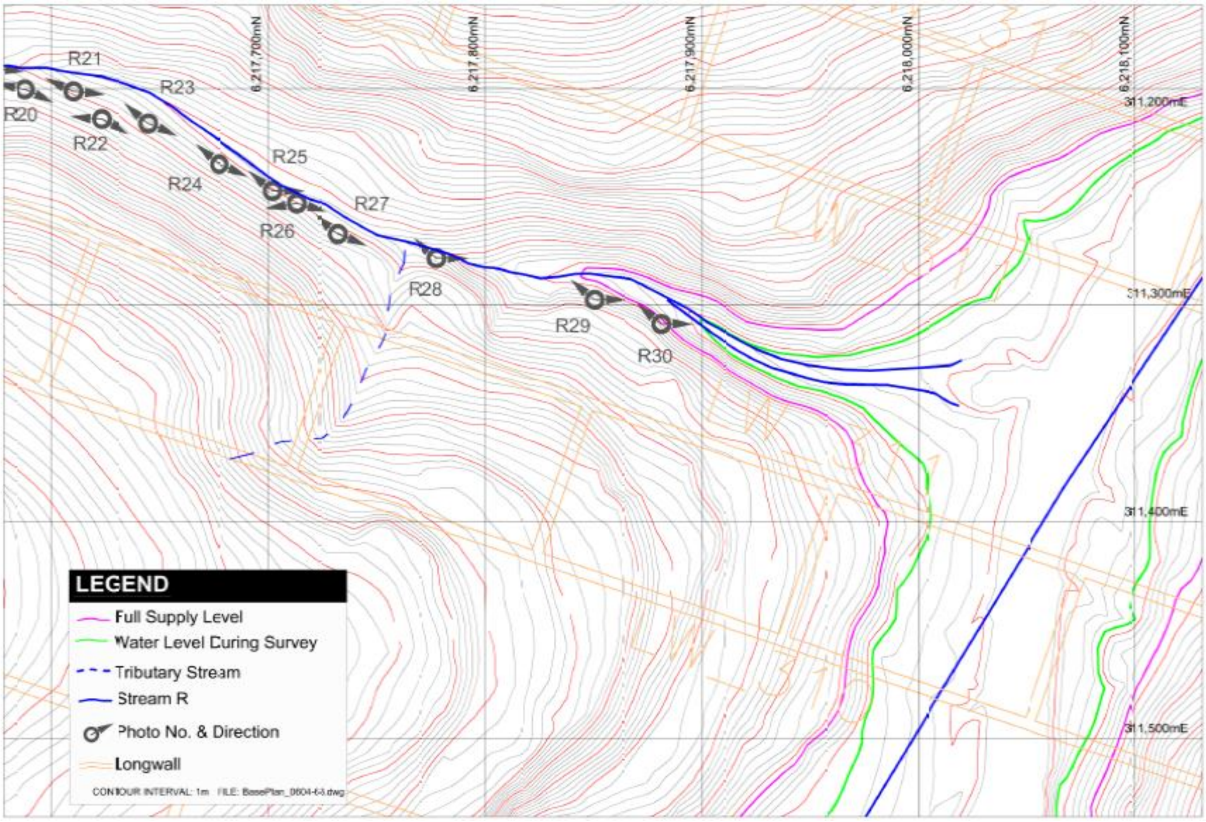


Photo R22 (Downstream)

Photo R22 (Upstream)

Photo R23 (Downstream)

Photo R23 (Upstream)

Photo R24 (Downstream)

Photo R24 (Upstream)

Photo R25 (Downstream)

Photo R25 (Upstream)

Photo R26 (Downstream)

Photo R26 (Upstream)

Photo R27 (Downstream)

Photo R27 (Upstream)

Photo R28 (Downstream)

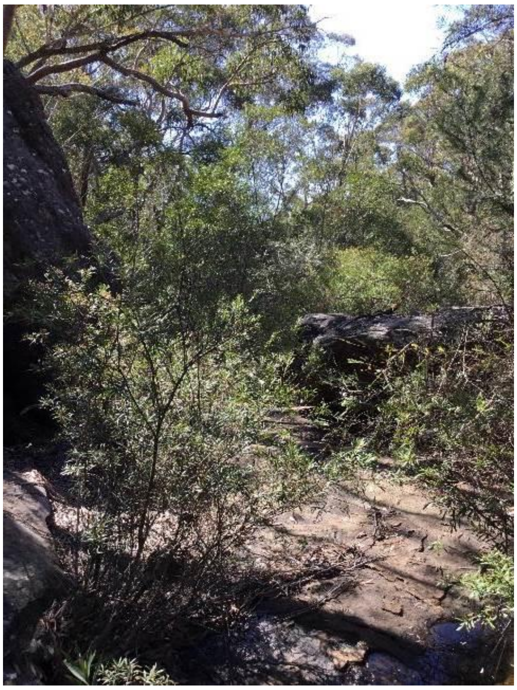


Photo R28 (Upstream)

Photo R29 (Downstream)

Photo R29 (Upstream)

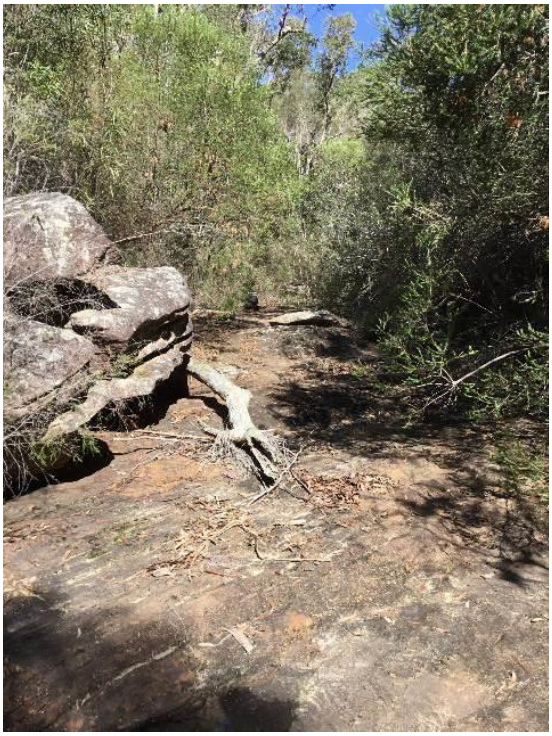


Photo R30 (Downstream)

Photo R30 (Upstream)

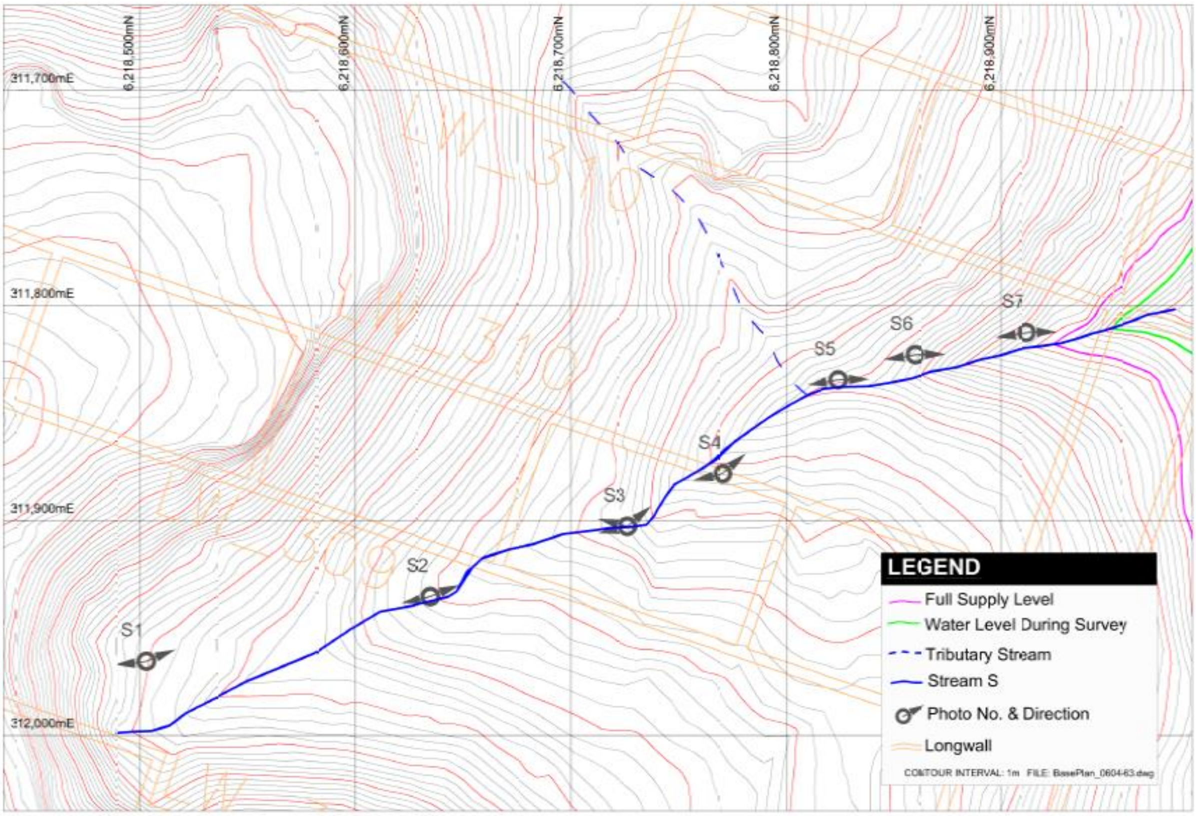


Photo S1 (Downstream)

Photo S1 (Upstream)

Photo S2 (Downstream)

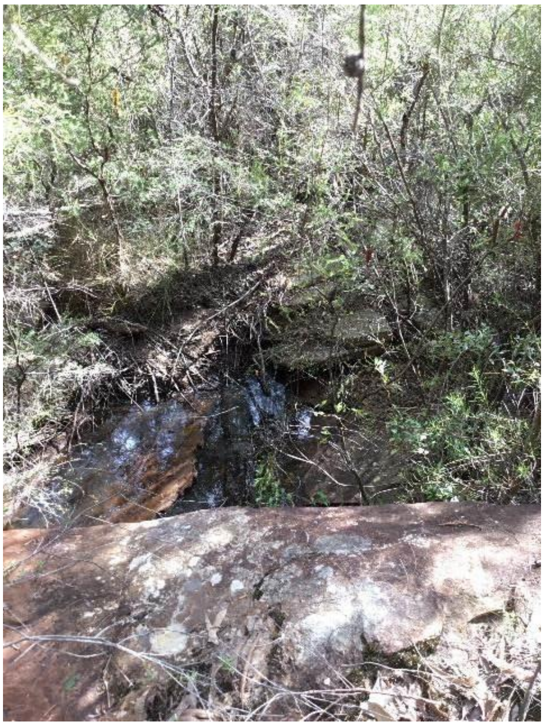


Photo S2 (Upstream)

Photo S3 (Downstream)

Photo S3 (Upstream 1)

Photo S3 (Upstream 2)

Photo S4 (Downstream)

Photo (Upstream)

Photo S5 (Downstream)

Photo S5 (Upstream)

Photo S6 (Downstream)

Photo S6 (Upstream)

Photo S7 (Downstream)

Photo S7 (Upstream)

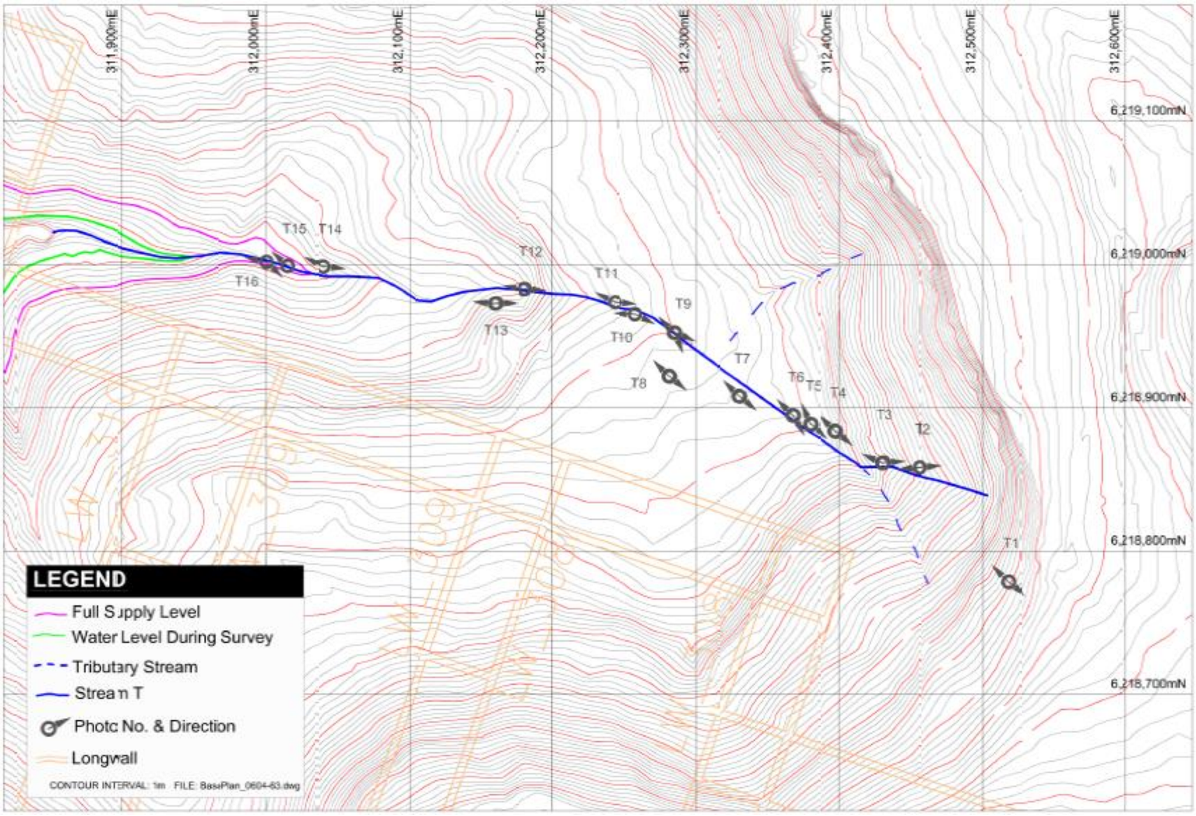


Photo T1 (Downstream)

Photo T1 (Upstream)

Photo T2 (Downstream)

Photo T2 (Upstream)

Photo T3 (Downstream)

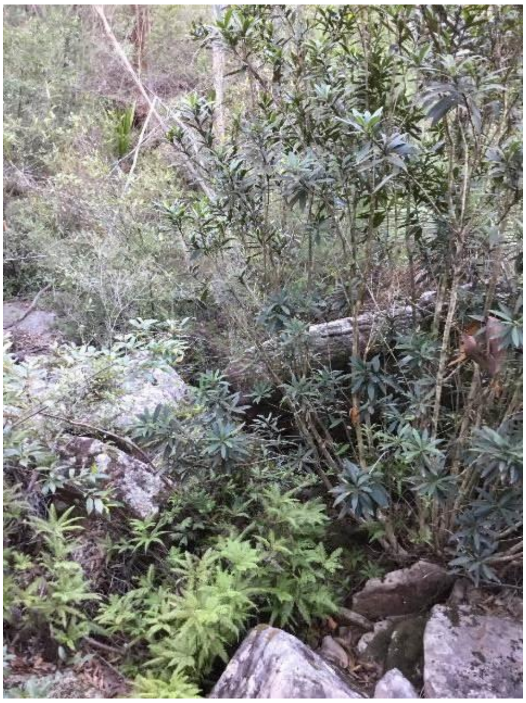


Photo T3 (Upstream)

Photo T4 (Downstream)

Photo T4 (Upstream)

Photo T5 (Downstream)

Photo T5 (Upstream)

Photo T6 (Downstream)

Photo T6 (Upstream)

Photo T7 (Downstream)

Photo T7 (Upstream)

Photo T8 (Downstream)

Photo T8 (Upstream)

Photo T9 (Downstream)

Photo T9 (Upstream 1)

Photo T9 (Upstream 2)

Photo T10 (Downstream)

Photo T10 (Upstream)

Photo T11 (Downstream)

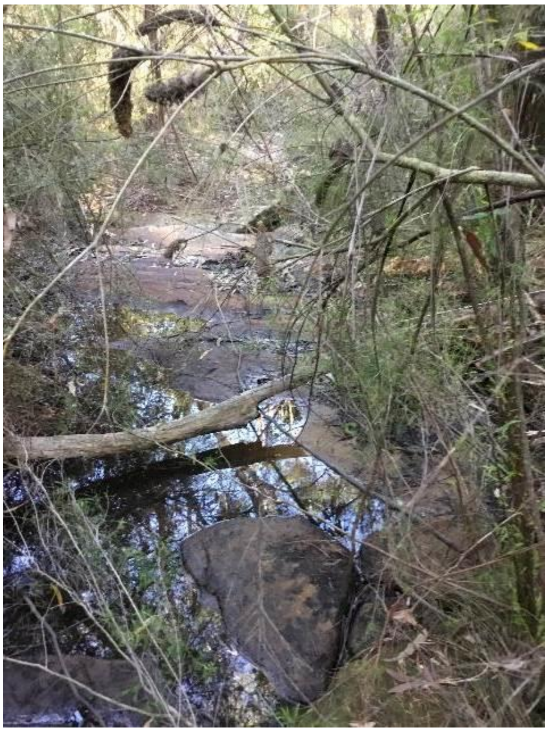


Photo T11 (Upstream)

Photo T12 (Downstream)

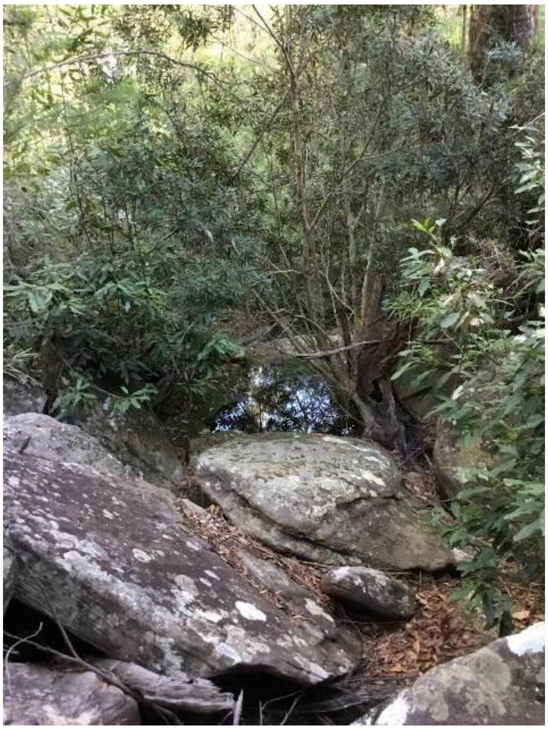


Photo T12 (Upstream)

Photo T13 (Downstream)

Photo T13 (Upstream)

Photo T14 (Downstream)

Photo T14 (Upstream)

Photo T15 (Downstream)

Photo T16 (Downstream)

Photo T16 (Upstream)